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Object Function Facilitates Infants' Object Individuation in a Manual Search Task

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Abstract

This study investigates the importance of object function (action-object-outcome relations) on object individuation in infancy. Five experiments examined the ability of 9½- and 12-month-old infants to individuate simple geometric objects in a manual search design. Experiments 1-4 (12-month-olds, *N*=128) provided several combinations of simple appearance-function relations defined by changes in form and colour (appearance) or objects' ability to make a rattling sound when shaken (function). Only when object function co-varied with the appearance-differences (Exp. 3) were infants able to individuate, suggesting that object function played a facilitating but not a determining role. In Experiment 5, 9½-month-olds (*N*=32) were unable to demonstrate such function-facilitated individuation, suggesting that this ability develops between the age of 9½ and 12 months.

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Object Function Facilitates Infants' Object Individuation in a Manual Search Task

In infancy research the ability of *object individuation* has received a great deal of attention in the past decade and a half (Krøjgaard, 2004). Object individuation is the process of determining the number of numerically distinct physical objects in a given event. This process or ability is considered to be fundamental to infant and adult cognition alike since it enables us to track individual objects (or persons) through time and space, thereby knowing if the object/person we see is the same as one we saw earlier or if it is another object/person (Xu, 2005). Human adults make use of several sources of information when they individuate objects, including *spatiotemporal information* (one object cannot be in two places at the same time and objects travel in spatiotemporally connected paths), *property information* (a spiky blue object seen on one occasion is unlikely to be the same individual as a rounded yellow object seen on another) and *kind information* (a bird cannot be the same object as a bicycle) (Van de Walle, Carey, & Prevor, 2000; Xu & Baker, 2005). Experimental studies have lead researchers to the conclusion that infants have access to these sources of information as well, but that spatiotemporal means of object individuation are the most fundamental and earliest developing, while the ability to individuate by property or kind develops somewhat later in infancy (Krøjgaard, 2007; Leslie, Xu, Tremoulet, & Scholl, 1998; Van de Walle et al., 2000; Xu & Carey, 1996; Xu, Carey, & Quint, 2004).

These experimental studies of infants' object individuation typically made use of the "violation-of-expectation"-method. This method exploits the well-documented tendency that infants look longer at event-outcomes if these are "surprising" to the infant, that is, if the outcomes contradict or violate the infants' understanding of the event they have just seen (Baillargeon, 1994a, 1994b; Krøjgaard, 2004). For instance, in a seminal study from Xu and Carey (1996), 10- and 12-

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month-old infants were presented with displays in which two objects (e.g. a ball and a cup) appeared alternately from behind opposite sides of an occluder (the property/kind condition). On the test trials, the occluder was removed to reveal either two objects (the expected outcome) or only one object (an unexpected outcome). If the infants had established representations of two distinct objects using property or kind information they should look longer at the one object outcome relative to a baseline measure since this would violate their expectation of two objects. The 12-month-old (but not the 10-month-old) infants did indeed look longer at the "unexpected" outcomes relative to baseline.

Apart from the studies directly addressing the individuation of physical objects, an interest has emerged in the contextual conditions *supporting* object individuation and how infants come to identify sources of information as relevant for the individuation problem (Wilcox & Woods, 2009). An example of this is Xu's (2002) study of the significance of language in early cognitive development. Xu presented 9-month-olds with the same object individuation task as in the Xu and Carey (1996) study described above. There was one critical manipulation though: As each object emerged from behind the occluder, the infants heard a label for it in infant directed speech. Two conditions were examined in this way. In the *Two-word condition* infants heard two distinct labels (e.g. "look a duck" and "look a ball"). In the *One-word condition*, the infants heard a single label applied to both objects ("look a toy"). Half of the trials were labelled and half of them were silent. The results showed that in the Two-word condition, but not in the One-word condition, the infants looked longer at the unexpected outcome of one object (Xu, 2002). Thus, even 9-month-olds were able to individuate the objects based on their kind, but only when the object was distinctly labelled. The success was not due to the presence of a word *per se* since the infants did not succeed in the One-word condition. Xu repeated the experiment with other auditory stimuli (two distinct tones,

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two distinct artificial sounds, and two distinct emotional expressions). *None* of these enabled the infants to individuate the objects, *only* two distinct words (Wilcox, Woods and Napoli (2006), using a different design, have later shown that 4½-month-olds can use rattle sounds as the basis for object individuation). Using novel objects and nonsense words (e.g. “a blicket” and “a tupa”) did not change this pattern. Nonsense word labels enabled the 9-month-olds to individuate even unfamiliar objects. This finding confirms that words can play a facilitating role in the way infants experience and individuate distinct physical objects. Later studies (Xu, Cote, & Baker, 2005) have even shown that the presentation of x (one or two) label-words *alone* (that is, without the initial presentation of any objects) can lead 12-month-old infants to expect x (one or two) objects in an individuation task.

In two series of studies, Wilcox and collaborators investigated the effect of priming infants with different kinds of experiences prior to object individuation tasks. These studies were conducted in the cognitively less demanding event-monitoring design developed by Wilcox and Baillargeon (1998a, 1998b). In one study Wilcox, Woods, Chapa and McCurry (2007) found that letting 10½-month-olds have access to multisensory (tactile and visual) exploration of red and green balls prior to an individuation test enabled the infants to individuate the balls visually based on colour differences in the test (whereas pre-exposure to visual exploration only did not have this effect). In another object individuation study by Wilcox and Chapa (2004) infants first saw small events in which object-colour predicted the functional use of a spoon-like object (either pounding or pouring). Subsequently, infants were given an object individuation task where the only difference between the contrasted objects (balls) was the two colours from the priming event. Without such priming infants 9½ months of age would normally be unable to individuate objects in this design based on colour differences (Wilcox, 1999), but in this study the 9½-month-olds individuated the objects after the colour-function priming. Wilcox and Chapa (2004) concluded that showing the

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infants the functional value of attending to colour information heightened the infants' sensitivity to colour features in the test event. The finding was confirmed in a later study by Wilcox, Woods and Chapa (2008).

As seen above, the study of object individuation can potentially answer a range of different developmental questions about processes related to object cognition. To our knowledge, the studies by Wilcox and Chapa (2004) and Wilcox et al. (2008) are the only studies at this point attempting to explore a relation between object individuation and function (although only indirectly so, since the design involves functional information exclusively as a mean to *prime* infants to attend to colour information in the individuation task). This seems a bit surprising since function by many has been argued to be central for instance in the formation of concepts (Nelson, 1974, 1985, 2008), in the development of conceptual categorization (Mandler, 1997, 2000, 2004), in the object-processing of the infant brain (Mareschal & Johnson, 2003) and even when discerning the cognitive characteristics particular to human beings (Kingo & Krøjgaard, 2009). A wider range of studies though, have investigated the importance of function in object/feature discrimination and object categorization primarily via *habituation-dishabituation* experiments (e.g. Booth, 2006; Horst, Oakes, & Madole, 2005; Madole, Oakes, & Cohen, 1993; Perone & Oakes, 2006; Träuble & Pauen, 2007). These studies have shown that functional information in important ways affect the way infants experience object-features and generalize them to object categories (see also Oakes & Madole, 2008).

Habituation–dishabituation studies provide information regarding which kinds of function/appearance-relations infants attend to when they observe multiple presentations of the same or equivalent objects and subsequently increase their interest to new objects. This paradigm informs us on feature saliency and on the formation of categories and it basically answers the

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question: Which differences between objects do infants attend to from event to event? This does not necessarily constitute the whole picture though. One could ask: Given certain function/appearance-relations, how many distinct objects would infants expect in an ambiguous event? This question would spur us to investigate infants' expectations regarding the likely "clustering" of functional and/or appearance –properties in time and space which would be an object individuation puzzle. We believe that we might potentially learn a great deal from looking at these spatiotemporal clusterings. For example it must be of significant importance whether the two specific movement patterns (e.g. rolling and bouncing) an infant might observe in an event are attributed to one and the same object or two distinct objects? Is the infant learning about one object that rolls *and* bounces, or about two distinct objects, one that rolls and another that bounces? Object individuation studies give us the possibility to investigate these matters, and the present study does exactly that: It investigates the possible impact of object-function on object individuation.

The Present Study

In the present object individuation study we adopted the manual search experimental design from Xu and Baker (2005). In the Xu and Baker study, which was actually a simplification of a study from Van de Walle et al. (2000), objects were shown to 10-month-old infants in small events as outlined in Figure 1. The objects were brought out from the box and shown to the infants two times. After that, infants were allowed to reach into the box and retrieve an object. In the No-Switch trials the retrieved object was identical to the object shown previously. In the Switch trials, however, the retrieved object was new: the experimenter switched the two objects inside the box, and then surreptitiously removed the presented object from the box while enabling the infant to retrieve the new object (G. Van de Walle, personal communication, January 31st, 2008). In both conditions infants were encouraged to reach into the box again. Following the violation-of-

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expectation paradigm infants were expected to search longer for an additional object in the Switch trials if they understood that two objects were in play based on the differences in object features (and kind). This was indeed what the experimenters found: Infants 10 months of age searched longer in the Switch trials than in the No-Switch trials thereby demonstrating the ability to individuate the objects (Xu & Baker, 2005).

FIGURE 1

Feigenson and colleagues (Feigenson & Carey, 2003, 2005; Feigenson & Halberda, 2004) used a manual search task very similar to this to investigate different aspects of infants' numerosity. Although not framed in an object individuation context, the designs of these studies generally adhere to the same logic as the studies from Van de Walle et al. (2000) and Xu and Baker (2005). The focus of the studies from Feigenson and colleagues, however, was not on feature-based differentiation of objects, and the stimuli objects used were identically looking ping pong balls (with the exception of Feigenson and Carey (2003, Exp. 2) where small toys differing only in size were used). Consequently, the present study has more in common with those of Van de Walle et al. (2000) and Xu and Baker (2005).

In the present study we added a "function" to the design from Xu and Baker (2005). Function has been defined in numerous ways in relation to cognitive studies (see Oakes & Madole, 2008) and no agreement as such exists on conventional ways to operationalize it experimentally. In the present study function was operationalized by a "rattling"-sound in some of the objects produced by shaking them; thus we defined function as a simple action-object-outcome –relation (only specific objects would rattle and only so when they were acted upon by shaking or similar

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actions). This was one of many possible ways of defining function (Oakes & Madole, 2008). In addition, and contrary to the Xu and Baker (2005) study, we used simple geometric objects instead of exemplars of kinds. Several studies have shown that kind-categorical information can influence the individuation of objects (Kingo & Krøjgaard, under review; Van de Walle et al., 2000; Xu & Carey, 1996; Xu et al., 2004; Xu & Baker, 2005). Since kind-categorical information was not the focus of our current research question we needed objects that as a minimum were not typical exemplars of kinds. Also in contrast to Xu and Baker (2005), we chose initially to test 12-month-old infants. We found our version of the manual search task to be more difficult than the version in Xu and Baker, partly because our test objects were simple geometric objects sometimes with internal properties, and partly because our study integrated elements of imitation. Thus, by testing 12-month-olds we wanted to ensure the active participation of the infants in spite of the added difficulty of the task.

The present study differs from the Wilcox and Chapa (2004) and Wilcox et al. (2008) studies since it is conducted in an event-*mapping* manual search design; more importantly, the functional information in the present study is directly related to the objects in the individuation task, not merely a part of a priming event with other objects. We found this to be an important difference based on the arguments on "spatiotemporal clustering" described above. In addition, it may be argued that the Wilcox and Chapa (2004) study conflated the effects of action and outcome (Oakes & Madole, 2008) whereas the present study controls for the individual effects of action and outcome.

Experiment 1

The overall aim of the present study was to investigate the importance of object function on object individuation. Specifically we were interested in the relationship between functional and appearance features of the objects. Thus, we needed to carefully consider the contributions of both kinds of features. In Experiment 1 we sought to investigate if infants would be able to individuate our simple geometric objects *without* the afore-mentioned rattle-function. This control was critical in order to interpret the subsequent experiments *involving* the rattle-function.

Participants

Thirty-two full-term infants participated (*M* age = 12:1 [months:days], range = 11:22 to 12:13; roughly half girls half boys. In addition, 8 infants in total were excluded, 6 for failure to reach into the box and 2 for fussiness.

For all the reported experiments infants were recruited from the Aarhus area in Denmark via registers from the National Board of Health. Families were contacted by letter followed by a telephone call. All infants received a token gift for their participation.

Materials and Apparatus

A box was constructed from 1 cm thick black chipboard. Closely resembling the one described by Xu and Baker (2005), it was 33 cm deep, 25 cm wide and 18 cm tall. The front surface of the box had an opening 15.5 cm wide and 8 cm tall, covered by black spandex material with an 8 cm horizontal slit. The back surface had an opening 18.2 cm wide and 14 cm tall; a black felt flap (25 x18 cm) covered the entire back surface. Felt was also placed under the box to reduce friction noise. Furthermore, the inside bottom of the box was covered with foam core to reduce noise from the objects while in the box.

The test objects consisted of small graspable balls and boxes. Two sets of green balls and red cubes were constructed. The balls measured 4 cm in diameter and the sides of the cubes measured 3.5x3.5x3.5 cm. The test objects were made from expanded polystyrene. They were covered in fabric (balls were green and cubes red) and then a layer of transparent non-toxic lacquer.

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Half of the balls and cubes were hollowed out and inserted with a small plastic pillbox containing small plastic and wooden beads. These modified objects would produce a rattling sound when shaken. There were no discernable weight differences between the rattling and non-rattling objects. For familiarization a colourful plastic spoon and a squeaking toy elephant were used.

The infants sat in a high chair in front of a table. Parents were seated slightly behind and to the right side of the infants. They were instructed not to talk or point during the experiment. The experimenter sat on the other side of the table facing the infant. Behind the infant and to the left was an assistant who would keep track of the critical time periods and control the video camera. The camera recorded the entire scene and was placed, so the front opening of the box was visible at all times. A mirror placed behind the infant allowed the experimenter to see whether the infants had grasped the objects.

Design and Procedure

The experiment consisted of two phases: familiarization and test. The familiarization phase was followed by three pairs of test trials. Each par of test trials consisted of one trial in which the object the infant retrieved was the same as the object the infant was shown (NS trials) and one trial in which the retrieved object was different from the object the infant was shown (S trials).

Familiarization phase. The purpose of the familiarization trials was to acquaint the infant with the box and the procedure. During these trials, the infant was given verbal encouragement to reach into the box and praise when objects were retrieved. The objects that the infants retrieved were always the same objects as they were shown. The first familiarization object was always the colourful spoon; she second was the squeaking toy elephant. On the first familiarization trial, the experimenter placed the box at the side of the table opposite from the infant, near the experimenter but out of reach of the infant. He then reached through the slit, removed the spoon and placed in on

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top of the box. He verbally directed the infant's attention to the object three times (translated from Danish: "See this? Look at that! Watch this!") before placing it back into the box. The object was left partially protruding through the slit to encourage reaching. The experimenter then pushed the box towards the infant. If the infant retrieved the object, the experimenter cheered. The infant was allowed to play with the object for 5 seconds after which it was taken away. The box was left in front of the infant for another 5 seconds. Then, regardless of the infant's reaching behaviour, the experimenter picked up the box, shook it and said, "It's empty! There's nothing there!" After this the box was placed in the starting position and the second familiarization trial began. The second trial was identical to the first except that the squeaking toy elephant was used instead of the spoon. In addition, the elephant was squeaked a couple of times by the experimenter, when it was presented to the infant before placing it on top of the box. Furthermore, the elephant was placed entirely inside the box before the box was pushed towards the infant.

Test phase. Each infant received six test trials, three NS trials and three S trials in the order NS, S, S, NS, NS, S or S, NS, NS, S, S, NS. Order of trials and the object presented (ball or cube) were counterbalanced across participants. In Experiment 1 none of the objects were able to rattle.

All test trials began with the experimenter placing two objects in the box out of the infant's view (the green ball and the red cube). The box was then placed on the table near the experimenter and out of the infant's reach. The experimenter reached into the box (through the front slit), pulled out one of the objects, shook it four times (even though in Experiment 1 the shaking would not produce a rattling sound) and placed it on top of the box. The infant's attention was verbally directed to the object three times ("See this? Look at that! Watch this!"). The object was then placed back in the box through the front slit. It was pulled out again, shaken four times, put on top of the box and referenced three more times. Then it was placed in the box again and the box was pushed toward the infant. Typically the infant would then reach into the box and retrieve an object.

In the NS trials the infant would retrieve the *same* object as it had been shown (the experimenter would make sure that the other object was kept out of the infant's reach inside the box). When the infant retrieved the object, the box was moved out of reach of the infant, and she was allowed to play with the object for 5 sec. During that time the experimenter referenced the object three times saying, "look what you've got! Look at that! See that?" The object was then taken away and placed out of the infant's view. The box was pushed back toward the infant and left in place for 10 sec., during which the experimenter smiled at the infant. The infant would never find an object in the box at this point, but the duration of search into the box during these 10 sec. was to be recorded. The 10 sec. interval was timed by the assistant who would play a key on a toy piano when the time was up. The timing began when the box reached a mark 4 cm from the edge of the table. At the assistant's signal, the box was removed from the reach of the infant again.

The procedure for the S trials was identical to the NS trials except that after the last presentation, when the object was returned to the box, the experimenter surreptitiously switched the two objects inside the box, keeping the presented object out of the infant's reach but enabling the infant to retrieve the *non-presented* object.

On rare occasions an infant who was otherwise willing to reach after the objects would not reach for the initial object in a trial. In such cases that trial was omitted and the experiment went on. Participants who did not complete at least 4 trials (two NS and two S) were excluded from the study. Otherwise, the means of the NS and S trials respectively were calculated from the remaining trials for each infant.

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The critical question now was not whether the infant reached into the box again after the first object had been retrieved but rather: once the infant reached into the box and found nothing, what would she do? If the infant did *not* expect an object to be in the box, the prediction was that she would likely reach shortly, find nothing and then withdraw (NS trials). If, however, the infant *did* expect to find an object, when she reached in and found nothing, the prediction was, that the infant would search the box more persistently (S trials) (see also Van de Walle et al., 2000; Xu & Baker, 2005).

Data Analysis

The analyses period of time was the 10 sec. after the infant had retrieved the first object. Following Xu and Baker (2005), the dependant measure was the duration of search in each trial (ranging from 0 – 10 sec.). The coding was done from the video recording by an observer that was unaware of our hypotheses and of the nature of the specific experiment each infant participated in. Following Van de Walle et al. (2000) and Xu and Baker (2005), an infant’s behaviour was considered to be a reach when the third knuckles of the hand was inside the slit of the spandex that covered the front opening of the box. A second observer (also unaware of the theoretical and empirical context) independently coded duration of search for 40 randomly chosen infants (out of the 160 participants in exp 1 – 5). The average interobserver agreement of the search duration was 94% (range = 92% - 96%).

The experimenter was face to face with the infants during the experiment. To address the concern that the experimenter would unintentionally influence the infants, we asked two of our assistants to look at video clips of 30 randomly chosen trials (from exp 1-5) showing only the experimenters face, arms and upper torso. The assistants were asked to guess if the trials were NS or S trials. Results of a binominal test revealed that the assistants were no more accurate than

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chance (assistant 1 guesses: 47% correct, p = .856; assistant 2 guesses: 60% correct, p = .362; mean guesses: 53% correct, p = .699).

Results and Discussion

Preliminary analyses found no effects of order of test trails, presented object (ball/cube) or trial pair (1-3). A *t*-test revealed no difference in reaching time between the S trials (M = 3.7 sec, SD = 1.6) and the NS trials (M = 3.8 sec, SD = 2.0), $t(31)$ = .385 p = .703.

Infants in Experiment 1 did not behave in a manner consistent with individuation of the green ball and the red cube. While we cannot conclude that the infants were unable to *detect* the appearance differences between the different objects, evidently these differences did not lead the infants to a reaching behaviour consistent with object individuation. Some *visual* object individuation studies have found that even younger infants are sometimes able to individuate objects based on shape and/or colour (e.g. Tremoulet, Leslie, & Hall, 2000; Wilcox & Baillargeon, 1998b; Wilcox, 1999), whereas others (Xu et al., 2004) have found that such feature-based individuation is only possible when the shapes of the objects correspond to the shapes of exemplars of different kinds. To our knowledge, though, no manual search study has yet found feature-based individuation of simple geometric objects or objects not specifically referring to different kinds. We shall return to these issues in the general discussion.

The next question now was whether or not the infants would encode the appearance differences differently if *both* objects were able to rattle. That is, would the addition of a rattling function somehow increase the saliency of the appearances thereby leading the infants to expect two objects in the S trials? This was the central question of Experiment 2.

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Experiment 2

Participants

Thirty-two full-term infants participated (*M* age = 11:25 [months:days], range = 11:15 to 12:13; roughly half girls half boys. In addition, 26 infants were excluded, 18 for failure to reach into the box and 8 for fussiness. In general we found the exclusion ratio (especially due to failure to reach into the box) of the present study to be relatively high. We attribute this to the fact, that the appearances of our stimuli objects were very simple and lacked the details of natural exemplars of kinds that might have increased the infants' interest in the task.

Materials and Apparatus

Materials and apparatus were identical to those of Experiment 1.

Design and Procedure

Familiarization phase. The familiarization phase was identical in all 5 experiments.

Test phase. The test phase was identical to the one in Experiment 1 with the following important exceptions: Both test objects of Experiment 2 were all able to rattle. Consequently, when the experimenter shook an object during a presentation, this object would rattle. Likewise, all objects retrieved by infants in this experiment would be able to rattle. The only difference between the contrasted objects in the S trials was their appearances (green ball or red cube); the ability to rattle was constant.

Data Analysis

Data analysis was identical to the previously described experiment.

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Results and Discussion

Preliminary analyses found no effects of order of test trails, familiarization object (ball/cube) or trial pair (1-3). A *t*-test revealed no difference in searching time between the S trials (M = 4.0 sec, SD = 2.1) and the NS trials (M = 4.0 sec, SD = 2.1), $t(31) = .198$, $p = .844$.

Infants in Experiment 2 as well did not behave in a manner consistent with individuation of the objects. In spite of the addition of a rattling function to all of the objects, infants did not search longer after finding an object that differed from the one they had been shown. Thus, we found no evidence that the addition of the rattling function by itself enhanced the infants' sensibility to the appearance differences thereby resulting in behaviour consistent with object individuation. The next question to be asked was what would happen if the differences in appearance and in function co-varied, that is if the rattle-function (a nonobvious feature) was only related to one of the two object appearances. This was the condition in Experiment 3.

Experiment 3

Participants

Thirty-two full-term infants participated (*M* age = 12:0 [months:days], range = 11:16 to 12:14; roughly half girls half boys. In addition, 28 infants were excluded, 17 for failure to reach into the box, 2 for experimenter error and 9 for fussiness.

Materials and Apparatus

Materials and apparatus were identical to the previously described experiments.

Design and Procedure

Familiarization phase. The familiarization phase was identical in all 5 experiments.

Test phase. The test phase was identical to those of Experiments 1 and 2 with the following important exceptions: The objects contrasted in the S trial differed in appearance *and* in the ability

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to rattle. The presented object would always be able to rattle (for instance a rattling green ball) and in the S trials the infants would then retrieve an object with a different appearance that was always *unable* to rattle - in this instance the non-rattling red cube (due to the logic of the manual search experiment we could not present non-rattling objects in Exp. 3 and 5. For individuation purposes infants would have had no chance of telling whether the newly found rattle-function of the retrieved object had been present but not manifest in the presented object). For half the infants, the presented rattling object would be the rattling red cube. In every case, appearance and ability to rattle would co-vary.

Data Analysis

Data analysis was identical to the previously described experiments.

Results and Discussion

Preliminary analyses found no effects of order of test trails, familiarization object (ball/cube) or trial pair (1-3). A *t*-test revealed that infants searched longer on the S trials (M = 4.3 sec, SD = 2.1) than on the NS trials (M = 3.5 sec, SD = 1.7), $t(31)$ = 2.501, p = .018, Cohens's d = 0.42. Nonparametric analysis confirmed this finding. Eighteen of the 32 infants searched longer following S trials than NS trials, Wilcoxon z = 2.21, p = .027.

From the behavioural measures of Experiment 3 infants were *able* to individuate the objects when these differed in appearance *and* function. At this point we did not know whether the object individuation was a result of a synergy effect of the co-varying appearances and function, or if the switch in function by itself accounted for the infants' success. Thus, we needed to investigate if a function-switch by itself would provide sufficient information for the infants to individuate. This was investigated in Experiment 4.

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Experiment 4

Participants

Thirty-two full-term infants participated (*M* age = 11:30 [months:days], range = 11:17 to 12:8; roughly half girls half boys. In addition, 21 infants were excluded, 13 for failure to reach into the box, 2 for experimenter error and 6 for fussiness.

Materials and Apparatus

Materials and apparatus were identical to the previously described experiments.

Design and Procedure

Familiarization phase. The familiarization phase was identical in all 5 experiments.

Test phase. The test phase was identical to those of the previously described experiments with the following important exceptions: The objects contrasted in the S trials differed only in ability to rattle but *not* in appearance. For instance, the presented object would be the rattling red cube and the object retrieved by the infant (in the S trials) would be a red cube without the ability to rattle. Half of the infants would be presented with the rattling green ball and would (in the S trials) retrieve the non-rattling green ball.

Data Analysis

Data analysis was identical to the previously described experiments.

Results and Discussion

Preliminary analyses found no effects of order of test trails, familiarization object (ball/cube) or trial pair (1-3). A *t*-test revealed no difference in searching time between the S trials (M = 3.6 sec, SD = 1.9) and the NS trials (M = 3.8 sec, SD = 1.7), $t(31) = .93$, $p = .36$.

Infants in Experiment 4 did not behave in an individuation-consistent manner based on a switch in function alone. It seems, by 12 months at least, that exclusive changes in object function

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did not lead the infants to conclude the presence of two objects in the manual search design. This makes sense in an adaption perspective, since children at some point are likely to encounter objects that, while maintaining their appearance, will seem to fluctuate in functional properties (new functions of a known object may be discovered, “old” functions may disappear due to internal malfunction etc.). Therefore functional information by itself is just not an effective predictor of numerical identity. When looking at Experiment 1-4 in unison, the only combination of appearance switch and function switch that resulted in object individuation was the co-varying combination found in Experiment 3. From a developmental perspective we wanted to investigate if the results from Experiment 3 could be replicated with younger infants (as in the study from Xu & Baker, 2005). This is what we did in Experiment 5.

Experiment 5

This experiment was identical to Experiment 3 with one exception: Test age in Experiment 5 was 9½ months.

Participants

Thirty-two full-term infants participated (*M* age = 9:18 [months:days], range = 9:9 to 9:30; roughly half girls half boys. In addition, 31 infants were excluded for failure to reach into the box, 0 for experimenter error and 6 for fussiness.

Design and Procedure

Design and procedure were identical to that of Experiment 3.

Materials, Apparatus and Data Analysis

All identical to the previously described experiments.

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Results and Discussion

Preliminary analyses found no effects of order of test trails or familiarization object (ball/cube) but, unlike all the experiments with the 12-month-old infants, we found a significant effect of trial pair (1-3), Wilks' Lambda = .74, $F(2, 30) = 5.23$, $p = .011$. Infants searched shortest in the 1st trial pair and longest in the 3rd trial pair (this particular finding is discussed in the General Discussion). A *t*-test revealed no significant difference in searching time between the S trials (M = 2.6 sec, SD = 1.8) and the NS trials (M = 2.1 sec, SD = 1.7), $t(31) = 1.38$, p=.18.

FIGURE 2

This data analysis led to the conclusion that infants aged 9½ months did not behave in a manner consistent with individuation of the contrasted objects although these differed in appearance *and* in function. A tendency to replicate the result from Experiment 3 can be seen from the graphs (Fig. 2). But the difference in reaching time between the NS and S trials was not significant.

General Discussion

Five related object individuation experiments tested the importance of object-function in a manual search design combining switches of the appearance of simple geometric objects with switches of function (operationalized as an internal rattle property). We found that only co-varying appearance- and function properties enabled 12-month-old infants to behave in a manner consistent with object individuation (Exp. 1-4). In addition, 9½-month-old infants were unable to demonstrate such individuation based on co-variation of appearance and function (Exp. 5). However, given that the reaching times increased significantly from the 1st to the 3rd trial pair in Experiment 5 (Fig. 3), caution needs to be taken in the interpretation of the results from this particular experiment. We

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hesitate drawing the simple conclusion that the 9½-month-olds failed to individuate the objects solely because of the inability to exploit the co-varying function and appearance. The progressive increase of the reaching times in Experiment 5 could suggest that the 9½-month-olds, in contrast to the 12-month-olds, were still in the process of being familiarized with the test-situation as such during the test-trials. Based on the present data, we simply do not know if the 9½-month-olds would have been able to demonstrate function-facilitated object individuation, similar to that of the older infants, if they had been allowed to complete this familiarization e.g. with additional warm-up trials. But we know that they were unable to do so with the present design and procedure.

FIGURE 3

Infants did not demonstrate object individuation when the rattle-function was left completely out of the experiment (Exp. 1). This finding is inconsistent with those of some other individuation studies. For instance, individuation of simple geometric objects differing in shape and colour has been found as early as 4½ months of age in a visual and simple event-monitoring design (Wilcox & Baillargeon, 1998a, 1998b) and individuation of simple geometric figures differing in colour only has been found with 12-month-olds (Tremoulet et al., 2000). These studies though, have used different individuation tasks and most importantly, they were measuring *visual* data only in contrast to the present manual search study. This difference has been argued to be important in infant categorization studies (e.g. Mandler, 1997, 2000, 2004) and may have played a role in the present object individuation study as well (see also Kingo, 2008; and Kingo & Krøjgaard, 2010). The findings from Experiment 1 *is* consistent though with the findings of Xu et al. (2004) in that neither colour-differences nor shape-differences, that do not indicate objects of different kinds, will enable 12-month-olds to individuate.

In Experiment 2 the addition of the rattle-function did not change the infants' reaching behaviour into one consistent with object individuation. So adding an internal property by itself did not result in the infants paying more attention to the appearance differences. Likewise, no individuation behaviour was found in Experiment 4, where only switches in function took place. So what does it mean that individuation behaviour was only found when appearance and function co-varied (Exp. 3)? In order to succeed in the specific task of the present study infants would need to be able to both *individuate* and *identify* the involved task objects, a distinction suggested by Alan Leslie and co-workers (Káldy & Leslie, 2003; Leslie et al., 1998; Tremoulet et al., 2000). Following this distinction, object individuation involves setting up an object representation (OR) whereas object identification means using the information stored in an OR to decide which, if any, previously individuated object is presently encountered (Tremoulet et al., 2000). In the present study, in order to reach longer in the S trials, the infants would have had to *identify* the retrieved objects as being different from the one(s) in the presentation and following that they would have had to *individuate* by expecting at least one object to be left in the box during the timed reaching. So the co-variance of appearance and function enabled the infants to individuate *and* identify the objects. This in turn means that their failure in Experiment 1, 2 and 4 could have been caused by an inability to *individuate* the objects, to *identify* them or *both*. As mentioned by an anonymous reviewer, a range of other factors such as limitations in working memory, inhibitory control, and any number of motor, or motivational factors may also have contributed to this failure. We would like to add that these limitations may have played an even more significant role with the 9½-month-

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olds in Experiment 5. This, however, does not change the fact that, under the right circumstances (i.e. Exp. 3) infants did indeed behave in a manner consistent with object individuation.

The ability to individuate based on co-variance of appearance and function does seem to be important for several aspects of early cognition. For instance, in an influential paper, Nelson (1974) argued that infants based their word learning on (object) concepts and that these concepts came from the infants' experience with what things do and what can be done with them. This experience would then form a "functional core" of the concept that would constitute the primary *meaning* while the perceptual features of the objects would guide the inclusion of new members (the Functional Core Concept (FCC) model, see also Nelson, 2008). This model has inspired much of the subsequent research in object function (Kemler Nelson, Russell, Duke, & Jones, 2000; Oakes & Madole, 2008). But, in order for the FCC model to be valid, infants must be sensitive to appearance-function correlations to some extent (as has been shown in habituation-dishabituation studies) and they must somehow be able to correlate or ″bind″ their experience with function to a *distinct* object if they are to recognise this object as one having certain functional or internal properties. This latter ability would be exactly that of individuating and identifying based on the appearance-function correlations. Now, if we were to expect a one-to-one relation between the functional cores (concepts) and the individuation of the objects we would have expected that the infants would be able to individuate the objects based on the functional information only, as was the task in Experiment 4 of the present study. Infants were *unable* to do this though. Thus, they needed the co-varying appearance features as well in order to take advantage of the functional information for individuation purposes (Experiment 3). This makes sense since a world with identically looking objects with different internal properties would be very difficult for infants to decipher.

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In a recent study though, Dewar and Xu (2009) found that 10-month-old infants expected nouns to refer to the internal properties (e.g. squeaking, rattling or jingling) of objects more than to object appearance. One-word labels would lead infants to expect one (and only one) kind of internal properties even in two objects with different appearances, whereas two-word labels would lead them to expect two different kinds of internal properties even in two objects with identical appearances. In conclusion, the 10-month-olds' expectations about internal properties were driven by the labelling and not by object appearances.

When this study is seen in relation to the present study, it seems that functional or internal properties are targeted when infants in this age group are to relate words (nouns) to objects while information on function *and* appearance go together when infants are attempting to keep track of the identity of distinct physical objects. The findings from Dewar and Xu (2009) and from the present study complement each other well in the perspective of Nelsons FCC model of word learning: Functional information can facilitate the individuation of objects when these differ in appearance. This ensures the representation of distinct physical objects that can be referenced with words. Noun labels, in turn, are expected to target the functional properties of these distinct physical objects, a finding that is consistent with the notion of functional core concepts.

In their daily lives, infants are confronted with the task of representing individual objects in their surroundings. The ability to individuate objects, we argue, is a necessity for learning the correlations of specific objects and their dynamic and functional characteristics. It is thus crucial for infants to be able to correctly "cluster" information on object-appearances and object-functions. The present study provides the first direct evidence for a facilitating effect of object-function information on object individuation in infancy. Co-varying appearances and functions will provide sufficient information for 12-month-olds and to individuate simple geometric objects whereas any

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other combination of appearance and function will not. In contrast, 9½-month-olds are not capable of demonstrating individuation based on such co-variation yet.

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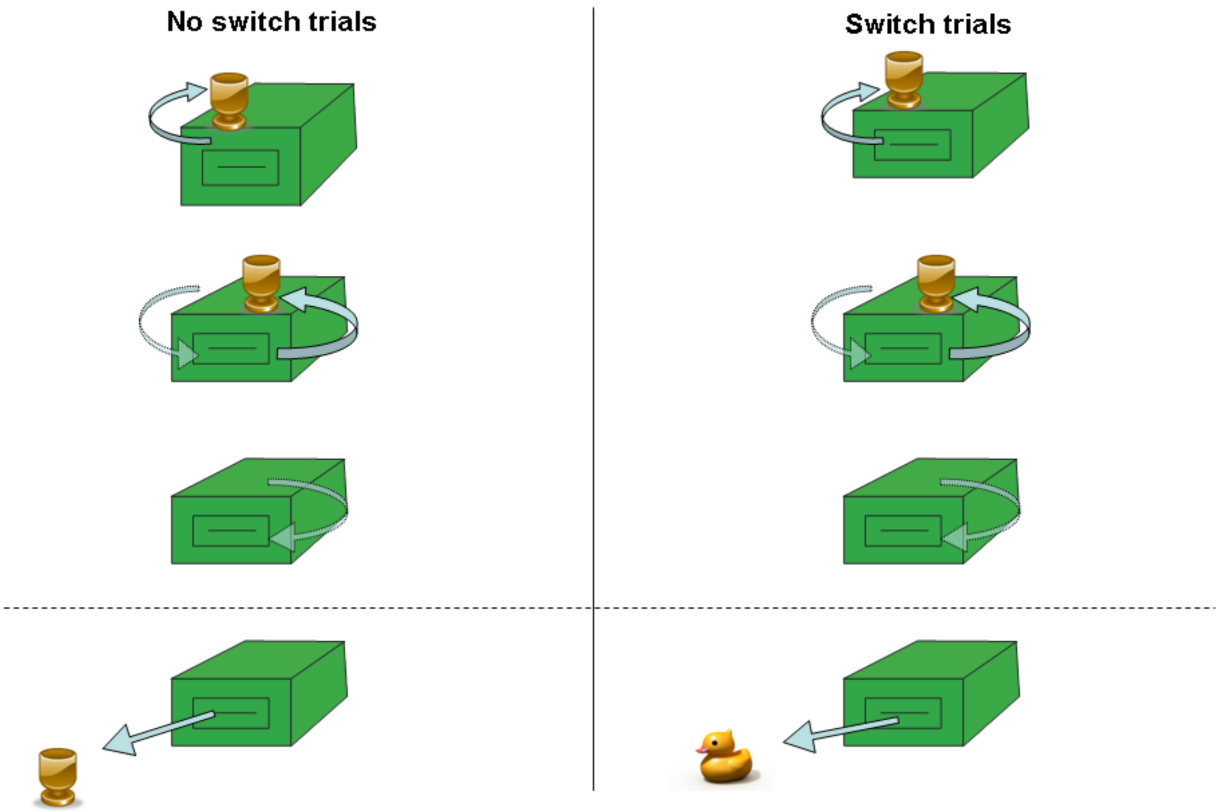

Figure 1: Schematic representation of Switch and No Switch trials in Xu and Baker (2005)

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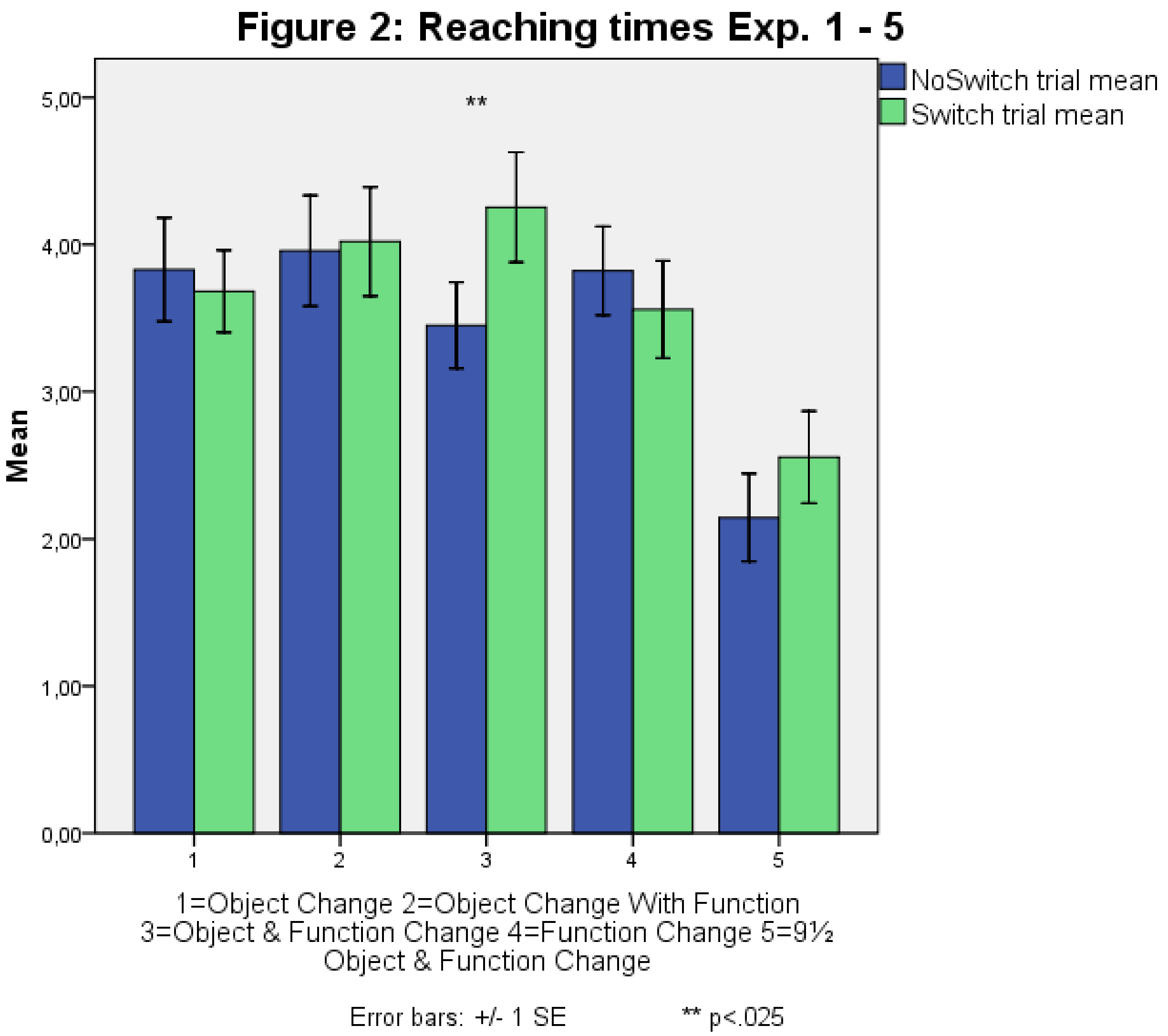

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Figure 3: Means of trial pairs Exp. 1-5