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## Infants' Agent Individuation: It's what's on the Inside that Counts

Hernando Taborda  
*University of Massachusetts Amherst*

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INFANTS' AGENT INDIVIDUATION: IT'S WHAT'S ON THE INSIDE THAT  
COUNTS

A Thesis Presented

by

HERNANDO TABORDA OSORIO

Submitted to the Graduate School of the  
University of Massachusetts, Amherst in partial fulfillment  
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Approved as to style and content by:

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Erik Cheries, Chair

---

Neil Berthier, Member

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Adrian Staub, Member

---

Hal Grotevant, Chair of Department  
Department of Psychological and Brain Sciences

ABSTRACT

INFANTS' AGENT INDIVIDUATION: IT'S WHAT'S ON THE INSIDE THAT  
COUNTS

MAY 2015

HERNANDO TABORDA OSORIO

B.S., UNIVERSIDAD NACIONAL DE COLOMBIA

M.S., UNIVERSIDAD DEL VALLE

M.S., UNIVERISTY OF MASSACHUSETTS AMHERST

Directed by: Erik W. Cheries Ph.D.

Developmental studies have revealed that preschool-aged children believe that an agent's internal properties are more important than its external properties for determining its 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.

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## CHAPTER I

### 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).

Young children's explicit judgments reveal an early understanding that 'insides' are more relevant than external properties when judging an agent's identity over time. For example, 4-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 without stripes 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 (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 likes chew bones) remain stable regardless of important 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, Kalish, Gelman, Medin, Luhmann, Atram, Coley, & Shafto, 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 bias towards internal features emerge? Some studies suggest that at least part of this understanding exists in infancy. By 8 months of age, infants expect that an object that looks and acts alive will possess some internal properties (Setoh, Wu, Baillargeon & Gelman, 2013). For example, infants who were shown objects displaying both self-propelled movement and agentive cues (e.g. being all covered with fur), looked longer when they were revealed to be hollow rather than full on their insides, suggesting 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 the 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 same insides, despite their 'outsides' being perceptually distinct (Newman, Herrmann, Wynn & 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 *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 just 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, 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. A great many of these individuation experiments have demonstrated that infants are able to 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., internally-caused motion) as more important than visible and external properties when representing agent identity. However, to our knowledge no prior individuation experiment has addressed the issue of whether or not infants are capable of using non-obvious biological properties as cues of agent identity. To address this issue we run a manual-search version of the 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 test whether infants' individuation judgments are sensitive to an agent's 'insides', we manipulated whether the internal and external features of transparent objects matched over time. 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). 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.

## CHAPTER 2

### EXPERIMENT 1

#### **Method**

**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).

**Stimuli.** Infants observed six transparent toys being hidden in a black foam-core box (see Figure 1). The box measured 25.5 cm wide x 32.5 cm deep x 15 cm high. Its front face had an 18.5 x 10 cm opening covered by green spandex material, with a horizontal slit. The back face of the box had a 21 x 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 Figure 2). 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 Same Insides 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 Figure 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.



Figure 1. Box



Figure 2. Example toys: Same Insides Condition

**Design.** All subjects received two Trial Types 1-Object and 2-Objects trials. In the 2-Objects trials, toys had either insides with the same color ('Same Insides') or insides with different colors ('Different Insides'). Subjects received two blocks (Same Insides Condition and Different Insides Condition) of four trials each (two 1-Object and two 2-Objects 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 Same Inside or Different Insides first, and Trial Order, whether infants receive either 1-Object or 2-Objects trial first, were counterbalance across participants.

**Procedure.** Infant subjects were seated on their parent's lap in front of a table. A camera recorded a side-view of the session.

*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.

*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 seconds. 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 seconds 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-second 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 seconds elapsed, the experimenter removed the box and the trial ended.

The 2-Objects trials had the same structure as 1-Object (Box Empty) trials but it contained two separate coding periods: one 10-second 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). In this trial the experimenter again placed the box on the table out of the infant’s reach and brought out a toy from the box that he moved in the same fashion as in the 1-Object trial. 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-second coding period (“1 Remains”) by looking down toward the ground in order to not bias the subject’s responses. After 10 seconds, 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-second coding period (‘Box Empty’). At the end of this coding period the experimenter retrieved the box and began the next trial.

**Data scoring.** The dependent measure was the duration of each reach that occurred within each 10-second 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 ( $r = .94$ ).

## 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: Same Inside vs. Different Inside) X 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 Inside condition ( $M = 2.7, SD = 1.87$ ) than in the Same Inside 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 than on Box Empty trials (see Graph 1). 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. The comparison between 1 Object Box Empty and 2 Objects Box Empty revealed no significant differences in both the Same Inside condition,  $t(15) = 1.33, p = .2, d = .33$ , two-tailed, and the Different Inside condition,  $t(15) = 1.26, p = .23, d = .36$ , two-tailed; therefore, these two trial types were collapsed in each condition in a single measure of Average Box Empty. In the Different Inside condition infants searched significantly longer on 1 Remain trials ( $M = 4.03$  s.,  $SD = 2.69$ ) than on Average Box Empty trials ( $M = 2.05$  s.,  $SD = 1.6$ ),  $t(15) = 4.62, p = .0003, d = .89$ , two-tailed. However, the comparison between 1 Remain trials and the Average Box Empty trials in the Same

Inside condition revealed a non significant difference,  $t(15) = 1.57$ ,  $p = .14$ ,  $d = .39$ , two-tailed ( $M = 2.16$  s.,  $SD = 1.77$ , for 1 Remain, and  $M = 1.54$  s.,  $SD = 1.34$ , for Average Empty).

The infants' performance in each Trial Type across Conditions was also compared. There was a significant difference in search times on 1 Remain trials across conditions,  $t(15) = -3.48$ ,  $p = .003$ ,  $d = .82$ , two-tailed, due to infants searching longer on Different Inside trials than in Same Inside trials. The difference in search times of Average Box Empty across conditions was not significant,  $t(15) = -1.24$ ,  $p = .23$ ,  $d = .34$ , two-tailed.

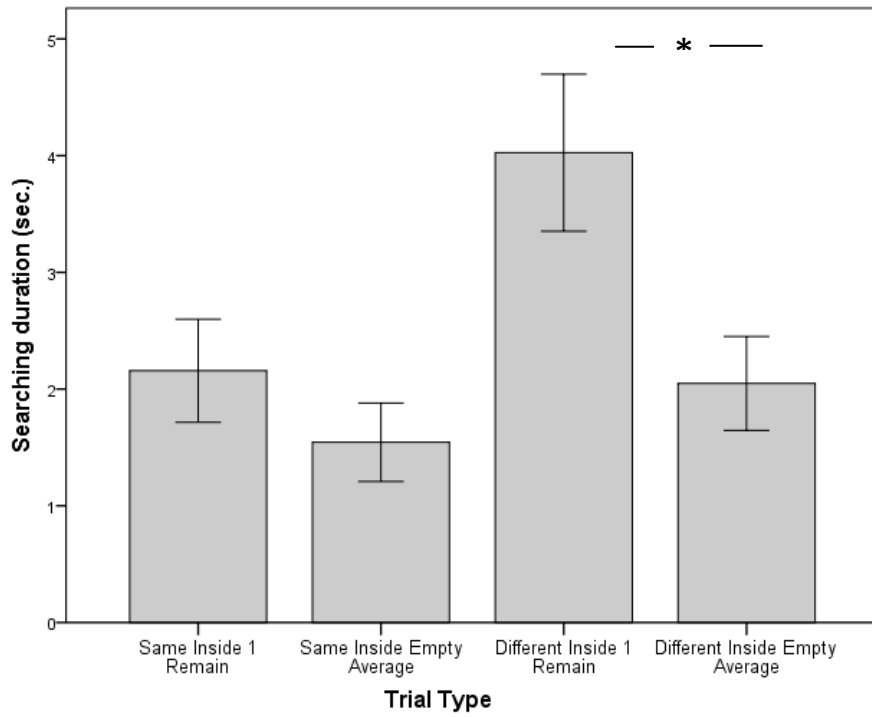
A non-parametric Wilcoxon test confirmed the pattern of results obtained with the planned t-test. The differences between 1 Object Box Empty and 2 Objects Box Empty trials in both conditions were not significant,  $Z = -.59$ ,  $p = .55$ , for Same Inside, and  $Z = -1.09$ ,  $p = .27$ , for Different Inside. While the comparison between 1 Remains and Average Box Empty trials was significant for the Different Inside condition,  $Z = -3.52$ ,  $p = .0002$ , it was not significantly different from chance for the Same Inside condition,  $Z = -1.5$ ,  $p = .13$ . Finally, the number of infants who searched longer in the 1 Remains trial than in the Average Box Empty trials was significant in the Different Inside condition, ( $n = 16$  out of 16;  $p = .00003$ , via a binomial test), but not significant in the Same Inside condition ( $n = 10$  out of 16;  $p = .45$ , via a 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. 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 powerful 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 based on 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 significance—that remain the same. Alternatively, the differences in infants' performance between Same Inside and Different Inside 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 a Experiment 2 replicated the same basic procedure except using inanimate objects that lacked eyes and self-propelled movement.



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

## CHAPTER 3

### EXPERIMENT 2

**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).

**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 Figure 3). 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 ( $r = 0.95$ ).



Figure 3. Example toy for Experiment 2.

### Results and Discussion

Preliminary analysis found no effects of Sex, Block Order, or Trial Type.

Subsequent analyses collapsed over these variables. A 2 (Condition: Same Inside vs.

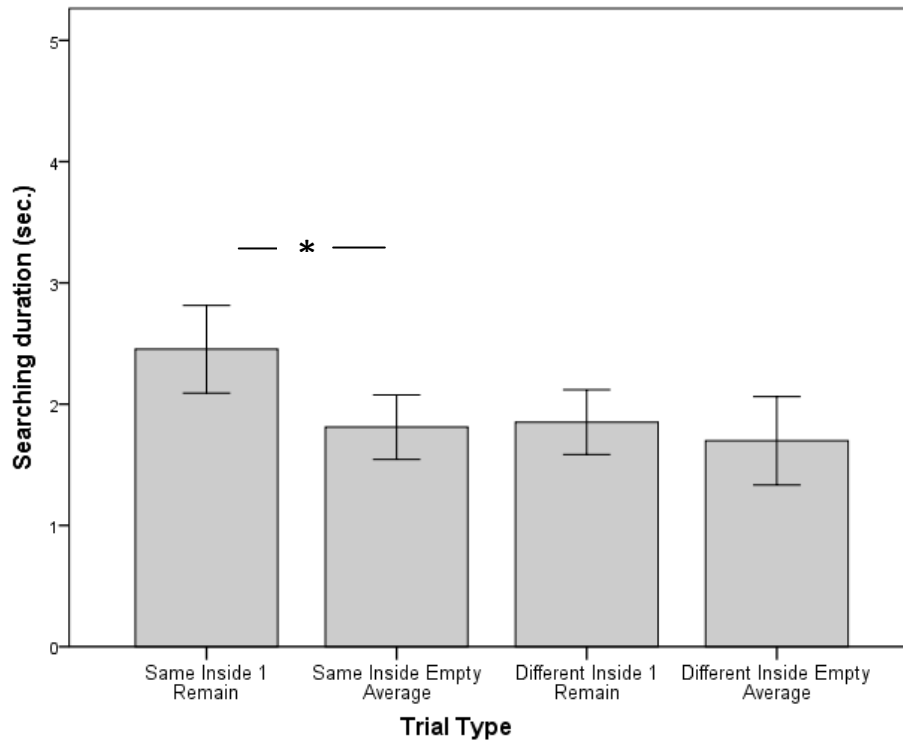
Different Inside) X 3 (Trial Type: 1-Object Box Empty, 2-Objects 1 Remain, 2-Objects Box Empty) ANOVA yielded no significant main effect for Condition,  $F(1, 30) = .61$ ,  $p = .45$ ,  $\eta^2p = .039$ , and Trial Type,  $F(2, 30) = 1.24$ ,  $p = .3$ ,  $\eta^2p = .07$ . This analysis also revealed a no significant interaction,  $F(2, 30) = 0.4$ ,  $p = .67$ ,  $\eta^2p = .026$ .

In spite of the lack of an interaction planned comparisons t-test across Trial Types in each Condition were carried out. The comparison between 1-Object Box Empty and 2-Objects Box Empty revealed no significant differences in both the Same Inside condition,  $t(15) = -.73$ ,  $p = .48$ ,  $d = -0.25$ , two-tailed, and the Different Inside condition,  $t(15) = -.45$ ,  $p = .66$ ,  $d = -0.14$ , two-tailed; therefore, these two trial types were collapsed in each condition. The comparison between 1 Remains trial and the Average Box Empty trials revealed a significant difference in the Same Inside Condition,  $t(15) = 2.35$ ,  $p = .03$ ,  $d = .51$ , two-tailed, which resulted from longer search times on 1 Remains trials ( $M = 2.45$  s.,  $SD = 1.44$ ) than on Average Box Empty ( $M = 1.81$ ,  $SD = 1.06$ ). However, in the Different Inside condition searching duration for 1 Remains ( $M = 1.85$  s.,  $SD = 1.07$ ) and Average Box Empty ( $M = 1.69$  s.,  $SD = 1.46$ ) did not differ significantly,  $t(15) = .48$ ,  $p = .64$ ,  $d = .12$ , two-tailed. The comparison of search time in each Trial Type across Conditions did not reveal significant differences on either Average Box Empty trials,  $t(15) = .028$ ,  $p = .78$ ,  $d = .09$ , two-tailed, or on 1 Remains trials  $t(15) = 1.52$ ,  $p = .15$ ,  $d = .54$ , two-tailed.

A non-parametric Wilcoxon test confirmed the pattern of results obtained with the planned t-test. The differences between 1-Object Box Empty and 2-Objects Box Empty in both conditions were not significant,  $Z = -.66$ ,  $p = .51$ , for Same Inside, and  $Z = -.9$ ,  $p = .36$ , for Different Inside trials. While the comparison between 1 Remains and Average Box Empty trials was significant within the Same Inside block,  $Z = -2.27$ ,  $p = .02$ , it was not significant within the Different Inside block,  $Z = -1.02$ ,  $p = .3$ . Finally, the number of

infants who searched longer in the 1 Remain trial than in Average Box Empty was significantly different from chance within the Same Inside block, ( $n = 13$  out of 16;  $p = .02$ , via a binomial test), but it was not significantly different from chance within the Different Inside block ( $n = 10$  out of 16;  $p = .45$ , via a binomial test).

The results of Experiment 2 show that infants had a stronger impression of two objects during Same Insides trials than in Different Insides trials, the opposite pattern as in Experiment 1. These results indicate that when observing inanimate objects, infants represent external properties differences as more closely related to a change in identity than internal property differences. Presumably, the transparent spheres were interpreted as containers, in which case the outsides are better indicators of a change in identity than the insides. For instance, a cup remains the same object regardless whether it is filled either with water or soda. When compared to Experiment 1, these data support the hypothesis that internal features are especially important for representing the identity of animate and agentive objects. This experiment also rules out the low-level alternative explanations for the 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.



Graph 2. Searching duration for Experiment 2. Error bars represent standard error of the mean. Asterisks mark statistically significant differences ( $p < .05$ ).

## CHAPTER 4

### 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 transparent objects with self-propelled motion and agentive features (i.e., 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 tend to use *external* properties to individuate the same transparent objects when they lack both self-propelled motion and agentive features. These findings suggest that infants represent internal properties as more closely connected to agents' 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 suggests that infants use domain-specific biological knowledge, where the insides are especially relevant for the agent's identity but not for the identity of inanimate objects.

Two different alternative explanations were ruled out in the second experiment. A non-significant difference between the Same Insides and Different Insides conditions when infants observe *inanimate* transparent objects indicates that insides are not especially important due to either their central position in the sphere or based on their 3D structure. In fact, the pattern of results suggests that the objects might be interpreted by infants as salient containers that possess other objects inside. By contrast, in Experiment 1 the insides might have been interpreted as the internal structure of one animate entity, in which case the insides and the outsides jointly would make up something like the agent's "body".

Another alternative explanation for the observed pattern of results could be that, from a frontal view, the toy's eyes draw attention towards the internal features. Since eyes

tend to be a very salient feature for infants, they might have encoded the color of the insides more robustly based on their proximity to the eyes. This interpretation, however, is unlikely for at least two different reasons. First, along its travel on the top of the box the toy is also seen from a side view where the eyes are not wholly perceived and the external features are more salient than the internal ones. Second, previous categorization studies using eyes on the toy's surface (Welder & Graham, 2006; Newman et al., 2008) show that infants are still biased to categorize objects based on the internal features even when the eyes do not overlap with the 'insides'. Therefore, it seems to be unlikely that the infants' attention to the internal features is due to any of the aforementioned low-level explanations.

Why might infants represent internal 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 agentic features, which suggests that infants represent 'insides' as a biological and causal factor in order to explain both motion and agency (the "Innards Principle"). Furthermore, several studies with adults and preschool aged children have revealed that causal properties are more central in the conceptual representation than so-called 'effect factors' (Anh, 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). Therefore, in the infant's early representation of agents, the 'insides' may play a role of a causal placeholder, which might be more informative than the external properties for categorizing and identifying agents. In particular, in the current study keeping track of



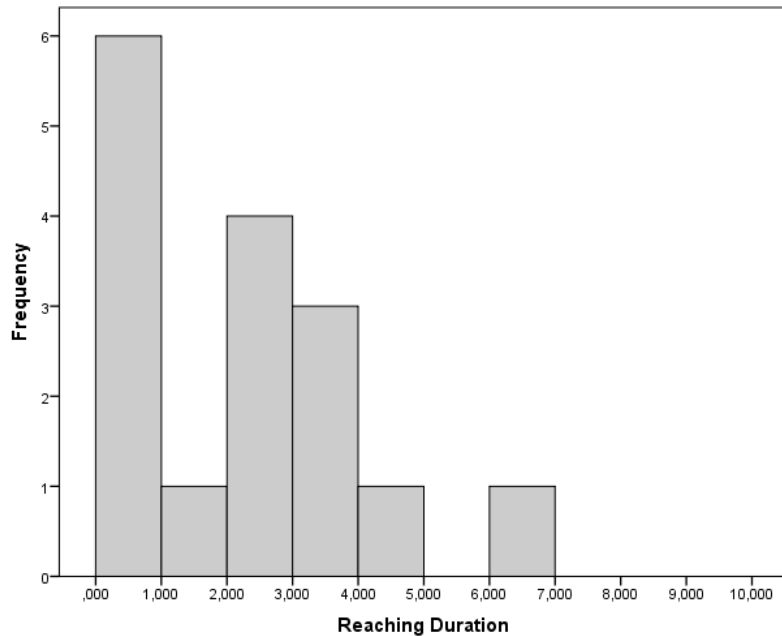
internal features as a causal factor could be more diagnostic of a change in identity over time than keeping track of external features.

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 agents' identity. A second possibility could be that the inference of internal 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 early on in development children represent the possession of a non-obvious property as determinant of an object's categorical identity. For example, infants expect objects categorized with the same label to share a non-obvious property regardless 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 (Gopnick & 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, Yoachim, Gopnik, Meltzoff & Blumenthal 2007; Sobel & Munro, 2009). 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

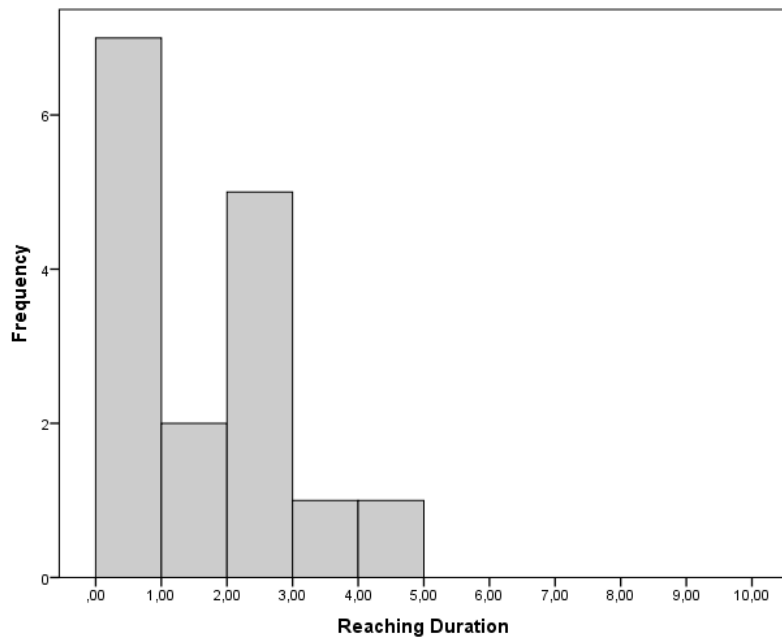
information than the outsides about the categorical identity of a particular agent. This understanding, in turn, may be further elaborated across development giving rise to more specific expectations in such a way that different biological kinds are attributed different insides with particular causal powers (Keil, 1989). Future research should investigate whether this is the case, and what type of factors, linguistic and non-linguistic, may be causally related to this transition.

APPENDIX  
HISTOGRAMS

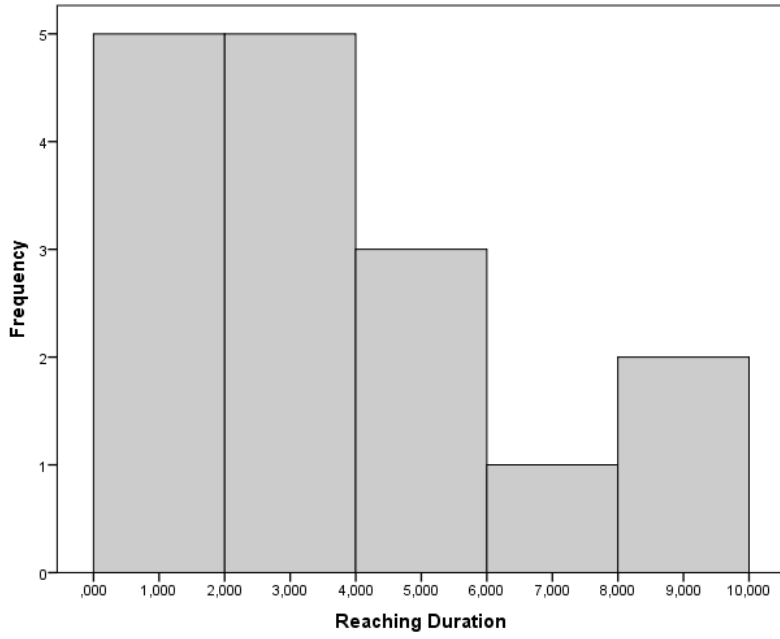
Experiment 1



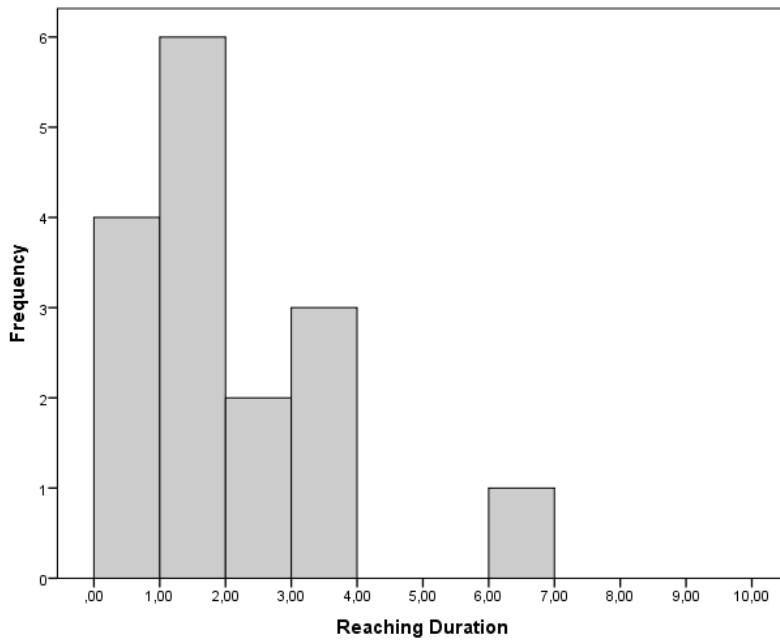
Graph 1. Histogram Same Inside One Remain



Graph 2. Histogram Same Inside Average Empty

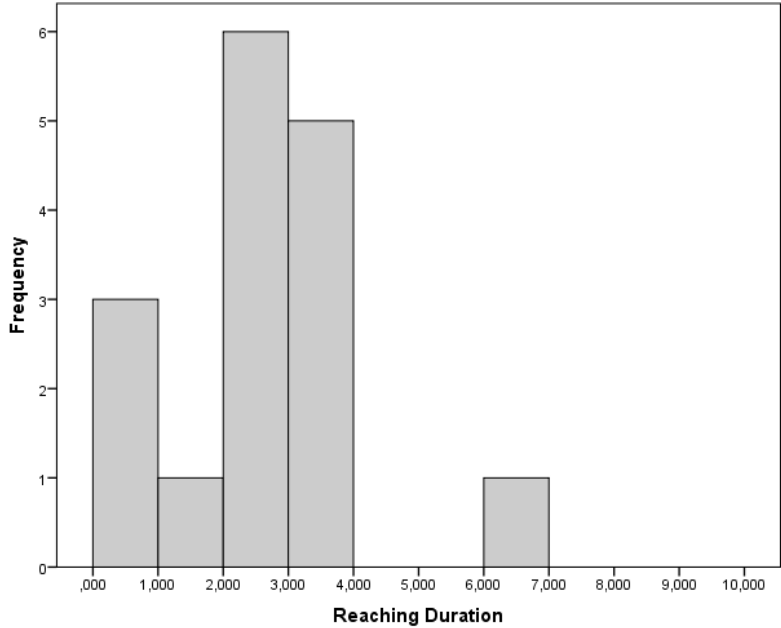


Graph 3. Histogram Different Inside One Remain

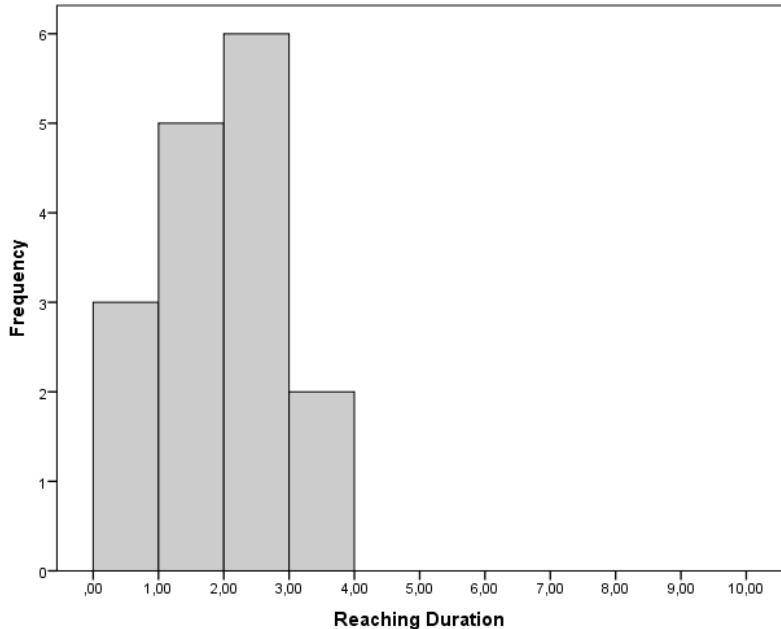


Graph 4. Histogram Different Inside Average Empty

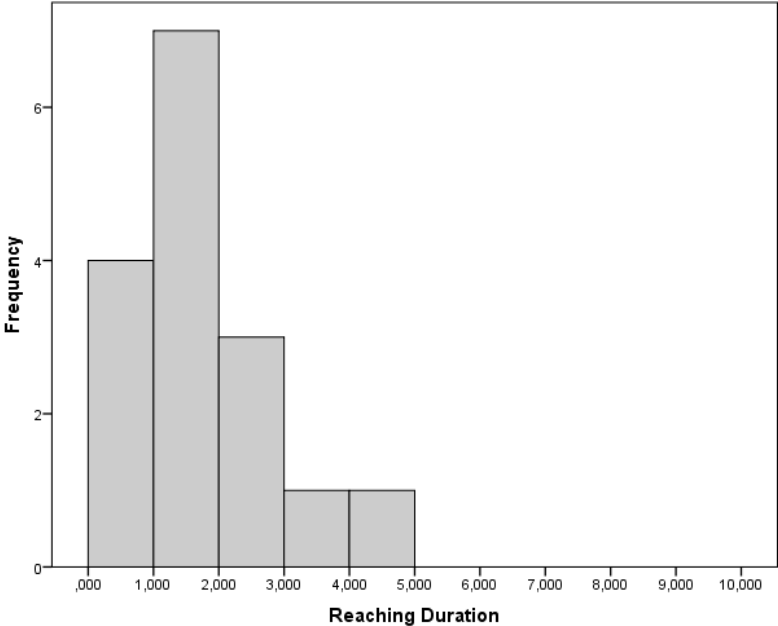
Histograms Experiment 2



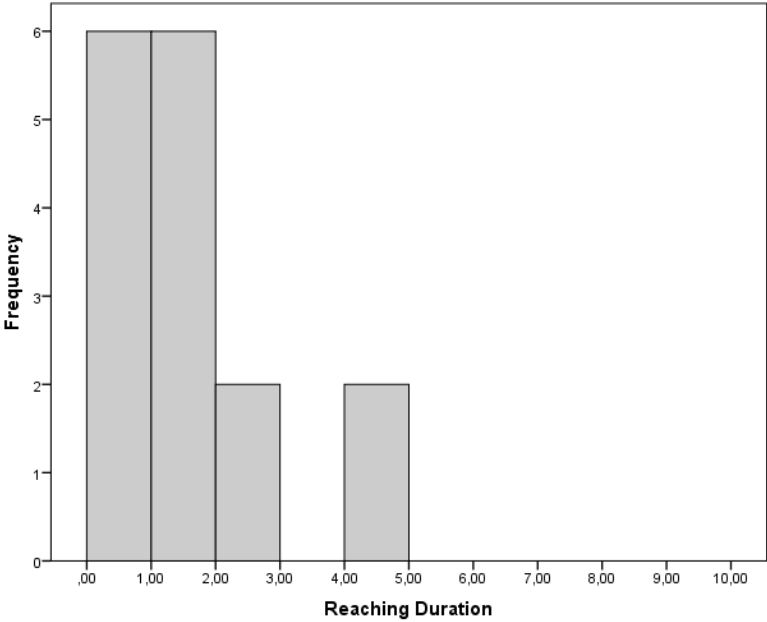
Graph 5. Histogram Same Inside One Remain



Graph 6. Histogram Same Inside Average Empty



Graph 7. Histogram Different Inside One Remain



Graph 8. Histogram Different Inside Average Empty

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