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Object Manipulation Facilitates Kind-based Object Individuation of Shape-similar Objects

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Abstract

Five experiments investigated the importance of shape and object manipulation when 12-month-olds were given the task of individuating objects representing exemplars of kinds in an event-mapping design. In Experiments 1 and 2, the results of the study from Xu, Carey, and Quint (2004, Exp. 4) were partially replicated showing that infants were able to individuate two natural-looking exemplars from different categories but not two exemplars from the same. In Experiment 3, infants *failed* to individuate two shape-similar exemplars (copied from Pauen, 2002a) from different categories. However, Experiment 4 revealed that allowing the infants to manipulate the objects shortly prior to the individuation task *enabled* the infants to individuate the shape-similar objects from different categories. In Experiment 5, such access to object manipulation *per se* did not induce object individuation of natural-looking objects from the same category. These findings suggest that object manipulation facilitates kind-based individuation of shape-similar objects by 12-month-olds.

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Keywords: Object Individuation; Object Shape; Object Manipulation; Kind Representations; Infancy.

Introduction

Imagine a young boy at Christmas. The boy sees his dad exiting the front door with the garbage. A few minutes later a man with a white beard and a red coat enters the hall, it's Santa Claus! The boy is ecstatic. He knows a lot about Santa from stories, from television, cartoons etc. and he knows that Santa's presence means presents. Santa is about the same height as dad, and his eyes and voice is very similar to dad's as well, but the boy knows it cannot be dad because it is *Santa*, a person with a different history, a different meaning to the child, and besides, dad is outside. Now imagine that Santa takes of his hat, puts down the bag of presents, opens the red coat, and removes the beard… At some point the meaningful representation of Santa breaks down and is replaced by the representation of dad. When does this happen? Does it happen gradually or in an instant? Are some perceptual cues more decisive than others in this process, and how similar can Santa and dad look before the representation of two different individuals breaks down?

These questions are of great importance to the way we understand the co-development of object representations, perception, categories, and concepts. The interplay of perceptual features and our meaningful representations of objects in the world is complex and compelling and has spurred the interest of many infant and child researchers. Numerous studies have looked into the processes of categorization, other studies have focused on the word-learning related to objects and events we experience, and yet others have investigated the ability to determine the identity of objects and persons. In realization that these areas of cognition are thoroughly intertwined (e.g. Nelson, 2008), researchers have recently begun to investigate the possible impact these different areas and processes may have on each other. Specifically, a wave of studies investigating the relation between numerical identity of objects or *object individuation* and words, categories, concepts, and actions in infancy have emerged (e.g. Wilcox & Chapa, 2004; Wilcox, Woods, Chapa, & McCurry, 2007; Wilcox, Woods, & Chapa, 2008; Xu, 2002; Xu, Carey, & Quint, 2004). The study of object individuation focuses on the workings of the important cognitive ability to single out and identify numerically distinct physical objects. Naturally, this specific area of study is only one among many possible approaches to these matters (Kingo, 2008a, 2008b). A possible strength, however, is that it allows us to closely investigate the ability to tell one object from another within an event-structure.

Object individuation has typically been studied using the "violation-of-expectation"-method (for reviews see Krøjgaard, 2004, 2009; Xu, 2005). 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 infant's understanding of the event they have just seen (e.g. Baillargeon, 1994a, 1994b). For instance, in a seminal study from Xu and Carey (1996), 10- and 12-month-old infants were presented with displays in which two objects (e.g. a ball and a cup) appeared alternately from opposite sides of an occluder (the property/kind condition). During this presentation the objects were never seen simultaneously. After this small event, the occluder was removed to reveal either *two* objects (the expected outcome from an adult point of view) or only *one* object (the unexpected outcome from an adult point of view). If infants had discriminated the features of the two objects, and more importantly, if they had used this discrimination to establish representations of two distinct objects they should expect two objects behind the occluder. This expectation would then be violated when only one object was revealed which (by logic of the violation-of-expectation paradigm) should produce longer looking times at the one object outcome relative to the two objects outcome. After statistically controlling for the infants' intrinsic (baseline) preference for one or two objects, longer looking times at the unexpected (one object) outcome relative the expected (two objects) outcome was interpreted as object individuation. The 12-month-old (but not the 10-month-old) infants did indeed look longer at the "unexpected" outcomes when intrinsic preference was controlled for. Thus, Xu and Carey concluded that 12-month-olds were able to individuate objects based on differences in property/kind. The results from this classic study have been replicated in several studies with equivalent designs (Bonatti, Frot, Zangl & Mehler, 2002; Krøjgaard, 2000, 2003).

Recently, using the same experimental setup, Xu et al. (2004) reported a series of experiments in which the relation between the ability to individuate objects and the more specific object features was examined closer. The impact of different aspects of the object features was investigated in four experiments: One, in which the two contrasted objects varied only in *color* (Experiment 1); one, with variation only in *size* (Experiment 2); one, in which the objects varied in a combination of *color*, *size* and *surface pattern* (Experiment 3); and finally one where only the overall *shape* of the objects differed while keeping the other properties constant (Experiment 4). These four different variations were chosen because, among the many dimensions by which objects can vary, shape has been found to correlate highly with kind membership (Xu et al., 2004) (we would like to add though, that shape's relationship with kind membership is not always purely correlation. In the artifact domain in particular, shape is often causally related to function and thereby to kind). In addition, Experiment 4 consisted of two different conditions: The Within-kind Condition, in which the two contrasted objects differed in shape but belonged to the same kind (two different cups, two different bottles, or two different toy ducks); and the Cross-kind Condition where the contrasted objects belonged to different kinds (a cup vs. a ball, a bottle vs. a box, and a toy duck vs. a toy seal).

The researchers found the following: The 12-month-old infants were *unable* to individuate based on the property information in Experiments 1, 2, and 3. The infants succeeded individuating the objects *only* in Experiment 4 and *only* in the Cross-kind Condition. Based on these findings Xu et al. (2004) concluded that perceptual properties *per se* were not sufficient to facilitate object individuation by infants of this age group. In this specific experiment infants had to have salient shape-information specifically pointing at two *different kinds* or categories of objects to be able to individuate them. Infants were thus using kind–information to solve the individuation puzzle.

By these conclusions, Xu et al. (2004) reaches into the field of categorization and concept formation (see also Xu, 2005). Naturally, in order for the infants to take advantage of kind–information in the above study, they must be able to categorize the objects in question, and in this case they did so based solely on the overall object shape (the only differentiating information available to the infants in that experiment), according to Xu et al. (2004).

Interestingly, there is some evidence, that infants are able to categorize objects of different *global* kinds without the mentioned salient shape differences (Mandler & McDonough, 1993; Pauen, 2002a). Mandler and McDonough (1993) reported that infants 9-11 months of age categorized small models of birds and airplanes differently in an object examination task (also called the "familiarization/novelty-examining task") even though these objects had similar shapes and similar texture. In the categorization study reported by Pauen (2002a), a set of natural-looking models of animals and furniture was compared to a set of artificial-looking animals and furniture (see a subset of these in Fig. 5). The latter was designed such, that each exemplar of the furniture category had the same global shape as one animal, the same colors as another animal, and the same surface pattern as a third animal. In preliminary experiments adults were asked to assess the perceptual similarities of both sets of objects. The natural-looking objects were rated to have *low* perceptual between-category similarity whereas the artificial-looking objects were rated to have *high* perceptual between-category similarity. When 11-month-old infants were tested with these two sets of objects in an object examination task, Pauen found that infants categorized the natural-looking and artificial-looking objects equally well into the adult-like categories [animal] and [furniture]. Furthermore, no other categories were formed with the artificial-looking objects in spite of their highly rated perceptual between-category similarity, and in spite of the fact that the object-shapes varied more within the categories than between them. Pauen argued that the only way to explain the successful (and adult-like) categorization of the artificial-looking objects was that the infants were drawing on already formed knowledge of the categories.

Categorization vs. Object Individuation

When comparing the studies above it is important to be mindful of the relationship between categorization studies based on the familiarization/novelty-preference paradigm (i.e. the studies from Mandler & McDonough and Pauen) and object individuation studies based on the violation-of-expectation paradigm (i.e. the Xu et al. study). Familiarization/novelty-preference studies provide information regarding which kinds of feature/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 question: "Which differences between objects do infants attend to from event to event?" These differences may or may not relate to the infants' conceptual understanding of the objects. Object individuation studies, on the other hand, basically ask the question: "Given certain feature/appearance-relations how many distinct objects would infants expect in an ambiguous event?” This question spurs us to investigate infants’ expectations regarding the likely “clustering” of features in time and space – expectations that *may* be influenced by the infants’ prior experience with such clusters. So, categorization studies and object individuation studies address different but overlapping aspects of some of the same processes in infant object cognition.

In sum, some interesting disparities seem to emerge when looking at the studies presented above. Despite the intimate relationship between kind-based object individuation and categorization, Xu et al. (2004) found that shape was important for kind-based object individuation while Mandler and McDonough (1993), and Pauen (2002a) found that it was not important for categorization. One potential explanation for this disparity is that the categorization studies focused on global-level categories while Xu et al. focused on basic-level categories. A first step in testing this possibility is to test whether shape (and the extent to which it differs between objects) matters in kind-based individuation of exemplars from clear-cut global categories. If shape matters here, then category level is not the sole explanation. Other possible explanations for the disparity have to do with different task characteristics e.g. exposure to single vs. multiple exemplars from a given category or the opportunity for object manipulation. The present study attempts to disambiguate these possibilities.

The Present Study

In the present study we first wished to closer investigate the impact of shape-similarity on object individuation by 12-month-olds. As discussed above, we wanted to investigate the possible explanations for the fact that object-shape was found to be relatively unimportant in the mentioned categorization studies while object-shape was reported to be very important for kind-based object individuation in the Xu et al. (2004) study. In order to do this, we sought to partially replicate and extend Experiment 4 (the Within- and Cross-Kind Conditions) of the Xu et al. (2004) study; this by using natural-looking objects for the replication and artificial-looking objects similar to the ones used in the Pauen (2002a) study for the extension (we thank Sabina Pauen for kindly giving us access to the exact measures and pictures of her artificial-looking stimuli objects). The replication was only partial since the category membership in the present study was in relation to global categories and not the so-called basic-level categories of the Xu et al. study. Our basic assumption was that infants would behave in a similar manner to the Xu et al. study in spite of these differences. We based this assumption on reports from categorization studies where infants of this age group responded primarily to the boundaries of global categories (e.g. Mandler & McDonough, 1993; Mandler & McDonough, 1996; Pauen, 2002a). Furthermore, some data (Pauen, 2002b) suggested that the sensitivity to basic-level (as opposed to global) categories is only just beginning by the age of 12 months. We also reasoned that if we were able to replicate the original findings of the Within-kind Condition in spite of the broader categories it would just reflect on the discussion of the "basic'ness" of basic-level categories (see Mandler & Bauer, 1988) and not greatly affect our main question on the impact of shape.

Although our design in most respects was a close replication of the Xu et al. (2004) study, a major difference in the experimental setups was that we chose to mechanize the process of showing the individuation events. We did this to ensure exact reproductions of the event sequences between trials as well as across infants (with regard to object speed, fixed stationary intervals, etc.), and to reduce the risk of experimenter error.

Experiment 1

This experiment was an attempt to partially replicate Experiment 4 (the *Within*-kind Condition) of the Xu et al. (2004) study with our own test objects.

Participants

Nineteen full-term and healthy 12-month-old infants (8 girls and 11 boys) participated in the experiment (*M* age = 11:26 [months:days], range = 11:15 to 12:11). Six additional infants were excluded due to fussiness (this category includes infants missing a single or more baseline or test trials). For all the reported experiments (Exp. 1-5), 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

Two pairs of objects were used in the experiment (see Fig. 1): Two natural-looking toy animals (a giraffe with the widest measures of 9 cm x 9.5 cm x 3 cm (height x width x depth) and a crocodile with the widest measures of 3 cm x 12 cm x 7 cm) and two natural-looking toy pieces of furniture (a cupboard with the widest measures of 10 cm x 6.6 cm x 3 cm and a bed with the widest measures of 5.3 cm x 9.7 cm x 5.7 cm). All objects were with natural coloring and surface patterns. They were attached to a black wooden base (10 cm x 10 cm) for the purpose of movement in the puppet theatre.

Four millboard screens (blue, red, lavender and pink), each 16 cm tall and 30 cm wide, were used in the experiment. Initially, we sought to utilize screens with the exact same measures as those of the Xu et al. (2004) study (26 cm tall and 34 cm wide). But, due to the nature of our study, we were constrained to utilize smaller objects than those of the original study and piloting showed that the "large" screens drew too much attention from our smaller objects. Consequently, we allowed ourselves to reduce the screen sizes.

FIGURE 1

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Apparatus

The events were presented in a mechanized puppet theatre with a stage opening of 30 cm x 80 cm x 60 cm (height x width x depth) and a black surface. A black curtain hung behind the stage to conceal the movements of the experimenter. Large white curtains extended from the stage opening and upwards and to the sides, to minimize distractions in the infants' visual field. A white curtain was also lowered to cover the scene opening before the test, between trials, and after the test. A gap in the stage floor from 23 – 35 cm from the front allowed the objects on the bases to be moved from side to side by a computer controlled motor. All such movement was at exactly 8 cm/second as in the reference study. In addition the bases were able to tilt down below the stage floor, so objects could "disappear" behind the screen. In order to make sure that the sound produced by the motors was similar across infants and outcomes, the bases were always either tilted down or halfway down and back before the screen was lowered.

A digital video camera was hidden 5.5 cm below the centre of the stage floor, recording the infant through a small hole (4 cm in diameter) in the front. The video camera was connected to a monitor placed behind the theatre to allow the experimenter to observe the infant, and to a second monitor (video only) in another room allowing an observer to record the looking times. Importantly, the observer could not see the events on the stage and was blind to the exact conditions of the experiment. A push button was connected to the computer that recorded the looking times.

The stage was lit from above. Infants sat in a car safety seat mounted on an elevation chair, their eyes were about 70 cm from the stage with eye level about 5 cm above the stage floor. The parent sat next to the child with his/her back towards the stage. He/she was instructed not to look at the displays, not to talk to the child, and to simply smile back reassuringly when the infant looked at him/her.

Design and Procedure

The procedure of both the baseline- and test- trials was a close replication of the Xu et al. (2004) study with regards to timing of sequences and scoring criteria.

Baseline trials. Each infant received four baseline trials. On each trial, the experimenter raised the scene curtain and then lowered the screen into a slit in the stage floor, revealing one or two objects. As the experimenter lowered the screen he drew the infants' attention by saying "Look [infant's name]" (in Danish). In all trials a red diode light turned off in the observers monitor when the screen was lowered, signaling to the observer to start timing. When the infant had looked for at least .5 second and then looked away for 2 consecutive seconds, the trial ended. This "stop"-criteria was applied throughout the experiment (baseline-, encoding-, and test-trials). The computer beeped to signal the end of the trial. At the end of each trial, the screen was raised again and the scene curtain was lowered. The screen was then replaced by a screen of a new color in preparation for the next trial.

The object pair used for the baseline trials was the one that was not used in the encoding and test trials for a particular infant. For example, if the giraffe and the crocodile were to be used in the encoding and test trials, the cupboard and the bed would be used during baseline trials. In Experiment 1 the giraffe was always paired with the crocodile and the bed was always paired with the cupboard. Which pair of objects was shown during baseline trials, which side the single object was on, and the order of the presentation (1, 2, 2, 1) or (2, 1, 1, 2) were counterbalanced across infants. The baseline trials provided a measure of the infants' intrinsic preference for one or two objects.

Encoding trials. Six encoding trials followed the baseline trials. For each trial, the experimenter raised the scene curtain revealing the screen with a pair of objects hidden behind it (this time the pair *not* used in the baseline trials). The first object moved out from behind the screen (Fig. 2). The experimenter tapped the object a couple of times from above with a small stick and drew the infants' attention by saying "Look at this". The observer started the timing when the infant looked at the object. When the infant looked away for two consecutive seconds, the computer beeped and brought the object back behind the screen (thus, to ensure proper encoding of each object, the specific time of object exposure was controlled by the infant and there was no fixed upper time limit). The second object was then brought out to the other side of the stage. Again the experimenter tapped it a couple of times with the stick while drawing the infant's attention and then left it for the infant to look at. When the infant looked away, the computer brought the object back behind the screen. Each object was brought out tree times for a total of six encoding trials. Which object was brought out first and to which side of the stage was counterbalanced across infants.

FIGURE 2

Test trials. At the end of the encoding trials and to remind the infant what each object looked like, each object was brought out to one side of the scene, rested for a fixed period of 2.5 seconds, and was then returned to behind the screen ("a reminder", Xu et al., 2004); this happened one object at a time. Subsequently, the screen was lowered, revealing one or two objects. As the screen was lowered the experimenter drew the infants' attention by saying "Look [infants' name]". Looking time was then recorded. At the end of each trial, the screen was raised and the scene curtain was lowered. A screen of a different color was prepared for the next trial, before the scene curtain was raised again. Each object was shown again for a fixed period of 2.5 seconds (the "reminder") and the screen was lowered to reveal the object(s). Each infant was shown four test trials, alternating between two outcomes. In the expected outcome, two objects were revealed when the screen was lowered; in the unexpected outcome, only one object would be visible to the infant (the other object had been tilted down below the stage floor while hidden behind the screen). The computer ran the "tilting" routine regardless of the specific event outcome in order to equate the sound produced by the motors in all trials. The order of outcome (1, 2, 2, 1 or 2, 1, 1, 2) and which object was the single object were counterbalanced across infants.

Data Analysis and Results

Following the Xu et al. (2004) study, we used the means of the looking times on one and two objects in the analysis. We compared the infants' baseline preference for one or two objects with their looking times for one or two objects in the test trials. Also following Xu et al., we included the baseline preference in the main analysis and for the same reasons: The analysis that reveals whether infants used the information provided in the encoding trials for object individuation is a comparison of the looking times at the two outcomes on the baseline trials with those of the test trials. Success consists of an interaction between Condition (Baseline vs. Test) and Outcome (1 vs. 2 objects) such that the preference for two is significantly less during test trial than during baseline trials. An α level of .05 was used in all statistical analyses.

Preliminary analysis revealed no effects of sex and order of outcome. Subsequent analyses collapsed over these variables.

An ANOVA examined the effects on looking times of Condition (Baseline vs. Test) and Outcome (1 object vs. 2 objects). There was a main effect of Outcome $F(1,18) = 7.881$, $p = .012$, $\eta_p^2 = .305$. Overall infants looked longer at two objects ($M = 9.9$ s, $SE = .97$) than one object ($M = 7.7$ s, $SE = .78$). There was no effect of Condition and more importantly, there was no interaction of Condition and Outcome $F(1,18) = .049$, $p = .827$, $\eta_p^2 = .003$.

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FIGURE 3

Discussion

In Experiment 1, infants failed to individuate the objects since no interaction of Condition and Outcome was found. We did find a main effect of Outcome pointing to an intrinsic preference for two objects. This preference was expected and probably has to do with the fact that two objects represent more information than a single object (see also Xu & Carey, 1996; and Xu et al., 2004), hence they draw more attention. Experiment 1 replicates the findings from Xu et al.'s (2004) Experiment 4, the Within-kind Condition. Note though, that our categories (furniture and animals) were considerably broader than the categories chosen in the Within-kind Condition of the original study (cups, bottles and toy animals). Thus, the failure to individuate the arguably more perceptually dissimilar objects in the present experiment strengthens the notion that perceptual dissimilarity alone does not facilitate object individuation by this age.

Experiment 2

This experiment was an attempt to partially replicate Experiment 4 (the *Cross*-kind Condition) of the Xu et al. (2004) study with our own test objects.

Participants

Sixteen full-term and healthy 12-month-old infants (6 girls and 10 boys) participated in the experiment (*M* age = 11:23 [months:days], range = 11:15 to 12:9). Sixteen additional infants were excluded: Eleven due to fussiness, 4 due to experimenter error, and 1 due to technical error.

Materials, Apparatus, Design, and Procedure

Materials, apparatus, design, and procedure was identical to Experiment 1, except that in this experiment, the giraffe was always paired with the cupboard and the crocodile was always paired with the bed.

Data Analysis and Results

Preliminary analysis revealed no effects of sex and order of outcome. Subsequent analyses collapsed over these variables. An ANOVA examined the effects on looking times of Condition (Baseline vs. Test) and Outcome (1 object vs. 2 objects). There were no main effects, but an interaction of Condition and Outcome was found: $F(1,15) = 6.767$, $p = .020$, $\eta_p^2 = .311$.

FIGURE 4

Discussion

In Experiment 2, infants were *able* to individuate the contrasted objects. This is a replication of the findings from the Cross-kind Condition of the Xu et al. (2004) study. All in all, the present Experiments 1 and 2 replicates both conditions of Experiment 4 in the Xu et al. study, using natural looking exemplars of furniture and animals. We took these findings as evidence that 12-month-olds do indeed take advantage of kind memberships when attempting to individuate objects and that kind membership seems to be more important that perceptual dissimilarity *per se* in the present context. Furthermore, these results confirmed to us, that our experimental setup was sensitive to the same factors as the setup in the Xu et al study. But in order to further investigate the more specific effect of object shape in this task, we sought to repeat Experiment 2 (the "successful" individuation) with a subset of the "artificial-looking" objects borrowed from the Pauen (2002a) study. These objects also represented exemplars from the animal and furniture categories and corresponded to the natural-looking objects of Experiment 1 and 2 on the basic-level (giraffe, crocodile, cupboard, and bed). The Pauen (2002a) study found successful categorization of these objects by 11-month-olds and we sought to investigate whether infants would be able to take advantage of the kind membership of shape-similar objects, in accordance with Pauen's findings, or if shape similarity would disrupt the individuation, more in accordance with the Xu et al. (2004) findings.

Experiment 3

This experiment was identical to Experiment 2 with one important exception: The objects used in experiment 3 were a subset of the stimuli objects of the Pauen (2002a) study.

Participants

Twenty full-term and healthy 12-month-old infants (8 girls and 12 boys) participated in the experiment (*M* age = 11:25 [months:days], range = 11:15 to 12:8). Five additional infants were excluded: Four due to fussiness and 1 due to experimenter error.

Materials and Apparatus

This was identical to Experiment 2 with the exception of the stimuli objects. Objects used in Experiment 3 were exact copies of a subset of Pauen's (2002a) "artificial-looking" stimuli objects (see Fig. 5). The subset consisted of: The giraffe with the widest measures of 9.7 cm x 3.8 cm x 1.5 cm (height x width x depth), the crocodile with the widest measures of 1.5 cm x 10.5 cm x 1.5 cm, the cupboard with the widest measures of 9 cm x 4.8 cm x 1.6 cm, and the bed with the widest measures of 3 cm x 10 cm x 3.5 cm. The giraffe and the cupboard had very similar overall shapes as had the crocodile and the bed. Since this was only a subset of the original artificial-looking objects and since an object from the subset was always contrasted with an object (from another category) with a very similar shape, we henceforth call this subset the *shape-similar* objects.

Design and Procedure

Design and procedure was identical to Experiment 2.

FIGURE 5

Data Analysis and Results

Preliminary analysis revealed no effects of sex and order of outcome. Subsequent analyses collapsed over these variables. An ANOVA examined the effects on looking times of Condition (Baseline vs. Test) and Outcome (1 object vs. 2 objects). There was a main effect of Outcome $F(1,19) = 7.239$, $p = .014$, $\eta_p^2 = .276$. Overall, infants looked longer at two objects (M = 8.7 s, SE = .85) than one object (M = 6.6 s, SE = .58). There was no effect of Condition and more importantly, there was no interaction of Condition and Outcome $F(1,19) = .077$, $p = .784$, $\eta_p^2 = .004$.

Discussion

Infants in Experiment 3 were *unable* to individuate the shape-similar objects from different categories. In fact, they reverted to the general preference for two objects also found in Experiment 1 of the present study. This finding is in accordance with the conclusions of the Xu et al. (2004) study, where overall shape-differences were found to be the most important features when determining kind-membership. While the failure to individuate in Experiment 1 seemed to be caused by the infants' lacking conceptual organization of exemplars from the same global category (when compared with Experiment 2), the failure in Experiment 3 most likely had to do with an inability to *recognize* the objects as members belonging to the two different global categories. This means that the conceptual distinction (found to be important in our Exp. 1 and 2) between the object exemplars is difficult to make when the shape-differences are blurred. The present finding does not, however, agree easily with the findings from the Pauen (2002a) study where infant examination of the exact same objects led to categorization described as "knowledge-based". If the artificial-looking objects are categorized into animals and furniture by 11-month-old infants, as reported by Pauen, we would expect that the 12-month-olds of the present study would be able to take advantage of such categories when attempting to individuate, just as they did in Experiment 2. However, a potentially important difference between the Pauen study and the present one is that infants manipulated the objects with their hands in the former but not in the latter (see the General Discussion for other factors potentially contributing to the differential findings). The present individuation study, adhering to the looking-time paradigm, only provides infants with visual information about the objects. It has been argued, that access to object examination is important for infants' responding to conceptual categories (Mandler, 2000). To investigate this possible explanation for the different findings of the present Experiment 3 and Pauens' study , we conducted Experiment 4, which was identical to Experiment 3 with the addition of a pre-test allowing the infants to manipulate the objects shortly.

FIGURE 6

Experiment 4

This experiment was identical to Experiment 3 with the addition of a pre-test phase.

Participants

Twenty full-term and healthy 12-month-old infants (9 girls and 11 boys) participated in the experiment (*M* age = 12:0 [months:days], range = 11:19 to 12:8). Eight additional infants were excluded: Seven due to fussiness and 1 due to technical error.

Materials and Apparatus

This was identical to Experiment 3.

Design and Procedure

Design and procedure was identical to Experiment 3 except for the addition of a pre-test phase. In this pre-test, infant sat at their parent's lap by a table near the puppet theatre. The experimenter gave the *test* objects (not the baseline objects) one at a time (in random order) to the infant while saying "look!", and the infant were allowed to manipulate these objects for 10 seconds each (never seeing the objects simultaneously). After the 10 seconds, the experimenter took the object away, and after the second object the infant was immediately moved to the puppet theatre, and the experiment continued as described in Experiment 1-3.

Data Analysis and Results

Preliminary analysis revealed no effects of sex and order of outcome. Subsequent analyses collapsed over these variables. An ANOVA examined the effects on looking times of Condition (Baseline vs. Test) and Outcome (1 object vs. 2 objects). There were no main effects, but an interaction of Condition and Outcome was found: $F(1,19) = 6.030$, $p = .024$, $\eta_p^2 = .241$.

FIGURE 7

Discussion

Infants in Experiment 4 were *able* to individuate the shape-similar objects from different global categories. In addition, the intrinsic preference for two objects disappeared in this experiment. The only way to interpret this result in relation to Experiment 3 was that the manipulation pre-test made a significant difference to the infants' ability to individuate these objects. One might speculate, though, that the success was caused simply by the extra ten seconds of *visual* exposure to the objects in Experiment 4. However, we found this possibility highly unlikely since the encoding trials were infant controlled and therefore provided the infants with all the visual processing time they wanted. It was impossible to tell at this point, though, if the success in Experiment 4 was due to a general individuation-facilitative effect of the manipulation pre-test *or* if the object manipulation had a more specific effect on the individuation of the shape-similar objects from different categories. For instance, evidence from a study by Wilcox, Woods, Chapa, and McCurry (2007) suggested that multisensory (visual and tactile) experience with objects facilitates 10.5-month-olds use of *color* information when individuating objects.

In order to investigate this closer, we conducted a fifth experiment, again with the addition of a manipulation pre-test. In Experiment 5 we used the same contrast-pairs as in Experiment 1 (the natural-looking objects from the same category). If the object manipulation facilitated object individuation in general, we would expect infants in Experiment 5 to be able to individuate the natural-looking objects thereby overcoming the assumed difficulties involved in individuating exemplars from the same category. If, on the other hand, the effect of the manipulation pre-test was specific to the shape-similar (hence more difficult in terms of kind recognition and individuation) objects, we would expect the pre-test to have no significant effect in Experiment 5 and for the result to resemble the previously obtained negative results of Experiment 1. We chose to use the natural-looking objects in Experiment 5 to test if the improved access to these detail-rich objects would enable the infants to individuate, in spite of the objects belonging to the same global category, simply because perceptual differences would now be easier to detect. Similarly, a failure in this experiment would be even more conspicuous if it happened with the detail-rich objects.

Experiment 5

This experiment was identical to Experiment 1 with the addition of the same pre-test phase as described in Experiment 4.

Participants

Nineteen full-term and healthy12-month-old infants (10 girls and 9 boys) participated in the experiment (*M* age = 12:0 [months:days], range = 11:25 to 12:12). Nine additional infants were excluded: Six due to fussiness, 2 due to experimenter error and 1 due to technical error.

Materials, Apparatus, Design and Procedure

Were identical to Experiment 1 except for the addition of the pre-test phase.

Data Analysis and Results

Preliminary analysis found no effects of sex and order of outcome. Subsequent analyses collapsed over these variables. An ANOVA examined the effects on looking times of Condition (Baseline vs. Test) and Outcome (1 object vs. 2 objects). There was no main effect of Condition, no main effect of Outcome $F(1,18) = 3.062$, $p = .097$, $\eta_p^2 = .145$, and more importantly no interaction of Condition and Outcome $F(1,18) = 2.864$, $p = .108$, $\eta_p^2 = .137$.

Finally, and in addition to the ANOVA's on each experiment in isolation, we also ran three-way ANOVA's comparing the relevant experiments with each other. The relevant comparisons were: Between Exp. 1&2 (to look for an effect of the within global categories vs. the across global level categories), between 2&3 (to look for an effect of natural-looking objects vs. shape-similar objects), between 3&4 (to look for an effect of the manipulation pre-test), and between 1&5 to confirm that performance in these were equivalent. The results were as follows: Exp 1vs2: F (1,33)=2.229 p=0.145; Exp 2vs3: F (1,34)=2.075 p=0.159; Exp 3vs4: F (1,38)=2.254 p=0.142; Exp 1vs5: F(1,36)=1.259 p=0.269. None of these analyses revealed significant three-way interactions. However, for the three first analyses (1vs2, 2vs3, 3vs4) the results resembled the result from a similar three-way analysis from the Xu, Carey & Quint (2004) study, where a p value of 0.1 was found, And like in our reference study, we draw our conclusions based on the pattern of positive and negative results found in the individual experiments. The last analysis (1vs5) confirmed that there were no significant statistical differences between the looking-time behavior of infants exposed to the natural-looking objects from the same global category, regardless whether they were introduced to a manipulation pre-test.

FIGURE 8

Discussion

Infants in Experiment 5 were *unable* to individuate the natural-looking exemplars from the same category. However, the intrinsic preference for two objects was disrupted. We found no significant effect of the pre-test phase when comparing this result with that of Experiment 1, which seems to indicate, that the effect of the manipulation pre-test found in Experiment 4 was specific to the individuation of the shape-similar exemplars from different categories. The present result emphasizes the importance of kind-information in this task since infants in Experiment 5 were presented with both detail-rich objects and an opportunity to manually examine these objects, and yet were still unable to individuate the objects from the same global category. Seemingly, by 12 months of age, the facilitative effect of object manipulation was not able to overcome the difficulties posed by contrasting two objects from the same global category. The fact that the intrinsic preference for two objects was disrupted, though, may be indicative of an emerging conceptual distinction at the *basic* level. Such an emerging ability to distinguish between basic level categories by 12 months of age was found in a longitudinal study by Pauen (2002b) involving an object examination task and has earlier been suggested by Mandler and McDonough (1993, 1998). An emerging basic-level distinction may very well have been revealed in our Experiment 5 because of the infants' opportunity to manually examine the objects (in contrast to the findings in Experiment 1 where no object manipulation was allowed).

General Discussion

Five experiments investigated the importance of shape similarity in kind-based object individuation by 12-month-olds. Experiments 1 and 2 partially replicated the findings of the Xu et al. (2004, Exp. 4) study. Infants were *able* to individuate natural-looking exemplars of animals and furniture when these were contrasted across the global categories, but *unable* to do so when they were contrasted within the global category. This pattern fits the notion that infants by this age are able to make use of conceptual information when they attempt to individuate exemplars of kinds. In Experiment 3, however, this ability seemed to break down when shape-similar exemplars from different global categories were contrasted; this in spite of the fact that evidence for *categorization* of the same objects had been reported by Pauen (2002a). When infants, in Experiment 4, were allowed to manipulate the shape-similar objects for 10 seconds each, the ability to individuate was restored. Furthermore in Experiment 5, the addition of the manipulation phase did *not* enable infants to individuate natural-looking objects from the same global category.

It should be mentioned, that an additional factor potentially contributing to the differential findings of the Experiment 3 of the present study and the study by Pauen is the degree of exposure to category exemplars. Since Pauens's study was a categorization study, infants were exposed to multiple (five) exemplars from each category in question. In contrast, infants from the present individuation study saw only one exemplar from each contrasted category of objects. It may be that the superior opportunity for comparison and contrast offered by exposure to multiple exemplars support bringing to mind the relevant concepts even under difficult conditions such as when observing the artificial-looking objects (we thank two anonymous reviewers for bringing this potential explanation to our attention). Thus, the multiple exposures of Pauen's study may have contributed to the different findings of her study relative to the present Experiment 3. However, the fact that infants successfully individuated in the present Experiment 4 indicates that exposure to multiple category exemplars cannot have been the *sole* contributor to these differences if a contributor at all.

As an additional note to our study, we mentioned earlier that the present study made the within-kind and cross-kind distinctions in relation to global-level categories. In contrast, Xu et al. (2004) made the same distinctions in relation to basic-level categories. Because of this, our within-kind condition (Exp 1: giraffe vs. crocodile and bed vs. cupboard) where infants failed to individuate actually resembles the basic-level cross-kind condition in the Xu et al. study where infants individuated successfully. It is difficult to explain why Xu et al. found that 12-month-olds were able to individuate objects that differed on the basic-level only while we found that they were unable to. Apart from the fact that our setup was mechanized and that we thereby were able to completely rule out any human bias in controlling the movement of the objects, the explanation could also be found in the fact that different basic-level exemplars were used in the two studies and that some of these may be easier to distinguish conceptually than others. For instance, in the basic-level cross-kind condition of the Xu et al. study, a cup was contrasted to a ball and a bottle to a box. It is not completely unlikely, we would argue, that infants would categorize cups and bottles as something you use during a meal while balls and boxes are used during playtime – two arguably quite different activities that may result in different conceptualizations of the involved object from an early age (e.g. Mandler, 2004).

This aside, how do the results from the present study correspond to the existing literature on these matters? From our results it seems plausible that object-shape has *some* impact on kind-based object individuation. When shapes become very similar as in Experiment 3, it becomes difficult to take advantage of the different categorical affiliations. This is in accordance with the conclusions from Xu et al. (2004) and it fits with the well demonstrated phenomenon in word learning called the *shape bias*. The shape bias is named as such due to the fact that children around the age of 2.5 years tend to extend noun labels based on the shape of an object across a variety of word learning situations (e.g. Booth & Waxman, 2008; Hupp, 2008). In addition, it has been demonstrated that the shape bias is not necessarily specific to lexical contexts (Graham & Diesendruck, 2009). Seen from this perspective, a shape bias in categorization and object individuation with infants seems plausible. But, how is the successful individuation found in Experiment 4 of the present study explained then? And why is the assumed effect of the kind information manifesting here and not in Experiment 3?

The Effect of Object Manipulation

As stated, the only difference between Experiments 3 and 4 was the addition of a manipulation pre-test. Mandler (2000, 2004) has suggested that infants performing in tasks involving object manipulation, like in the object examination task, tend to invoke their conceptual knowledge to a much larger degree than when performing in tasks involving visual exploration only. Mandler argues, that conceptual information has to do with what objects *do*, their movement patterns, and interactions with other objects. So when infants are *actively* engaged in object examination/manipulation, as opposed to the more passive visual observation, they tend to pay more attention to features that relate to conceptual categories. Mandler further states: "Right from the beginning, infants form concepts in a way that looks remarkably like using defining features rather than overall perceptual appearance" (Mandler, 2004, p. 11). The pool of potential features could cover a range of more or less subtle object characteristics such as moving parts, small details (e.g. eyes in the case of animals), parts that are relevant for the human interaction with the objects (e.g. handles) or shape to name a few. The *defining* features would always be fairly specific to the formation of concepts, though.

This theory proposed by Mandler *could* provide an explanation for the differential behavior of infants in Experiment 3 and 4 of the present study. It may be the case that object manipulation *primes* the activation of infants' conceptual knowledge/memory and that kind-defining features (shape or other features) are therefore highlighted in a manipulation context. This "highlighting" may have helped the infants in Experiment 4 to detect the very subtle shape differences of the shape-similar objects as well as other feature differences thereby responding to the categories [animal] and [furniture]. In this perspective, one possible explanation for the present findings could be that object-shape is an important feature for determining kind-membership but mostly so in studies based solely on *visual* attention, such as in the Xu et al. (2004) study; while studies involving object manipulation (e.g. Mandler & McDonough, 1993; Pauen, 2002a) may support the attention to other less salient kind-defining features as well, thereby enabling the infants to determine the object kind. This could be called the "highlighting-kind-defining-features" explanation of the effect of object manipulation.

An alternative explanation could be that object manipulation may increase the attention to *all* object features (kind-defining or not), enabling the infants in Experiment 4 of the present study to notice the kind-defining shape differences, even though these were artificially reduced, and to individuate accordingly. This could be called the "increased-attention-to-all-features" explanation. Based on the findings from the present study we favor this second explanation. The more specific explanation ("highlighting-kind-defining-features") derived from Mandler's theory could possibly be valid but a privileged link between object manipulation and certain kind-defining features is not needed to explain our data. With the "increased-attention-to-all-features" explanation in mind a conclusive summary of the pattern of our findings would be as follows (we thank an anonymous reviewer for suggesting this concise summary of the pattern of results to us):

In Experiment 1, infants fail to individuate because they (in contrast to in Experiment 2) lack the necessary conceptual knowledge to do so. In Experiment 2, they succeed because they do have the conceptual knowledge that distinguishes between the global categories of [furniture] and [animals]. In Experiment 3, infants fail because the perceptually impoverished stimuli (the shape-similar objects) prevent them from tapping into this global-level conceptual knowledge. They succeed in Experiment 4 because manipulation heightens their attention to all features and allows them to identify the objects' kind membership – thereby tapping into the relevant conceptual distinctions that are facilitative of individuation in this design. They fail in Experiment 5 because even though manipulation has led to a thorough processing of the perceptual properties of the objects, the infants still cannot identify the objects as belonging to distinct kinds (because the do not yet fully represent basic-level conceptual distinctions of the objects in question).

From this pattern of results we conclude that object manipulation seems to facilitate the kind-based individuation of shape-similar objects in the present study. Several important questions remain unanswered, though. We cannot yet conclude beyond doubt that additional object-exposure, involving for instance the visual modality only, would not produce a pattern of results similar to the present. Furthermore, we do not yet have data informing us on whether object manipulation would facilitate kind-based object individuation on other category-levels than the global later in development. In fact, our data (in addition to the conclusions from Mandler and McDonough (1993, 1998) and Pauen (2002b)) suggest that the individuation of objects contrasted on the basic level might be facilitated in a similar way in slightly older children. These questions are for future studies to answer.

Investigating Kinds with Individuation Tasks

The present study sought to investigate aspects of the infants' knowledge of kinds within an object individuation design. We hope to have shown, that object individuation experiments can be a valuable addition to other methods of investigating early understandings of kinds or categories (i.e. the habituation-dishabituation paradigm). Object individuation studies, we argue, provide information about different aspects of this kind-knowledge than the more traditional instruments for investigating categories in infancy. In studies such as the present, categorization *per se* is not investigated, and one important reason for this is that we did not use more than two exemplars from each category in the experimental design. Rather, kind-knowledge is investigated as a factor affecting the infants' *expectancies* about the behavior of physical objects in small events (the violation-of-expectation method). These expectancies, in turn, will affect the behavior of the infants towards objects in the real world. Kinds and categories are interesting by themselves but even more interesting when we learn about the way they affect behavior. Consequently, we believe that studies like the present one constitute a valuable source of information that *complements* the existing knowledge of early categorization and ensures a more complete description of kind-knowledge as a phenomenon (for a more thorough discussion of these issues see Kingo, 2008a, 2008b).

The present study provides evidence that object manipulation facilitates the individuation of shape-similar objects and consequently, that object-shape has different impact on kind-based object individuation depending on the infants' access to active manipulation of the objects. This should reflect on the ongoing discussions of the importance of shape in the categorization of objects *and* on discussions of the comparability of visual-based and manual-based studies.

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Figure 1. Natural-looking objects

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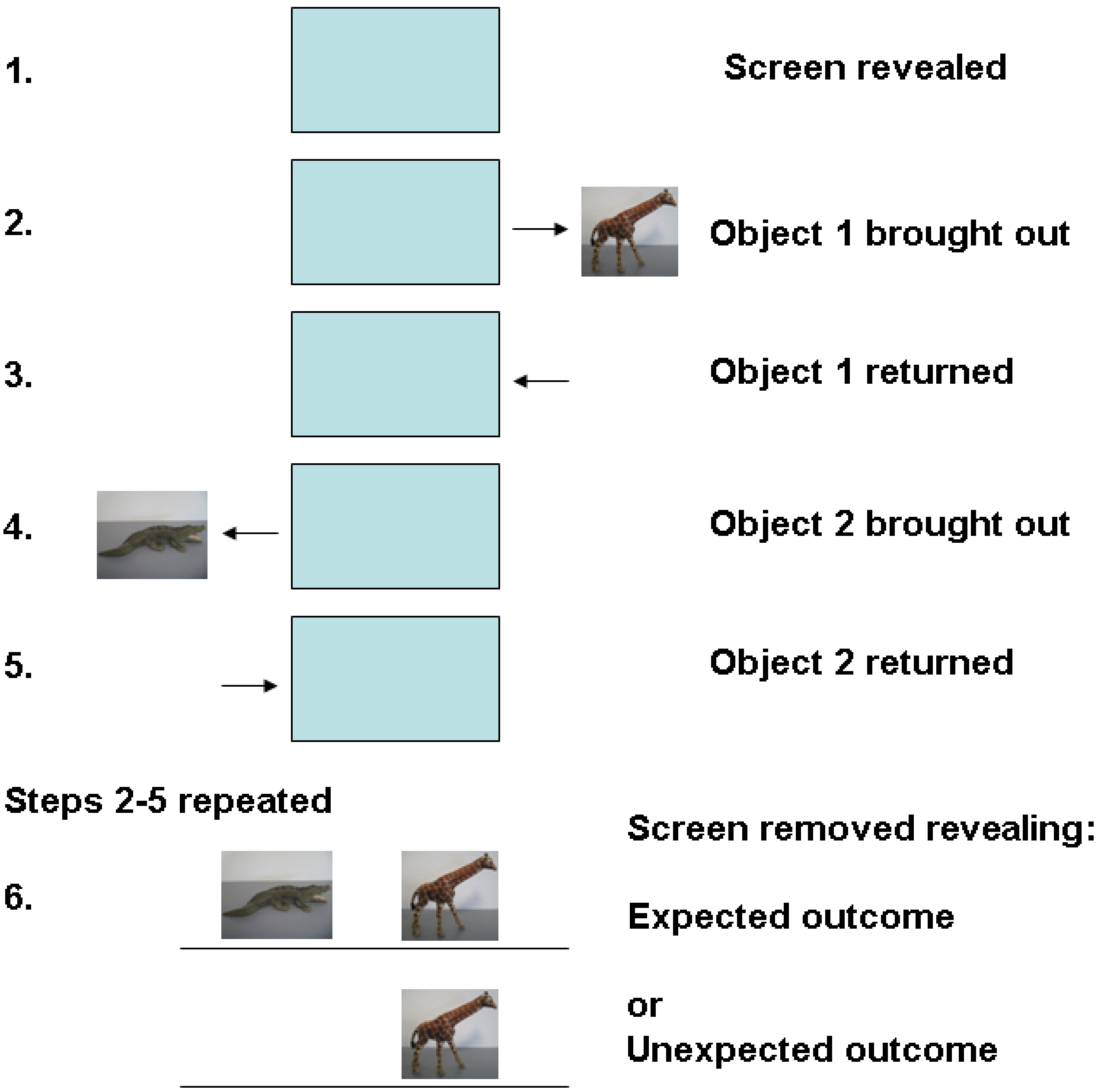

Figure 2. Schematic representation of events in Experiment 1

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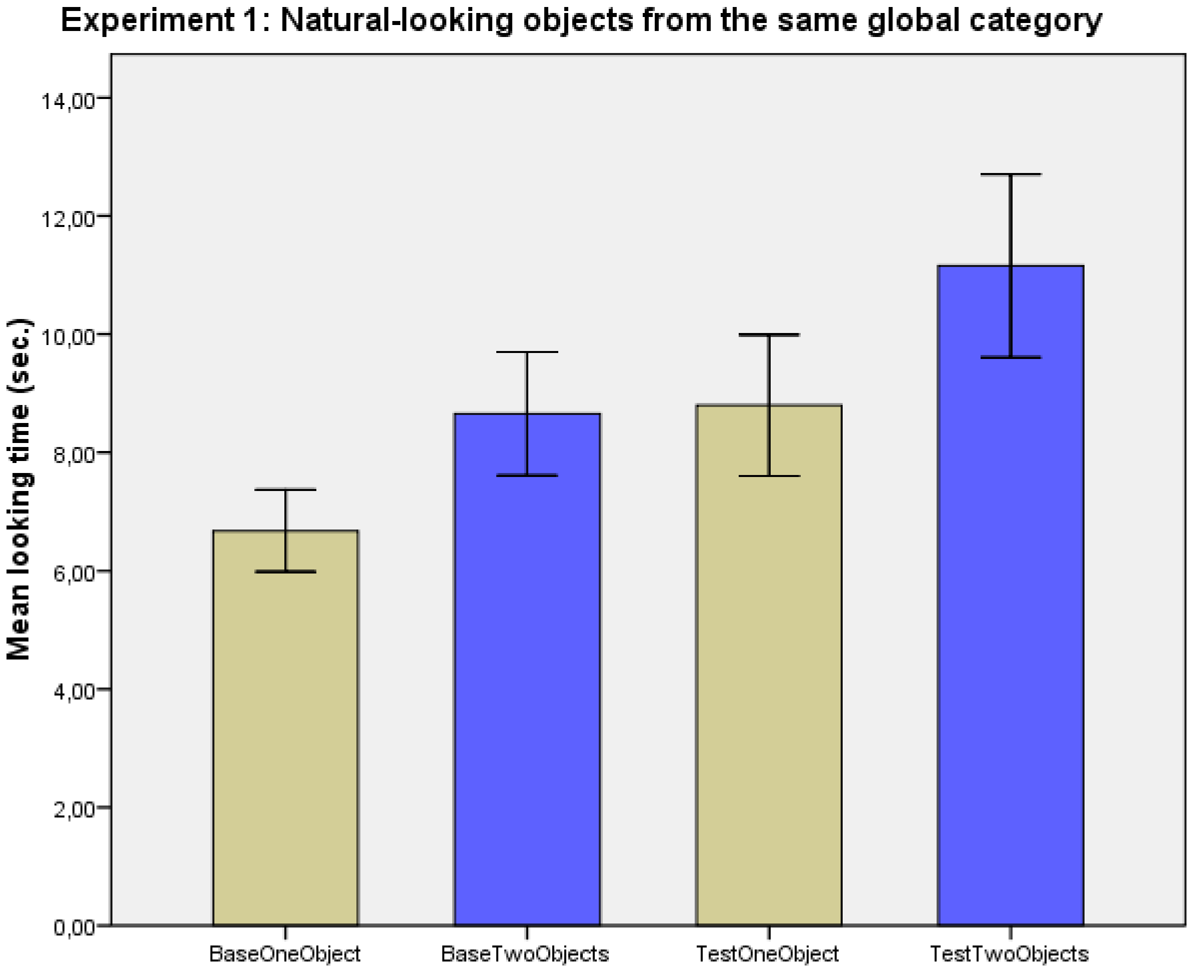

Fig. 3. Mean looking times of Experiment 1.

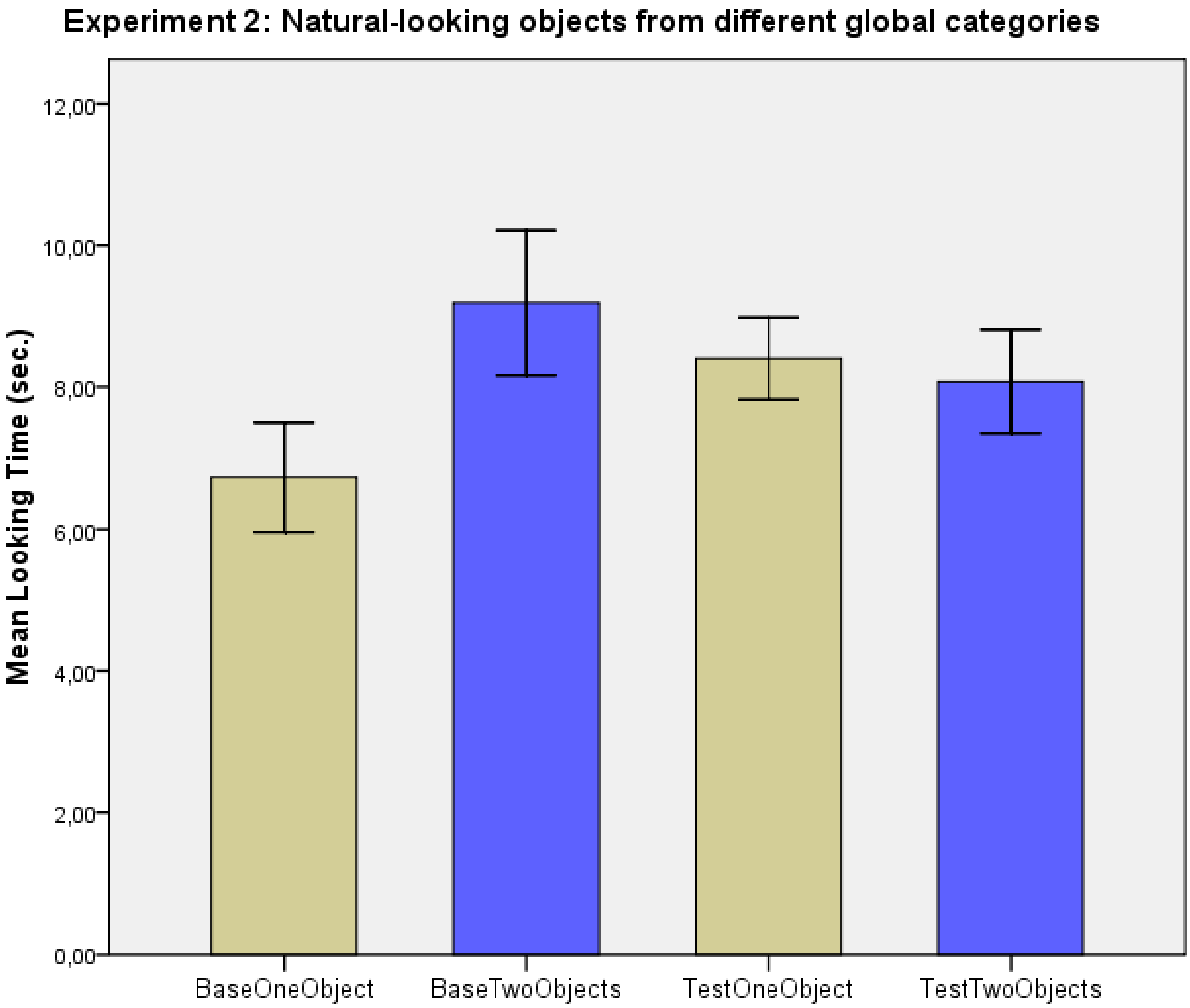

Fig. 4. Mean looking times of Experiment 2.

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Figure 5. Shape-similar subset of Pauen (2002)'s artificial-looking objects

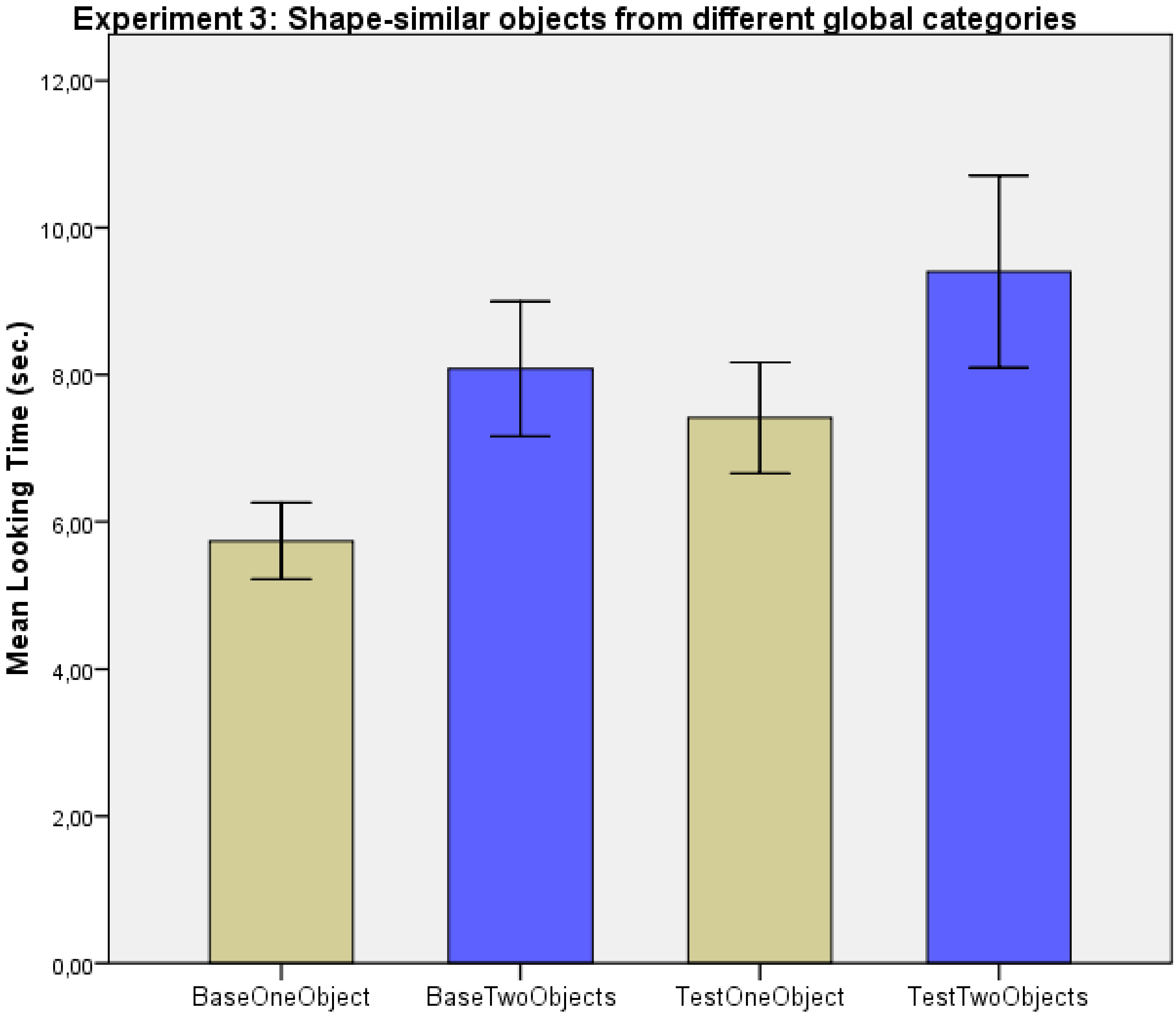

Fig. 6. Mean looking times of Experiment 3.

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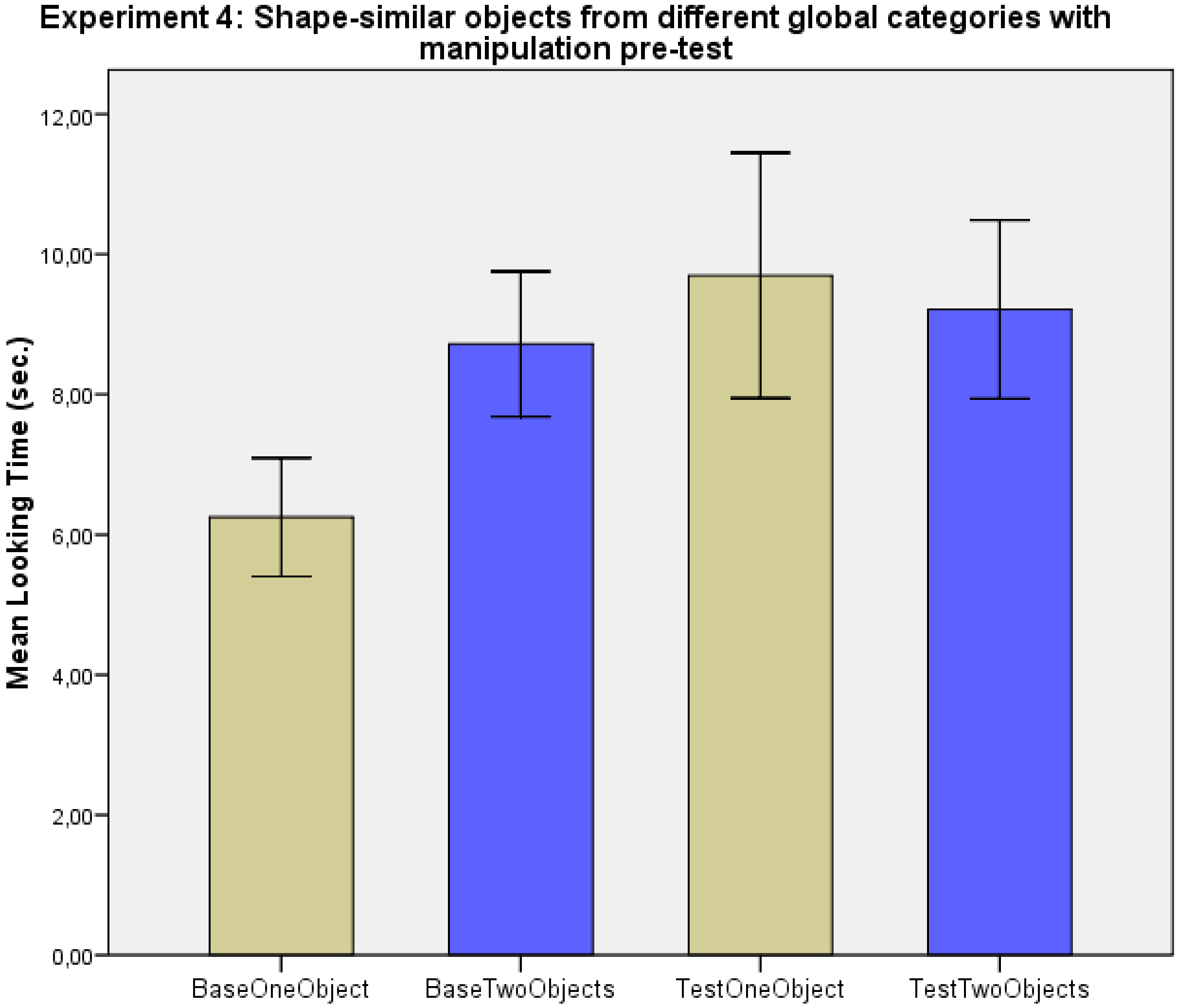

Fig. 7. Mean looking times of Experiment 4.

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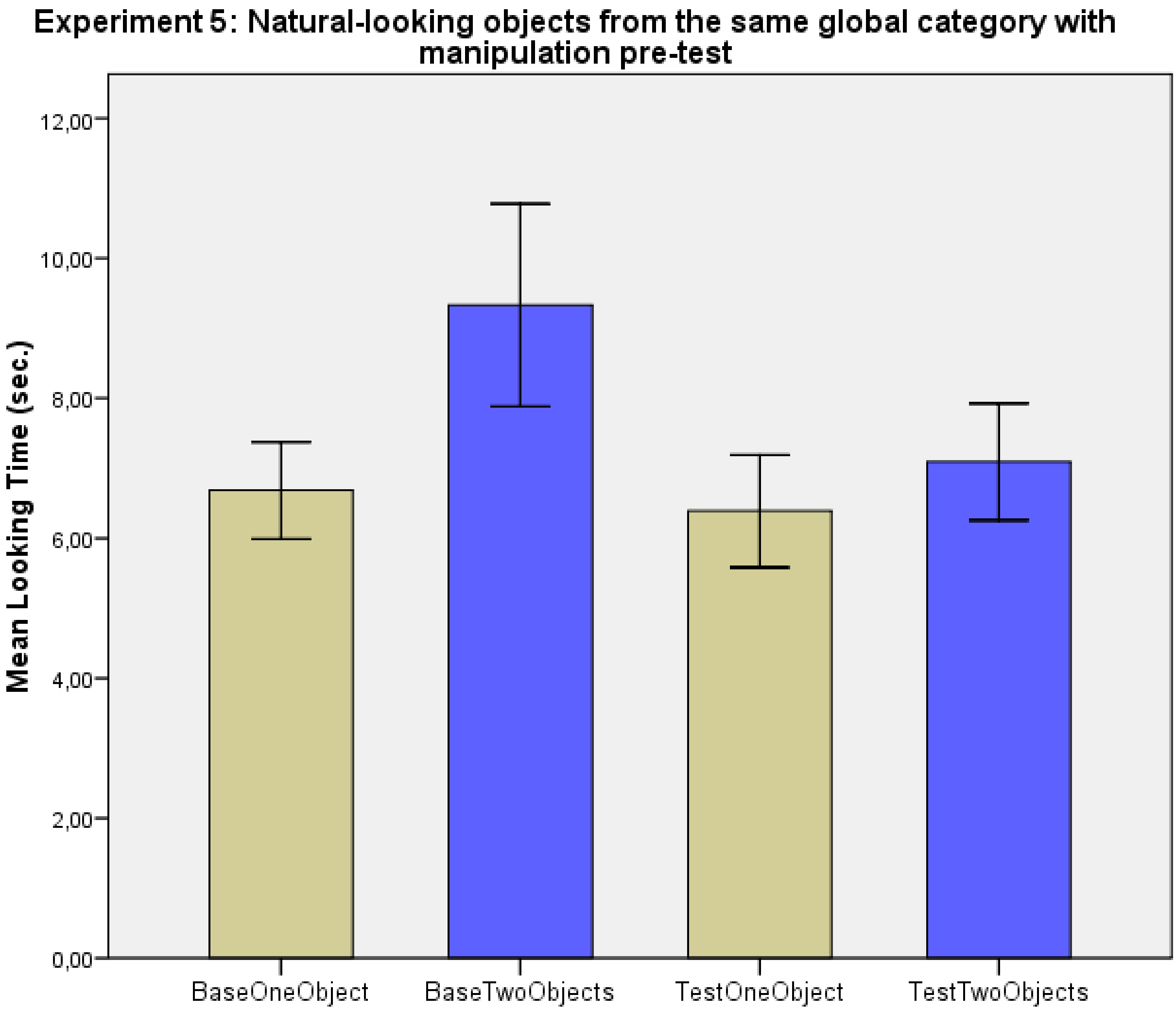

Fig. 8. Mean looking times of Experiment 5.