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"OUT OF SIGHT – OUT OF MIND?"

OBJECT REPRESENTATION IN EARLY CHILDHOOD WITH FOCUS ON THE ABILITY TO INDIVIDUATE MOVING OBJECTS

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LYSETT BABOCSAI

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REVIEWERS:

Prof. Dr. Sabina Pauen
Psychologisches Institut der Universität Heidelberg

Prof. Dr. Joachim Funke
Psychologisches Institut der Universität Heidelberg

THIS WORK IS DEDICATED TO MY PARENTS CATERINA UND UWE BABOCSAI

We shall not cease from exploration.
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.

T.S. Eliot

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CONTENT

ABSTRACT

A consistent pattern of results indicates that from an early age humans are competent to represent objects and characterize them in terms of their properties, their behaviors, as well as their involvement in actions and events. Thereby, infants' event knowledge not only consists of static information regarding the structure and form of objects but also includes dynamic components. The comprehension of the dynamic aspects of an event is essential in making decisions about the number of objects involved or in judging whether a particular object seen at one time is the same object as one viewed at a previous time. This problem is referred to as *object individuation*. The study of object individuation demonstrates that infants employ a variety of sources of information in this process. Despite its great importance in early infants' perceptual and cognitive abilities, one particular source of dynamic information has been unexplored in the occurrence of object individuation. The present work is concerned with the role domain-specific motion plays in infants' understanding of events and its impact on object individuation.

The following four experiments investigated 10- and 12-month-old infants' ability to recall how many objects were involved in a motion event by means of domain-specific motion cues (animate-inanimate) the objects provided. Using an adapted version of the Xu and Carey (1996) paradigm, 10- and 12-month-old infants saw an animate and an inanimate object repeatedly travel from behind a screen. It was predicted that the distinct motion characteristics would facilitate object individuation by activating underlying conceptual knowledge about the animate-inanimate distinction and thus, generating the expectation of different kinds of objects.

In the current set of studies infants of both age groups did not show evidence that they were able to apply such knowledge to the individuation task. Infants did not demonstrate object individuation on the basis of domain-specific motion information by looking longer to an unexpected outcome. It remains to be tested whether it is a question of inability or whether motion information activates different concepts that are employed in the present task. The discussion offers theoretical as well as methodological explanations for the absence of object individuation in the experiments on hand.

I INTRODUCTION

THE NATURE OF OBJECT REPRESENTATION

One of the most fundamental cognitive capacities humans possess is the ability to represent the world in terms of objects. Coherent objects, which have a continuous existence over time and space, enable us to perceive the world surrounding us as stable and unified. The more over, distinct objects (individuals) provide the basis for many perceptual and cognitive processes and determine how we think about and act upon them. The knowledge about the appearance and the properties of objects as well as the laws that determine how objects move and interact allows adults to group units into three-dimensional objects and consequentially enables them to organize and parse visual displays in meaningful ways. However, we not only have to represent objects as permanent and be able to separate bounded figures from a background. In addition, because we live in a dynamic world in which the perceptual input constantly changes, the ability to track those objects over time and space is just as essential for human thinking. We constantly make use of all these processes in everyday life. For instance, adults establish effortlessly the relative location of objects in the environment, which is critical when moving around. Little thinking is necessary for this. Instead adults register objects in space often without particularly being aware of the process. The same applies to the tendency to segregate and group things in the environment. Adults tend to segregate visual scenes into figure and background (figure-ground organization) and group objects to the degree of their similarity or depending on their proximity. In regard to perceptual grouping and perceiving form, gestalt psychologists proposed organizational principles that guide mental processing. Alongside the just mentioned characteristics such principles additionally include the tendency to connect contours that are not quite closed and to group items that move in the same direction or at equal speed. With the help of these cues adults form units that are maximally simple and homogeneous (Wertheimer, 1958). In sum, human adults have no difficulty experiencing objects as entities that persist over time even when the encounters have been brief and intermittent. Thereby principles of continuity, solidity, smoothness of motion, and the contact rule guide adults' apprehension of identity (Spelke et al., 1995).

Principles of identity from a philosophical standpoint are provided by the concepts of a 'sortal' (Geach, 1962; Wiggins, 1967; Hirsch, 1982; Macnamara, 1987; Lowe, 1989). According to philosophical reflections on 'sortals', these concepts describe representations used for individuation and identity. They tell us what to count as an instance of something and whether something is the same as what we have encountered before (Hirsch, 1982; Macnamara, 1987; Wiggins, 2001). For example, ice cube represents a 'sortal' whereas water does not. "Identity criteria are sortal-specific, in the sense that the same property difference may or may not indicate a change in identity" (Xu, 2007, p. 400). This in turn depends in the kind of object in question. Size might be an indicator for an identity change of a furniture item or a vehicle but it is not a predictor of change in a person, animal, or plant. Hence, 'sortal' concepts are closely related to issues about identity, persistence, and change. In order to answer questions regarding "how many?" or " is this the same?" a 'sortal' has to specify what is talked about, that is, the exact item of a kind (Xu 1997, 2007). One would derive at different answers if the 'sortal' in question referred to a book or pages of a book regarding the question "how many?". The same problem applies to the second question. Whether something "is this the same black?" has only a definite answer when related to an object or the shade of the color. This explains why 'sortals' are linguistically defined as count nouns in languages with a count-mass noun distinction. Neither adjectives like "black" nor verbs like "reading" or mass nouns like water map onto kinds of individuals. This grammatical distinction implies a related conceptual structure. All concepts define their content, but not every concept provides criteria for individuation and identification (e.g., colors or traits such as good). 'Sortal' concepts allow enumeration and identity tracking over time (Xu, 2007). For example when we watch children at the playground. Adults perceive the child standing on top of the slide and the one who arrives at the bottom as the same person even when he/ she was occluded while going through a tube in the meantime. In case the child at the bottom looks different however, adults would conclude that another child must have hidden in the tube and continued to slide while the first child hides there now. Or when observing a ball that rolls behind a pile of sand where a couple seconds later a toy truck comes out from behind, adults would probably describe the scene as a ball rolling behind a pile of sand, laying there, followed by an appearance of a toy truck, which presumably stood behind the sand pile to begin with and then got hit by the ball which caused it to move. These examples show how important the representation of objects of various kinds is in order for us to understand the world. Older children and adults have no problem in making sense of such complex scenes. How about infants' understanding of such scenarios? Is their picture of the world a "blooming and buzzing confusion" as William James (1890, p. 488) described it or are we talking about sophisticated creatures with adult like abilities?

Developmental psychologists concentrate on the evolution of capabilities that make us uniquely human and are interested in how a "seemingly helpless and cognitively deficient baby grows into an adult who processes a vast amount of knowledge and impressive cognitive skills" (Xu, 2003, p. 161). In order to achieve such an understanding the infant's conceptual system has to be specified through investigations on how and at what age certain skills develop (e.g., Baillargeon, 1993; Piaget, 1954; Spelke, 2003; Pauen, 2003 for an overview). Even half a century after James' remark concerning infants' perception and understanding of their environment infants were still thought to be "reflex bundles" whose world is fundamentally different compared to the one adults experience (Xu, 2003). Psychologists and philosophers like Piaget (1954) and Quine (1960) thought, for example, that for young infants no persisting objects exist. According to Piaget and his followers, infants do not possess true object permanence until the end of their second year of life. Even though he acknowledged that infants are able to successfully retrieve hidden objects at the age of 8 or 9 month, he believed that they lack criteria that allow them to decide whether an object seen in one occasion is the same as or distinct from an object seen on a different occasion (Xu, 2003). If those assumptions were true infants would indeed have difficulties to make sense of the environment surrounding them. But with the development of more sensitive methods (e.g. habituation-dishabituation paradigm) to study infant cognition the view on infants' perceptual and cognitive abilities has changed. Since then, the great deal of research on how infants perceive the objects in their environment convinced most developmental psychologist that infants are far more competent then once assumed. Work on early perceptual abilities demonstrated that infants discriminate between visual forms, are able to perceive partly occluded objects (Kellman & Spelke, 1983) and by the age of 8 months they use a variety of perceptual cues and types of information such as common motion, spatial separation between surfaces, object shape, color, and pattern for organizing displays (Johnson, 2000; Spelke, 1990). Besides the relevance to organize certain units into bounded objects and making use of perceptual information, having conceptions about objects is equally important. When thinking about objects various contents come to mind. Objects can be characterized in terms of their properties, their behaviors, or their involvement in actions and events. They can be assigned to categories and conceptualized as different kind of things (Mandler & McDonough, 1993). The capacity to analyze objects enables infants to structure their environment and form representations of the characteristics objects have. Additionally, it facilitates the assessment of physical, psychological, and biological principles of objects. Research on physical reasoning in infants (see Baillargeon, 1994, and Spelke, Breinlinger, Macomber, & Jacobson, 1992, for reviews) showed that infants as young as 4 months of age share many of the basic beliefs adults hold about the behavior of objects. For instance, infants expect objects to collide with other entities rather than pass through them (Leslie & Keeble, 1987), fall when their supports are removed (Baillargeon et al., 1992), and continue to exist when hidden (Baillargeon, Spelke, & Wasserman, 1985).

Related to the last assumption is the question of how infants decide that a particular object seen at one time is the same object as one viewed at a previous time. This problem regarding the object concept is referred to as *object individuation.* Research provided evidence that once infants have grouped surfaces into three-dimensional objects and segregated these from the background they also keep track of these objects through space and time. In addition to object permanence, infants as young as 2.5 months are able to establish representations of individuated objects, even when occluded (Xu, 2003). Under what conditions do infants decide that they are in the presence of one, two, or more distinct objects? How do they decide whether the objects they have encountered on different occasions are the same or different objects seen at different times? What criteria do infants employ in making such decisions?

This dissertation project is concerned with infants' object individuation as one aspect of the ability to represent objects in the first year of life. It investigates the question of how infants arrive at representations of multiple moving objects and how they trace their identity through time and space. Thereby, the focus lies on the types of information infants use to establish representations of separate and distinct entities in their environment, i.e. the sources of information employed in the process. One specific kind of information that seems to be very important in early infancy is motion information. Research along these lines reveals that from early on infants rely on motion to make perceptual and conceptual inferences. They use movement to make inferences about object unity, reason about continuity and are able to represent object motion over temporary occlusion. Not only do infants use motion information, though, they also depend on it, for example, to register the form of an object (Kaufmann-Hayoz et al., 1986), to separate an object from its background (Kellman & Spelke, 1987), for the detection of coherent structures (Bertenthal et al., 1987), or to distinguish between animate and inanimate objects (Mandler, 2004). The present work looks at the role domain-specific motion information may play in an object individuation task and questions if motion information about living and non-living objects helps infants to solve this task at a younger age by using property/ kind information. In order to do so this research builds on experiments by Xu and Carey (1996) and explores the impact of motion cues on object individuation in infants 10 and 12 months of age. Thus, this project aims to provide insights into how motion aids infants in going about building object representations and how it supports infants' ability to retrieve and use their object representations. Simultaneously, it gives information about the nature and the content of such representations.

The present thesis will begin with an overview of what is known about the abilities and complex cognitive processes infants embody that ultimately lead to a unified model of object representation in infancy (Wilcox et al., 2003). Thus, Chapter 1 includes sections on object segregation, object permanence, object individuation, and object identification defining important terms. The following Chapter 2 gives a literature review on object individuation covering psychological accounts regarding this topic. At the same time it will include empirical evidence concerned with infants' ability to individuate objects as well as procedures used to access this ability with an emphasis on the information that is given in an individuation task, and the characteristics that are applied in the individuation process. In Chapter 3 the second line of research theoretically related to the present work will be outlined. The section on domain-specific motion characteristics will concentrate on the development of the distinction between animate-inanimate information types and experimental investigations. Based on those reviews, a connection between the two fields of study in cognitive development is established in Chapter 4, which concludes with the hypotheses to be tested in the following studies. Thereafter, the methodology and the procedure used in the current work will be explained in Chapter 5, followed by the presentation of the results (Chapter 6 – 9). The discussion part (Chapter 10) will focus on the development of object individuation and offers some thought on the implications the use of motion information might have. Issues that might occur with the method and open questions that might lead to new ones will be discussed. The dissertation ends with a prospect of how the results enrich our understanding of object individuation and possible interesting questions for future research.

II THEORETICAL BACKGROUND

CHAPTER 1

ASPECTS OF OBJECT REPRESENTATION IN INFANCY

The study of object representation in infancy refers to questions concerning the development of registering object and event components, retaining them in memory, integrating them across space and time as well as forming associations between them. As infants experience and learn about the environment they observe many different types of physical events which involve various objects. In the course of development infants build mental representations of these objects and events, which in turn are used in many cognitive processes (Baillargeon, 1998; Leslie, 1994; Mandler, 1997; Spelke, 1991). It is the goal of developmental psychologists to shed light in the nature of these representations. Thereby, some researchers have been concerned with specifying possible innate constraints on infants' object representations (e.g. Leslie, 1994, 1995; Spelke, 1994; Spelke, Breinlinger, Macomber, & Jacobson, 1992) whereas others make learning mechanism responsible for the development of infants object representations. Instead of determining innate principles these investigators focus on the changes that take place within infant's object representations as they accumulate knowledge and experience (e.g. Baillargeon & Aguiar, 1998; Baillargeon, 1998, 2004a; Mandler, 1997; Needham, Baillargeon, & Kaufman, 1997). According to their view, when learning about physical objects, infants identify increasingly more variables evermore accurately over time that enable them to predict outcomes in events these objects are part of. In contrast, Spelke and her colleagues have proposed a number of physical principles (i.e. cohesion, boundedness, rigidity, and no action at a distance) that confine how objects move and interact within infants' event representations (e.g., Spelke, 1994).

Primary to the reasoning about physical objects, however, is the perception of three-dimensional entities. Therefore, it is necessary to separate regions of visual space that constitute visible surface fragments. Research on early object perception provides evidence that the ability to segregate objects is present in infancy.

1.1 Object Segregation

Object segregation is the capacity to organize visual arrays of surfaces into individual, unitary, and bounded objects. It permits the apprehension of physical objects as persisting bodies with internal unity and stable boundaries (Spelke, 1990; Xu et al., 2004). In contrast to Gestalt theory after which perception tends to organize visual arrays into maximally simple and regular units, surface motion and spatial arrangements rather than static Gestalt properties[1] determine how infants perceive object unity and boundaries (Spelke, 1990). Even though infants tend not to comply with Gestalt principles, they are still sensitive to them but it is not until later that Gestalt relations influence object perception (Bornstein, Ferdinandsen, & Gross, 1981; van Giffen & Haith, 1984; Spelke, 1990). Before, infants anticipate object unity when perceptual arrays move as connected wholes (cohesion), move separately from one another (boundedness), and when they act upon each other only on contact (rigidity, no action at a distance) (Spelke, 1990).

The most explicit evidence for the existence of several objects is when they are simultaneously visible and separated in space. One way to address the question how infants assign surfaces to distinct objects is by applying object segregation tasks involving partly occluded displays. Under conditions where perceptual or spatiotemporal continuity is lost, infants must judge whether the parts simultaneously visible on either side of an occluder constitute of one or two objects (Craton, 1996; Johnson, 1997; Kellman & Spelke, 1983; Slater et al., 1990; Spelke, 1990; Wilcox & Baillargeon, 1998b). Using this method, Kellman and Spelke (1983) were the first to systematically investigate how infants segregate objects. In their study they explored the sources of information required to perceive the visible portions of a partly occluded object as belonging to a single entity. They concluded that at 4 months of

[1] The Gestalt theory proposes several principles that determine the arrangement of surfaces into objects. The principle of similarity states that units homogenous in color and texture are perceived as one entity. Under terms of the principle of good continuation even contours contribute to this perception. Objects more regular in shape and uniform in their motion are observed according to the principle of good form and the principle of common fate as coherent (Spelke, 1990).

age infants use common motion, but not common features to connect visible surfaces and perceive a single object. Aside from occlusion, problems of object segregation arise in case of shared boundaries. The conceptual formulation infants have to complete in tasks that consist of displays with diffuse object boundaries is parsing a display into two distinct objects and tell were one object ends and another begins (Xu et al., 1999). In order to address this issue, investigators employ non-occlusion tasks in which infants are familiarized to a stationary display composed of three-dimensional objects and then presented with move-apart or move-together events[2] (Needham, 1997; Needham & Baillargeon, 1997; Xu et al., 1999). This research put forth that infants use a variety of different sources besides object motion and spatial separateness as cues for object boundaries. Needham and her colleagues (Needham & Baillargeon, 1997; Needham, 1999) revealed that by 8 month of age infants use physical (support relations, solidity, spatial arrangements) and featural (shape, color, pattern) information to form an interpretation of a display and assign surfaces to distinct objects. When both types of information are available infants consider physical information to be the more accurate source of information about object boundaries even if the interpretations implied by featural and physical information create a conflict (Needham & Ormsbee, 2003). That is, shown stationary displays of a box and an adjacent cylinder that were either suspended in mid air or on the floor, infants used their physical knowledge about support to segregate the display. In the cylinder-up condition infants looked longer at the move-apart compared to the move-together event whereas infants in the cylinder-down condition showed longer looking toward the move-together event. This indicates that infants viewed the box and the cylinder in the cylinder-up condition as belonging to one object and that infants perceived two objects in the cylinder-down condition. Thus, if features suggest separate objects and physical information indicates a single unit, infants chose the interpretation consistent with the physical information (Needham & Baillargeon, 1997). If only featural information is present infants mostly rely on object shape. Needham (1999) explored this possibility by presenting adjacent objects sharing a

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[2] These test events showed a gloved hand that moved one part of the display. The other portion of the display either remained stationary (move-apart condition) or the two parts moved as a whole (move-together condition). The logic used in interpreting infants' reaction to the events is as follows: If infants apprehended the stationary display as a single unit they should show surprise in the condition in which the object brakes into pieces when pulled. In case the infants perceived the display consisting of more than one unit, their expectation should be rather violated in the move-together condition (for review see Needham & Ormsbee, 2003).

boundary but being dissimilar in their object features. Shape, color, and pattern lead to different interpretations regarding object unity. They found that infants use shape, rather than color and pattern to segregate objects in the displays presented to them. The studies noted so far were mainly concerned with the ability to segregate objects by means of physical knowledge or perceptual differences. Xu et al. (1999) add to the findings presented yet a series of studies concerned with object kind information[3] as variable for object segregation. In their task infants were habituated to a display consisting of a toy duck perched on top of a toy car. In the test trials, a hand either lifted up the top object leaving the bottom object standing on the stage floor or lifted up the top object in conjunction with the bottom object as if it were a single object. Xu et al. (1999) expected the infants to react with longer looking to the latter if they separated the display into two distinct objects. The results indicate that 12-month-old infants successfully segregate by making use of the kind distinction between duck and car whereas 10-month-old infants failed to do so. The authors take these findings to conclude that there is a developmental change in representing object kinds. The last-mentioned studies go beyond the mere perception of objects and the assignment of boundaries because for infants to draw on object kind information when separating an ambiguous array, they have to represent functionally relevant and inductively rich knowledge about the objects involved in the event (Xu et al., 1999). In order to acquire such knowledge it is required to perceive and represent objects as permanent.

1.2 Object Permanence

One necessary step infants have to make from perceiving objects to reasoning about them is to mentally remember them, i.e. perceive them as permanent. Thus, the ability to perceive objects is related to the ability to reason about them and their behavior (Spelke, 1988).

Piaget (1954) was the first investigator who examined the question if infants are able to represent occluded objects. In research with young infants Piaget found that they typically do not search for objects they have observed being hidden. When

[3] Kind information is explained as information “derived from classifying the stimuli according to antecedently represented categories in long-term memory” (Xu et al., 1999, p. 140). See also section 1.5 for further explanation.

presented with a manual search task in which a toy is covered with a cloth infants ages 5 to 7 months made no attempt to lift the cloth and grasp the toy, even when capable of performing these actions. Infants at this age believe that objects discontinue to exist when they become invisible. Hence, Piaget concluded that infants' event representations include only those objects they can perceive directly and it is not until about 8 months of age that infants begin to represent the continued existence of occluded objects (Aguiar & Baillargeon, 2002). However, this representation of permanence is still limited because although infants now search for hidden objects, they only do so at a particular place, namely where they found the object first. Piaget (1954) interpreted this as a tie between action and location. In case the object is hidden in a new location, infants younger than 12 months of age repeat the act that was successful before. By the end of the first year, infants begin to represent visible displacements of objects and assume that occluded objects are located wherever they have been hidden before (Baillargeon & DeVos, 1991). Nevertheless, a representation of invisible displacements is still missing. Hence, according to Piaget and his followers, infants do not possess true object permanence[4] signalized by the capacity of representational or symbolic functioning until the end of what he called the sensorimotor period around 18-24 months of age.

This long-standing conclusion began to change when evidence was obtained with novel more sensitive tasks, which employed visual rather than motor measurements (see Chapter 2, p. 20). The reason behind this is the consideration that young infants fail Piaget's search tasks because they require the coordination of separate actions on separate objects. Therefore, infants might not lack the concept of object permanence but instead they have a limited capability to plan means-end search sequences (Baillargeon, 1987). Perceptual factors such as the separation between object and occluder or the relationship between an object and its cover appear to affect searching behavior and yield a problem for infants to deal with certain types of disappearances (Bremner, 1994). Baillargeon, Spelke, and Wassermann (1985) were among the first researchers who applied the habituation/ dishabituation task to test this concern. The authors found that, contrary to Piaget's theses, 5-month-oId infants understand that an object continues to exist when occluded. Later experiments

[4] At this stage infants are thought of possessing full object knowledge, which means for one thing that they are completely aware of the predictable patterns of objects' appearance and disappearance (Baillargeon & DeVos, 1991). For another thing this signifies the understanding that occluded objects follow the same physical rules as visible ones.

applying the drawbridge paradigm reduced the starting age at which infants have this kind of knowledge to 3.5 months (Baillargeon, 1987; Baillargeon & DeVos, 1991). In addition, Baillargeon (1986) provided evidence that 6.5 month old infants are able to not only reason about the existence but also about the location and trajectory of occluded objects. Later experiments revealed that these young infants already include object properties such as height in their reasoning about occluded objects (Baillargeon & Graber, 1987).

Today there is consistent evidence from various laboratories that infants as young as 2.5 months believe that a stationary object continues to exist and retains its location when occluded and that a moving object continues to exist and pursues a continuous path when occluded (e.g., Aguiar & Baillargeon, 1999, 2002; Baillargeon, 1991; Baillargeon & DeVos, 1991; Baillargeon, Graber, DeVos, & Black, 1990; Goubet & Clifton, 1998; Hespos & Baillargeon, 2001; Hespos & Rochat, 1997; Hofstadter & Reznick, 1996; Koechlin, Dehaene, & Mehler, 1998; Newcombe, Huttenlocher, & Learmonth, 1999; Rochat & Hespos, 1996; Simon, Hespos, & Rochat, 1997; Spelke, Breinlinger, Macomber, & Jacobson, 1992; Wilcox, 1999; Wilcox & Baillargeon, 1998b; Wilcox, Nadel, & Rosser, 1996; Wynn, 1992). In agreement with Piaget, experiments point likewise to a clear developmental change young infants' reasoning about occluded objects undergoes (Aguiar & Baillargeon, 1999; Baillargeon & DeVos, 1991; Spelke & Kestenbaum, 1986; Spelke, Kestenbaum, Simons, & Wein, 1995). These experiments show that infants solve some object-hiding tasks before others. For example, ten-months-olds search for an object placed on a table and covered by a cloth before they seek an object that a hand deposited underneath the cloth (Moore & Meltzoff, 1999). The latter task, which involves the inference that the hand put the object under the cloth, is not worked out until 14 months of age. This emphasizes that searching for an object is a true cognitive advantage. Therefore, the ability to perform coordinated actions such as search tasks has to be distinguished from the capability to perceive objects as permanent.

Once infants see an entity, which they had segmented from the background, as permanent, they can go about building object representations in specific events (e.g. Oakes, 1994; Oakes & Cohen, 1995; Spelke & Kestenbaum, 1986; Spelke, Kestenbaum, Simons, & Wein, 1995; Xu & Carey, 1996). One fundamental issue in the course of this is that of object individuation – the ability to determine how many objects are involved in an event (Spelke & Kestenbaum, 1986; Spelke et al., 1995; Xu & Carey, 1996).

1.3 Object Individuation

In object individuation processes segregated entities seen on different occasions are assigned to a single or multiple objects (Xu et al., 2004). The issue of object individuation arises under conditions where perceptual access to boundaries and spatiotemporal continuity is lost (Xu et al., 1999). Thus, in order to individuate objects one has to determine the participating objects and establish corresponding object representations. It is a necessary ability whenever one makes decisions regarding object's numerical identity (Kojgaard, 2004). The more over, individuation is a prerequisite for being able to decide whether objects present in the here and now are identical to the ones encountered before or thereafter. On many occasions we represent distinct objects and track them through time and space. In order to do so certain references are necessary. Human adults are able to rely on several sources of information to solve an individuation task and to establish representations of distinct objects over space and time. They include spatiotemporal information, property information, and kind information. Most research in infancy has likewise focused on the kind of information infants use to individuate objects. These individuation criteria are explained in the following paragraphs.

Spatiotemporal information

The first source for the establishment of numerical identity is spatiotemporal information. Spatiotemporal criteria derive from certain universal constraints that apply to solid objects and provide information about an object's location, its path of motion, and its speed of motion (Xu, 1999). For instance, since a single object cannot be in two different places at the same time and two distinct objects cannot occupy the same space at a given time, this information indicates the number of objects in an event (Spelke, 1988). Furthermore, because objects travel on spatiotemporally connected paths, the representation of two distinct objects arrives from the detection of spatiotemporal discontinuity, i.e. there is no spatiotemporally continuous path that unites the objects (Spelke, 1990). Likewise, a single object is assumed if spatiotemporally connected paths are noted.

From a very early age, infants interpret spatiotemporal discontinuities as indices for the presence of distinct objects. When shown an event in which an object disappears behind the first of two spatially separate screens, and then emerges from behind the second screen without appearing between the two screens, infants as young as 3.5 months are led by the discontinuity in path to conclude that two distinct objects are involved in the event (Aguiar & Baillargeon, 2002; Spelke, et al., 1995). In addition, Wilcox, Schweinle, and Chapa (2003) found that a discontinuity in speed signals the presence of two distinct objects. In their study they presented infants 4.5 months of age with an event in which an object disappears behind one edge of a wide screen and immediately reappears at the other edge. In case of a single object on the platform when the screen was lowered infants responded as if they expected two objects involved in the event and thus, present behind the occluder. The authors concluded that speed of motion is essential to the individuation process as well. In the absence of spatiotemporal information infants turn to a second source of information for the individuation of objects – featural information.

Featural information

Featural or perceptual property information refers to perceptual features of objects such as color, size, shape and texture (e.g., a red ball and a green ball seen on a different occasion are two distinct objects). Adults conclude that the perceptual difference in object properties is indicative of separate objects (Xu et al., 2004). They just compare the features (e.g. shape, size, color, and pattern) of the objects seen on different occasions and typically conclude that two objects are present when the features are different and one object is in place when the features are identical (Wilcox & Baillargeon, 1998). There is disagreement about the role featural information plays in infants' individuation processes (Wilcox et al., 2003). Whereas some researchers have claimed that young infants are incapable of using featural information to individuate objects until the end of the first year of life (Xu & Carey, 1996; Xu, Carey, & Welch, 1999), others have suggested that this ability emerges much earlier, by at least 4.5 months of age (Wilcox, 1999; Needham & Baillargeon, 2000; Wilcox & Baillargeon, 1998a; Wilcox & Schweinle, 2002; Needham, Baillargeon, & Kaufman, 1997). In order to resolve this discrepancy Xu and Carey (2000) pointed out that their task requires access to another source of information, namely the one of kind concepts. According to the authors were the results obtained in their studies based on the use of kind representations rather than perceptual property representations, as they play distinct roles in object individuation. Therefore, kind information represents an additional criterion for individuation.

Kind information

Kind information bears on our knowledge about categories of objects. It specifies conceptual knowledge of objects united by functional or causal as well as perceptual features (Xu et al., 1999). Adults reason that a bottle and a cup seen on different occasions are two distinct objects or the dog that went behind the bush cannot be the same individual as the cat that turned up thereafter (Xu & Baker, 2005). The relevance of perceptual property differences, however, is thereby kind relative (Xu, 2003, p. 163):

> *"A puppy may be the same creature as a large dog a month later, but a small cup cannot be the same object as a large cup a month later. Similarly, color differences do not signal distinct individual chameleons, but they do signal distinct individual frogs."*

These examples make clear how our knowledge about the kinds of things there are in the world influences the answer to the question how many objects are involved in an event. In addition it shows how such information helps us to establish representations of distinct objects in a visual scene despite their appearance (Xu et al., 1999). Consequently, changes in appearance like the size of a growing living organism does not necessarily lead to the perception of multiple creatures over time. In contrast, when it comes to inanimate things size variations are a clear sign for several exemplars. In contrast to featural information, kind information derives from stable, accessible, and long-term kind representations that pick out functionally relevant categories (Baldwin et al., 1993; Mandler, 1992). Studies by Xu, Carey, and Quint (2001) provided evidence that kind representations and featural information play different roles in object individuation at 12 months of age. In a series of studies they presented one year olds objects of the same kind (e.g. balls) that differed in the features size, color, and pattern or a combination of the three found no indication for object individuation. Infants also failed when a within-basic-level-kind shape contrast (e.g., a regular cup with one handle compared to a sippy cup with two handles) was given. Only when infants viewed a cross-basic-level-kind shape contrast like a cup and a bottle did they expect two individual objects. Control conditions ensured that infants were able to perceive the color and size variations and that they were equally sensitive to the shape contrasts. Together these results lead to the conclusion that kind representations rather than perceptual property representations underlie object individuation at 12 months and thus, they are distinct forms of information (Xu, Carey, & Quint, 2001).

Taken together, the previous remarks reveal that a variety of information (e.g. spatiotemporal continuity, shape, texture, kind and so on) drives object individuation. For the purpose of this work, I adopt the distinction of spatiotemporal, featural, and kind information even though Wilcox and her colleagues (1998b, 2003) as well as Meltzoff & Moore (1998) propose additional properties (mechanical/ physical characteristics and functional attributes), which may be represented within the context of physical events.[5] However, one could argue that mechanical as well as functional information are part of kind information. In any case, young infants employ many strategies to detect the numerical identity of objects in everyday events and even integrate different sources of information. In the course of this spatiotemporal information is fundamental to the individuation process and seems to be superior compared to perceptual property as well as kind information. That is, in cases where several sources are in place spatiotemporal criteria can even override other types of information, i.e. certain spatiotemporal parameters yield the representation of a single object despite perceptual property differences (Xu, 2003). For instance, when faced with the phenomenon of apparent motion, adults view objects in consecutive displays under certain conditions, like a short interstimulus interval between two displays, as turning into each other rather than as separate entities. Similar impressions occur under conditions of occlusion, as in the tunnel effect (Burke, 1952). Here, given a

[5] In their view, *mechanical or physical information* is important in events in which more than one object is involved (e.g. objects that are on top of each other, are underneath, inside or pass behind one another) and designates the relation between these objects. Adults bear on sophisticated knowledge about the lawful ways in which objects move about in the world and the nature of their interactions when evaluating how many objects are included in occlusion events. *Functional information*, in addition, defines what objects do and how they can be used (Wilcox et al., 2003).

certain range of speed and occlusion time, adults perceive an object, which disappears in a tunnel and one that appears thereafter with different properties as a single item that changed its properties but persisted through occlusion (Xu, 2003). The same accounts for the relation of object kind information and spatiotemporal information. Thus, although featural and kind information are most definitely useful in object individuation processes they are not always necessary (Xu et.al., 1999).

Following individuation another task occurs, that of object identification which is the competence to use information stored in an object representation to decide which previously individuated object is being encountered (Kaldy & Leslie, 2003; Leslie et al., 1998; Tremoulet et al., 2000). Whereas object individuation is concerned with the number of objects, object identity answers the question of the objects' nature.

1.4 Object Identification

When identifying an object one has to make a decision about what kind of objects are present in an event. Therefore, object identification is seen as a process that follows object individuation (Kaldy & Leslie, 2003; Leslie & Kaldy, 2001; Tremoulet et al., 2000). Tremoulet et al. (2000) as well as Kaldy and Leslie (2003) addressed the question of object identification. Following the experimental paradigm of Xu and Carey (1996) they familiarized 12-month-old infants to a disk and a triangle, which appeared from behind a screen one after the other. Instead of presenting two distinct objects in test, though, Tremoulet et al. (2000) showed two objects that were exactly the same. The authors reasoned that this would still be the expected outcome from an individuation point of view. However, in the case of object identification this could represent an unexpected outcome as well, since one object's appearance changed even though the number of objects remained the same. Hence, in their study, Tremoult et al. (2000) presented one group (identification-by-shape group) of 12-month-old infants with two objects that were alike (disks) after they had been familiarized with two distinct objects (disk and triangle) and another group (control group) with the two objects (disk and triangle) they had been familiarized with. The looking times revealed that infants who belonged to the identification-by-shape group looked longer compared to the control group. These results indicate that 12-month-old infants were able to identify the objects by shape. However, when Tremoulet et al. (2000) applied the same paradigm but used color as the distinguishing object feature, they were not able to replicate the results stated above. This time infants 12 month of age did not show any surprise as indicated by longer looking when the objects in question changed color in test. Thus, infants did not set the objects apart by color. Nevertheless, even though infants failed to identify object by color, they succeeded in individuating objects by color at this age (Tremoulet et al., 2000). In addition, when Kaldy and Leslie (2003) showed 9-month-olds differently shaped and colored objects each moving behind spatially separated screens, infants of this age group were able to use shape but not color information to identify objects, too. In applying an alternation procedure in which the objects changed location with each trial, the authors ensured that infants did not simply associate shape and location and that both objects were represented. Based on these behavioral findings Leslie and his colleagues constructed a cognitive model in which individuation is seen as the establishment of an object representation and identification as the use of information stored in the object representation (Leslie et al., 1998; Kaldy & Leslie, 2003; Tremoulet et al., 2000). According to their model information has to be bound to an object representation in order to be available for declaring, which previously individuated object the representation bears on (Kaldy & Leslie, 2003; for further details see Chapter 2.4).

1.5 Summary

Setting up an object representation is a complex process involving several steps. Once infants have segregated objects from the background, they face the problem of keeping track of these objects. In order for infants to decide whether a single or multiple objects are present and whether the objects they have encountered on various occasions are the same or distinct objects seen at different times they have to perceive them as permanent. Aside the impact of object motion on infants' perception, it also plays a role in infants' reasoning about object boundaries, occluded objects, and object identity.

The present work focuses on one aspect of object representations, namely the issue of object individuation and the questions how do infants arrive at representations of multiple objects and what sources of information do they employ in this process. Several theoretical accounts have been proposed on the development of the ability to determine how many objects are involved in a present event. These are outlined in detail in the subsequent chapters.

CHAPTER 2

THEORETICAL APPROACHES TO THE INFANTS' SYSTEM OF OBJECT INDIVIDUATION

Through Bower's (1971, 1979, 1982) investigations of early cognition the understanding of infants' object identity became a central topic for cognitive psychologists. Following Michotte's (1963) work with adults, Bower presented infants with similar tasks and evaluated their response with various non-motor measures[6] (Kojgaard, 2004). When examining infants' tracking of objects that disappear behind screens, he discovered that infants as young as 5 months of age were able to trace objects which emerged from and vanished behind an occluder. In particular, after habituation to a sequence in which a rabbit disappeared into a tunnel and then reemerged out the other side, the infant saw an event in which the rabbit went behind a screen, but a different object (a shiny ball) showed up on the other side. Bower (1974) claimed that 5 month-olds' looking behavior was disrupted which he interpreted as surprise due to their realization that the object that emerged from behind the screen was a different one from the object that entered. However, the question whether infants perceived one or two objects behind the screen remained unanswered at the time mainly due to the lack of adequate methods that were sensitive to infer mental states from nonlinguistic behavior. The *habituation-dishabituation paradigm* pioneered by Fantz (1961, 1963, 1964) and further enhanced by Spelke and her colleagues (Kellman & Spelke, 1983; Spelke, 1985) represents such a method. In this paradigm looking times are simply monitored as the infant watches what is happening. Therefore, this method taps spontaneous representation of objects and events without requiring any training (Carey & Xu, 2001). Day and Burnham (1981) used habituation-dishabituation measures in their tasks and found those to be a reliable and useful method to investigate not only object discrimination but also recognition of moving objects.

One procedure that was generated from the original habituation method and has proven its worth in studying amongst other things individuation processes of

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[6] Such measures included eye gaze, facial expressions, and heart rate.

preverbal infants is the violation-of-expectation paradigm (Bogratz, Shinskey, & Speaker, 1997; Haith, 1998, 1999; Haith & Benson, 1998; Baillargeon, 1999; Spelke, 1998). In this method infants are presented with displays that either confirm or violate their expectations. Based on the fact that infants have a preference for novelty after being familiarized or habituated (e.g. Bornstein, 1985; Spelke, 1985), the rational is as follows: If infants understand a phenomenon they will react with surprise indicated by longer looking toward certain scenes or objects when exposed to outcomes violating the phenomenon in question (Baillargeon, 1994, 1998, 1999). Therefore, after familiarization or habituation they are typically presented with an expected and an unexpected test event on alternating trials. An expected outcome is consistent with the phenomenon in question and an unexpected outcome is constructed in a way to violate it. In the later case it is assumed that infants' behavior will be affected accordingly. Thus, it was not until the violation-of-expectation paradigm was developed that the key question regarding the number of objects could be addressed. The violation-of-expectation paradigm provides the foundation for the methods applied in individuation studies.

Spelke, Kestenbaum, Simons, & Wein (1995) as well as Xu & Carey (1996) were the first researchers using the violation-of-expectation paradigm to investigate th question how many objects are present in an event. In both lines of studies infants had to visually track objects in order to judge the number of objects. Besides numerical identity, Xu and Carey (1996) were concerned with another central question regarding object individuation. They, as well as others (Wilcox, 1999; Wilcox & Baillargeon, 1998b; Wilcox & Schweinle, 2002; Xu, Carey, & Quint, 1997), asked about the impact of kind concepts on early individuation judgments and looked at the criteria employed for individuating objects, i.e. spatiotemporal information, featural information, or kind information. The first study that investigated this question during infancy was by Xu and Carey (1996). At the present time, different lines of research (which will be explained in detail in the next chapter) suggest that although infants typically succeed at individuating objects when given spatiotemporal information, the same does not always hold for property and kind information, respectively. Xu and Carey (1996) were the first to uncover this in several experiments addressing the hypothesis that young infants may represent only a general concept that provides criteria for individuation and construct more specific concepts later (dubbed the *Object-first Hypothesis*). To test this idea they had developed a task (later referred to as event-mapping task) in which 10- and 12-month-old infants repeatedly watched an occlusion event involving two perceptually different objects such as a duck and a ball. The results obtained in this set of experiments suggest a developmental trend in the hypothesized direction. Infants seem to use general characteristics like spatiotemporal information before they include more specific ones like object property information to individuate objects. Against the assumption that infants younger than 12 months are not able to fulfill this task by means of featural information, speak findings provided by categorization research, which conveys that infants form categories not only of objects (Mandler, 2004; Pauen, 2002) but also of physical events (Baillargeon, 1995, 2000, 2002, 2004a). Part of this framework is the methodological distinction between *event-mapping* and *event-monitoring*. As will be described in more detail later, results derived from event-monitoring tasks provide evidence for successful object individuation in infants as young as 4.5 months.

In addition to these two main theoretical accounts, several other approaches on how principles for object individuation are acquired and how the process evolves exist. For instance, Xu as well as Bonatti and colleagues refined the Object-first Hypothesis with their approaches to object individuation, namely the *Theory of Different Kinds of Information* (Xu, 2003, 2007) and the *Human-first Hypothesis* (Bonatti et al, 2002), respectively. Leslie and colleagues developed the *indexing model* to account for the way objects come to be represented as belonging to object kinds and thus, can be referred to by the cognitive system (Leslie & Kaldy, 2001; Leslie et al., 1998). From a neuropsychological perspective Leslie et al. (1998) reckon that different pathways (ventral and dorsal) are responsible for the processing of information regarding objects (“what system”) or location (“where system”) and thus, brain maturation leads to the age difference discovered in several studies. Meltzoff and Moore (1992, 1998, 2001) on the other hand proposed the *identity theory* stating that it is representational persistence present at birth coupled with spatiotemporal criteria, which enables to keep track of the numerical identity of perceived objects (Meltzoff & Moore, 1998).

The adjacent chapters describe these accounts incorporating the methodological realization of each approach. In addition, empirical findings will be listed to provide a better understanding of the nature and content of the early individuation system. This report is accompanied by conceptions on how such systems develop.

2.1 The Object-first Hypothesis

Theory

The Object-first Hypothesis by Xu and Carey (1996) incorporates the philosophical notion of sortal[7], a concept which makes principles of individuation and identity available and thus, permits the selection of individuals. In addition, the theory builds on Bower's (1974) conjecture that infants use spatiotemporal criteria for individuating and tracing identity of objects before they can use other property information. Consequently, the presumption of this theory is two-folded: Corresponding to the sortal concept, Xu and Carey (1996) proposed that infants hold general sortal objects before they have more specific sortals such as basic level objects (e.g. ball). Based on their findings, the authors claim that infants younger than 12 month possess only the most general concept that provides criteria for individuation, namely the one of "physical object" as formulated by Spelke (1990)[8]. Such criteria include that one object cannot be at two places at the same time, that two objects cannot occupy the same place at once, and that objects travel on spatiotemporally connected paths[9]. The Object-first Hypothesis combines these principles into the spatiotemporal criteria for individuation (see chapter 1.1 for elaboration). With regard to the usage of different criteria, the studies by Xu and Carey (1996) give rise to the assumption that 10-month-old infants can only use spatiotemporal cues for object individuation and thus, lack the representation of object kinds (see also Xu, 1997, 1999). That is, because in order to hold property/ kind criteria, one has to be able to infer that there are two numerical distinct entities upon viewing a member of a kind at one time (e.g. a duck) and a member of a different kind at a later time (e.g. a truck). The research conducted by the authors implies that only by 12 months of age are infants able to do so. 10-month-old infants fail to use property/ kind information to establish representations of numerical distinct objects

[7] As elaborated in the introduction, philosophers of language introduced the term sortal to denote a concept that provides criteria of numerical identity. For an object to be a sortal one should be able to use the differences between objects to set up representations of numerical distinct individuals (Xu, 1999, 2003).

[8] Spelke (1988, 1990) describes physical object as a unitary, coherent, bounded, three-dimensional entity that moves as a whole.

[9] This means that objects move continuously from point A to point B. People perceive two or more objects in an event in which the path an object traveled appears spatiotemporally disrupted.

under a variety of conditions (e.g. unfamiliar and familiar objects). Only when given spatiotemporal information or verbal cues were infants of this age group able to succeed in Xu and Carey's original experiments. In contrast 12-month-olds master the task, which might be due to maturational changes underlying the developmental accomplishment. Hence, the Object-first Hypothesis suggests a developmental conceptual change between 10 and 12 month of age with regard to the kind of information infants rely on when individuating objects.

Three learning mechanisms were proposed in the original version of the Object-first Hypothesis to explain this difference in performance. First, infants learn through spatiotemporal criteria how properties fluctuate within individuals and the predictions that come along with certain properties (Xu & Carey, 1996). A second possibility would be that infants possess the concept of more specific kinds in the absence of any examples and it is not until they are able to comprehend words that they demonstrate object individuation based on property/ kind information. It might be that word comprehension and individuation is correlated. Several recent studies speak for this alternative. Naming each object as it emerged from behind a screen (e.g. duck or ball) helped infants at 9 month of age to individuate the objects in Xu and Carey's original task (Xu, 2002). This was even the case when two unfamiliar objects were labeled with nonsense words. However, 9-month-old infants failed the task when the same label was given to both objects. These findings have been replicated and extended. For instance, Rivera & Zawaydeh (2006) submitted results indicating that 10- and 11-month old infants exhibit looking behavior consistent with object individuation when they comprehend the words of both objects in place. Hence, it seems like learning count nouns plays a causal role in acquiring basic-level sortal objects (Xu, 2007). The third possibility proposed by the authors is that learning the function of objects might facilitate the construction of kinds and in return helps infants to predict kind distinctions (Xu & Carey, 1996). It is not ruled out that these three learning procedures play a combined role in the change of the infant's representational system, which by 12 months of age begins to distinguish kinds from properties.

Taken together, the theory argues for a primacy of spatiotemporal information relative to property/ kind information in object individuation. This implies that infants younger than 12 months of age rely almost exclusively on spatiotemporal information when individuating (Xu, 2003). Because spatiotemporal principles apply regardless of kind membership to all physical objects in the same way this seems plausible. Tracing identity under more specific criteria, however, requires kind-relative information about types of objects and which of their properties change over time and which stay the same (Xu & Carey, 1996). For example, spotting a small cup on the coffee table now and a large cup there later implies two numerical distinct cups. However, seeing a tall candle on that table at some point and a short one at a later time does not necessarily infer two different candles but rather indicates a candle that burned down. Thus, certain property changes signal a change in identity only within specific kinds of objects (Xu, 1997). The ability to take such information into account emerges at around 12 months of age with the development of the kind-based system of individuation (Xu, 2003, 2007).

Method: Event-mapping tasks - object disappearance

In order to address the question when the kind-based individuation system develops during infancy, the paradigm had to be designed so that spatiotemporal information would be ambiguous. Xu and Carey (1996) implemented this by (1) presenting only a single screen occluding the objects and (2) showing the objects asynchronous during familiarization in the property kind condition. Therefore, in this condition Xu and Carey's (1996) task gave no clear spatiotemporal evidence that there are two distinct objects. At no point during the course of the experiment were both objects visible together at the same time. Thus, to solve the task, which required the construction of a representation of two objects, infants had to rely on knowledge about object kinds. They had to know that ducks and balls are two different kinds of objects, which typically do not turn into each other behind screens. Such understanding would then lead to the conclusion that there must be two distinct objects. Xu and Carey (1996) tested this assumption by presenting the following order of events: at first infants viewed an empty stage. The experimenter taped on the ends of the stage to emphasis its blankness. Then a screen with objects concealed behind it was lowered onto the stage floor. Four introductory trials came next. In those infants were taught that there are objects located behind the screen, sometimes one and sometimes two (e.g. bunny; bunny and basket; toy truck; toy truck and toy camel). With a different set of toys (a ball and a bottle or a cup and a book) and a new screen infants were familiarized to the following event: One object (e.g. a ball) was moved from behind the left edge of the screen to the left wall of the apparatus and then was returned behind the screen. Thereafter a different object (e.g. a bottle) was moved from behind the right edge of the screen to the right apparatus wall and then was returned behind the screen. This sequence was repeated until the infant had watched four emergences of each toy. On the fourth trial each toy was left stationary in view for a couple of seconds before returning behind the occluder to show infants that the toys could be stationary. Thereafter the screen was turned aside revealing either one (e.g. a ball; unexpected outcome) or two distinct objects (e.g. a ball and a duck; expected outcome). After the infant looked away for two continuous seconds the screen was turned back to its original position and the stage was cleared (Figure 1).

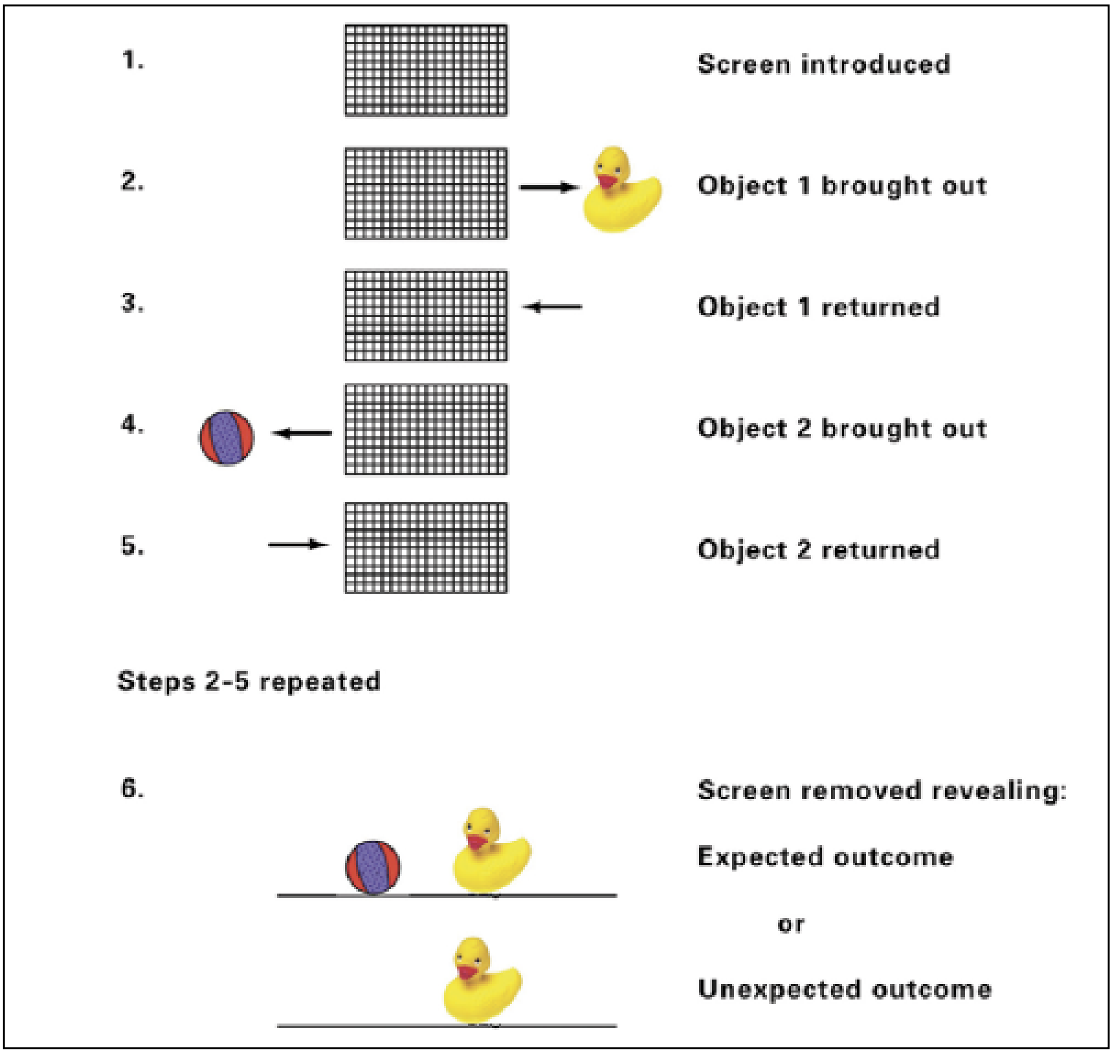

Figure 1. Schematic illustration of the procedure employed by Xu and Carey (1996).

A different screen masking the same two objects was lowered to the stage floor and infants were again familiarized to the successive reappearance of the objects. This time, however, they just saw two appearances of each toy before the screen was removed to the side and the opposite outcome was revealed. The entire sequence was repeated with two new objects.

The rational behind this method is as follows: whereas the looking times to the images will be either equally long or signify a preference for the two-object display during introduction, a change in preference toward the one-object display is expected for the test trials. This is, at first both displays are new and therefore should be similarly interesting to the infants. However, because the two-object display contains more material to observe, it actually could attract more attention. Either way this should change in test. The exposure to two successively appearing objects differing in their features and/ or kind in familiarization should build up an expectation that there are two distinct objects involved in the event. Due to this infants should show surprise indicated by longer looking when the screen is removed to reveal the one-object display (unexpected outcome) instead of the two-object display (expected outcome) in test compared to baseline. When presented with this task, this was exactly the case for 12-month-old infants. They had an intrinsic preference for two objects during introduction, which resulted in initially longer looking toward the two-object display. During test trials they overcame their intrinsic preference for two objects, which led to equal looking times for both test displays. Younger infants, however, kept their favoritism revealed during introduction in test. Thus, the younger infants did not find the one-object test display surprising. It was not until spatiotemporal information was provided that younger infants were able to infer the numerical identity of the objects involved in the event. Only when infants saw both objects simultaneously on the left and right side of the occluder before the start of the movement sequence (spatiotemporal condition) did they look longer at the unexpected event, too. Taken together these results, the Xu and Carey (1996) concluded that only by 12 months of age did infants encode the objects on the basis of property/kind information. In contrast, younger infants did not recognize two distinct objects being involved in the occlusion event provided this information. They showed the expected pattern solely in the spatiotemporal condition, indicating that they could individuate objects based on distinct locations but not on the basis of their identifying features. These conclusions led to the Object-first Hypothesis (see previous section).

Another line of convergent evidence for this developmental change comes from work with a manual search procedure (Van de Walle et al., 2000). In these studies 10- and 12-month-old infants were trained to reach into an opaque box to retrieve objects. Infants were taught that there could be one or two objects hidden[10]. Instead of looking time as dependent measure, patterns of search were examined. The question was: how many times would the infant reach into the box to extract objects from it? The authors expected that if infants had established a representation of two objects based on kind contrasts, they should search more persistently in the event of two objects being hidden (Van de Walle et al., 2000). The findings were completely consistent with those of previous looking time studies (Xu & Carey, 1996; Bonatti et al., 2000; Wilcox & Baillargeon, 1998a, Experiments 1 & 2). Twelve-month-old, but not 10-month-old infants, showed the hypothesized pattern of results (Van de Walle et al., 2000; Xu 2003, 2007). Again, only in the case of presenting both objects simultaneously during familiarization (spatiotemporal evidence), did 10-month-old infants search more for two objects on contingent trials (Van de Walle et al., 2000; Xu, 2003, 2007).

Contrary to the evidence provided by Xu and Carey (1996) as well as Van de Walle et al. (2000) are the results obtained by Baillargeon, Needham, and Wilcox. They presented findings that challenge the claim that infants less than 12 months of age are not capable to use featural information to individuate objects (see for example Baillargeon & Wang, 2002; Needham & Baillarageon, 2000; Wilcox, 1999; Wilcox & Baillargeon, 1998a, Experiments 3 & 8; Wilcox & Schweinle, 2002). Besides the interpretation that younger infants are fundamentally unable to apply featural information in the process of individuation, these authors argue that the original task has been to demanding at the younger age. An alternative explanation of the failure of younger infants to individuate objects obtained in event-mapping tasks could be information-processing requirements. In each of Xu and Carey’s (1996) studies, infants saw an event in which one or two objects emerged successively to each side of a screen, the screen was removed, and then infants viewed a display containing either one or two objects. In line with this reasoning, the procedure applied by Xu & Carey

[10] When one object was concealed the experimenter extracted the object (e.g., a toy telephone) and placed it back into the box. In case of two objects the experimenter pulled the first one out (e.g., a toy telephone) and put it back. Afterwards he/ she took out the second object (e.g., a toy car) and then placed it back into the box. On two-object test trials the experimenter surreptitiously removed the second object through an opening in the back box.

(1996) is an event-mapping task (Wilcox & Baillargeon, 1998a). It not only requires infants to react to a violation of their expectation but also to retrieve a representation of the familiarization or habituation event, map it onto the test event, and judge whether they match (Wilcox & Chapa, 2002). Thus, Baillargeon, Needham, and Wilcox argue that this paradigm entails too high information processing demands for young children. Derived from empirical findings these authors come to the conclusion that design characteristics play an important role when investigating object individuation. When a simplified version of the design assembled by Xu and Carey (1996) is used, infants as young as 4.5 month of age, who were only given featural information accomplished object individuation (Wilcox & Baillargeon, 1998a). The following chapter outlines their approach to the investigation of the development of object individuation.

2.2 Event Categorization

Theory

Event categorization is a framework on how infants form and use representations of physical events. Baillargeon, Wilcox, Needham and their colleagues see individuation as one specific problem of infant’s event categorization across different physical domains (e.g. Baillargeon & Wang, 2002; Needham & Baillargeon, 2000; Wilcox & Schweinle, 2002). Investigators holding this view assume that infants assign physical situations to broad categories including occlusion, support, arrested-motion, and containment and build up a mental representation of the physical event watched with respect to spatial, temporal, and mechanical information (Baillargeon, 1998; Leslie, 1994; Xu and Carey, 1996). Thus, not only do infants have to categorize the available information into a simple structure that makes up the event. In addition, they have to consult already stored information about the specific kind of event and confine it from other kinds of events (Arguiar & Baillargeon, 2002; Baillargeon & Wang, 2002; Hespos & Baillargeon, 2001; Wilcox & Schweinle, 2002). According to the model of infants’ acquisition of physical knowledge (Baillargeon, 1994, 1995, 1998, 2000; see Figure 2), a specialized learning mechanism is held accountable for the formation of physical categories, which correspond to distinct ways in which objects behave and interact. When learning about a physical category, infants first establish a "preliminary, all-or-none concept" that captures only the core of the category (Baillargeon, 1994). Typically this includes only basic spatial and temporal information as specified in principles of continuity and solidity (Baillargeon, 2004). During the course of development the initial concept is progressively elaborated and refined. With further experience, infants identify more variables that are relevant to an event category[11] and incorporate this additional knowledge into their reasoning. As a result infants are able to make increasingly accurate predictions and interpretations over time (Baillargeon, 1999).

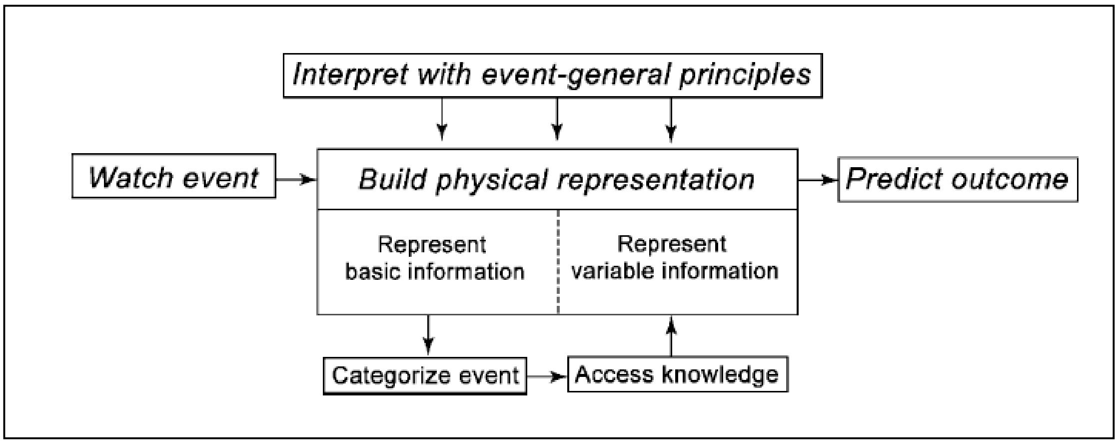

Figure 2. The physical reasoning account. From Baillargeon (2004).

For instance with respect to object individuation, Baillargeon and her colleagues provide evidence that precursors of this competence are found in infants as young as 2.5 months. However, even though infants at this age expect that an object continues to exist after it becomes hidden (Aguia & Baillargeon, 1999; Spelke et al., 1992; Wilcox et al., 1996), their knowledge about occlusion events is still incomplete and it takes the identification of relevant variables such as shape or color to improve the ability to individuate. Therefore, the acquisition of knowledge about occlusion events follows the same developmental trend as observed in other physical categories showing that the range of violations, infants solve, increase with age (Baillargeon,

[11] Learning occurs separately for each event category since these variables are not transferred between relevant categories (Baillargeon, 2004).

1999). Whereas infants at 3.5 months of age identify height as an occlusion variable it is not until 7.5 months of age that infants include transparency in their judgments (Baillargeon & DeVos, 1991; Luo & Baillargeon, 1994).

From the event categorization perspective, occlusion events confront infants with a special problem. In order to be able to individuate the objects which are part of an occlusion event, infants not only must decide whether the entities successively seen on either side of an occluder constitute one or two distinct objects, they also have to determine if the sequence they view consists of one or more events (Baillargeon, 2004, Wilcox & Baillargeon, 1998). Wilcox and Baillargeon (1998) contended that in Xu and Carey (1996), the infants were confronted with a task that involved two separate categories of events. Whereas during familiarization they saw an occlusion event in which objects moved back and forth behind a screen, they viewed a non-occlusion event in which objects rested on a platform in test with no screen being present. According to the event categorization approach, the presence or absence of the screen creates a crucial difference between familiarization and test events and produces a change in event category. As a consequence, instead of viewing the screen's removal as a change in an ongoing situation, infants may view it as the start of a separate physical situation. Such being the case infants reclassify and initiate a new event representation. Further, when presented with two different physical situations infants not only have to establish two separate event representations, they also must form a link between them (Baillargeon, 2004). This linking or event-mapping requires several processing steps. In order to follow and make sense of categorically distinct situations infants need to remember what occurred in one event, map this information onto the ongoing in a second one and compare the two events. The more complex an event sequence, the more difficult this process becomes. Xu and Carey's event-mapping task involved featurally distinct objects that follow complicated trajectories. Thus, infants had to judge whether the objects' movements and interaction are consistent with their existing knowledge (Wilcox et al., 2003). The familiarization event is supposed to build up an expectation that is tested in the events during test. This can only be done if the two events are perceived as belonging together. Proponents of the event-categorization approach doubt that infants perceive a single continuous situation in event-mapping tasks on which the 'Object-first-Hypothesis' is based on. Thus, the failure to respond correctly in an event-mapping task at 10 months of age could be attributed to the inability to complete the mapping process during test. That is, infants were not able to judge whether the event seen during familiarization mapped onto the one seen during the test phase. So it could be that infants successfully individuate objects at this age, but they were simply not able to reveal this ability within the context of an event-mapping task. Therefore, event-mapping is seen as a limitation that results from infants' bias to form distinct physical categories and to reason and learn in terms of these separate categories (Wilcox and Baillargeon, 1998). It alters infants' categorization of the physical situation presented to them. What speaks for this hypothesis are results maintained by tasks explained in the proceeding paragraphs.

Method: Event-monitoring tasks - object changes

Evidence for this presumption that infants under the age of 12 months are able to individuate objects comes from studies concerned with event categorization showing that infants group physical events into different categories (Baillargeon, 1995, 1998; Hespos and Baillargeon, 2001). Based on the assumption that the main difficulty with event-mapping is the retrieval of a clear representation of the occlusion event, Wilcox and Baillargeon's (1998b) designed a new procedure, namely event-monitoring task. In order to aid infants in accessing an event representation they showed a continuous occlusion event in which infants see only one event involving one or two objects. By doing this, infants do not need to engage in event mapping and thus do not have to compare an earlier familiarization or habituation event with a test event but focus on the test event itself (Wilcox & Baillargeon, 1998b). Therefore, the only task infants have to solve is monitoring whether the event is consistent in itself. This makes event-monitoring tasks less cognitive demanding in comparison to event-mapping tasks, because event-monitoring involves only one processing step whereas event-mapping incorporates multiple ones. Empirical findings suggest that it is presumably easier for infants to monitor the internal consistency of one event compared to the mapping of one event representation to another (Aguiar & Baillargeon, 2002; Hespos & Baillargeon, 2001; Leslie et al., 1998; Wilcox, 1999; Wilcox & Baillargeon, 1998b; Wilcox & Schweinle, 2002). In a large number of studies that applied an event-monitoring task the ability to use featural information to individuate objects was demonstrated with infants aged 4.5 to 11.5 months (e.g. Wilcox, 1999; Wilcox & Baillargeon, 1998a, b; Wilcox & Chapa, 2002). Three general approaches can be divided: (1) “the single-trajectory experiments,” (2) “the narrow/ wide screen experiments,” and (3) “the opaque/ transparent occluder experiments”.

The single-trajectory experiments

In the single-trajectory experiments Wilcox & Baillargeon, (1998b, Experiments 8) used a simplified version of the Xu and Carey (1996) task. For one thing this was done by making the events shorter. During familiarization the objects just moved from left to right without reversing their trajectory (Wilcox & Baillargeon, 1998b). For another thing this was accomplished by using only one test display that contained a single object. Instead of checking looking times to a one-object test display against a two-object test display, they compared infants’ reactions to a one-object test outcome. Therefore, they randomly assigned infants to one of two conditions: the box-ball condition or the ball-ball condition. In the box-ball condition, infants were familiarized to a sequence of a box moving from one side of the stage and disappearing behind a screen, followed by a ball emerging from the other side. In the ball-ball condition on the other hand, infants saw a ball going behind an occluder and the same ball coming out the other side. The screen was then lowered to reveal a single ball on the stage in both conditions. Infants looked longer at the single ball outcome in the box-ball condition than in the ball-ball condition. Wilcox and Baillargeon (1998b) concluded that the infants must have used perceptual property information to establish a representation of two distinct objects. Therefore, the single ball outcome was unexpected in the box-ball condition. Thus, the authors were able to show that infants at 9.5 months of age individuate objects by means of object properties alone when the number of object trajectories involved in the introduction/ familiarization sequence was lessened and the experimental procedure was simplified. Later work by Wilcox & Schweinle (2002) suggests that the age in which the ability to individuate object could be shown reduced to 5.5 and 7.5 months in the case of just a single trajectory. Thus, when the task is sufficiently simple, infants younger than 10 months of age appear to be able to individuate objects on the basis of their perceptual features. Wilcox et al. (2003) present evidence that young infants are able to use featural information as the basis for object individuation.

The opaque/ transparent occluder experiments

Wilcox and Chapa (2002) proposed another way of tailoring the procedure to the information processing capacity of younger infants. In their version of the event-monitoring paradigm they made the task simpler and more traceable by employing a transparent occluder in the test events. Thus, 9.5-month-old infants viewed either one object (i.e. a ball) or two objects (i.e. a box and a ball) emerge successively to opposite sides of an opaque occluder. When the screen was lowered a single ball behind a transparent screen was revealed. This was compared to a condition without an apparent screen standing behind the occluder. Only the infants who saw the ball in the transparent screen condition correctly judged that the one-ball display was inconsistent with the box–ball sequence. The authors' interpretation of the results was that infants categorize events involving opaque and transparent occluders as the same kind of physical situation (i.e. occlusion). Thus, infants only had to engage in event-monitoring of a single event, which according to Wilcox and Chapa (2002) enabled them to solve the object individuation task. For this reason the findings support the notion that infants are more likely to give evidence of object individuation when they need to reason about one kind of event (i.e. occlusion) than when they must retrieve and compare categorically distinct events (i.e. occlusion and no-occlusion).

The narrow/ wide screen experiments

Besides simplifying the task demands Wilcox and Baillargeon (1998b) thought of an additional way to assess infants' interpretation of occlusion situations with an event-monitoring task. They presented 9.5-month-old infants with a sequence in which a red ball disappeared behind a screen and after a brief interval a blue box emerged at the other side of the occluder. Subsequently, the box reversed its trajectory and vanished behind the screen followed by the ball appearing on the other side. This event was presented without interruption for the time the infants kept their attention on the stage area. In order to keep a continuous event even during test the screen was not removed to reveal one or two objects. Instead of lowering the occluder in test trials, infants had to judge whether the screen was sufficiently wide to hide the two objects simultaneously (Wilcox & Baillargeon, 1998b). Two conditions were checked against each other: a narrow-screen condition in which the screen was too small to fit both objects behind side-by-side and a wide-screen condition in which the screen was broad enough to fit both objects simultaneously (Xu, 2003). The hypothesis was that if infants were led by the perceptual property differences between the ball and the box to conclude that there were two distinct objects, they would look longer at the narrow-screen event because the two objects could not fit behind the small screen at the same time. Wilcox and Baillargeon (1998b) obtained this result and concluded that when the experimental task was modified in this way, 9.5-month-old infants were able to use perceptual property/ featural information for object individuation. This finding could be extended to younger infants of 7.5 and 4.5 months (Wilcox & Baillargeon, 1998a, b). Using the same methodology, Wilcox (1999) investigated the features (shape, size, pattern, and color) infants were sensitive to. Infants 4.5 to 11.5 months of age were tested on displays in which the objects differed only in one perceptual property (e.g., size or color) at a time. Results indicate a developmental trajectory: Infants 4.5 months of age looked longer at the narrow-screen event when shape or size alone changed, but they did not look longer when surface pattern or color were manipulated solely. At 7.5 months, infants used the change in surface pattern to reason about the number of objects involved in an occlusion event and it was not until 11.5 months that infants included the color change in their judgment. Wilcox (1999) interpreted these results as evidence that infants at various ages use different types of perceptual properties for object individuation.

Three examples of event-monitoring tasks provided evidence that infants, much younger than 10 months of age, are capable of individuating occluded objects by means of featural information. Thereby these studies show that when infants must rely on property information as opposed to spatiotemporal information, event-mapping tasks in which infants are asked to relate an occlusion event with a no-occlusion event are more challenging for infants than event-monitoring tasks in which they have to reason about only an occlusion situation (Aguiar & Baillargeon, 1999; Baillargeon & DeVos, 1991). The more over, these experiments yielded detailed information about the timetable and hierarchy for the development of this competence. When given an occlusion event in which infants can only draw on featural information to individuate the objects in an occlusion situation they succeed in case the same objects are involved at some point between the ages of 2.5 to 10 months (Baillargeon, 2004a; Spelke et al., 1995; Xu & Carey, 1996). In occlusion events in which different objects are involved infants succeed between 10 and 12 months of age (Xu & Carey, 1996). Despite her original claims, Xu has meanwhile acknowledged that younger infants are able to successfully include featural information in the process of individuation under certain conditions such as a simplified experimental procedure (Xu, 1997, 1999, 2002, 2003, 2007). Nonetheless, the author maintains the conception that spatiotemporal information is primary compared to featural information and that older infants make use of more references for individuation. Her advanced account on the development of object individuation is delineated next.

2.3 Theory of Different Kinds of Information

Theory

In their original study Xu and Carey (1996) distinguished two types of information that are available for the individuation process. The two information types are spatiotemporal and property/ kind information. Based on their work they concluded back then that infants are not able to use property/ kind information until the end of the first year of life. In contrast to the 'Object-first Hypothesis', Xu meanwhile distinguishes featural and kind information, which was claimed confounded in the seminal study (Needham & Baillargeon, 2000). More recent work concerning the early use of kind information supports the idea that kind representations are distinct from featural representations implying that the initial success of 12 month olds was due to the kind difference of the objects rather than their feature contrast (Xu, Carey, & Quint, 2001). Consequently, Xu and her colleagues maintain the view that it is not until the end of the first year of life that infants are able to include kind information in their judgments regarding numerical identity. However, Xu (2003, 2007) concedes that featural information can be used at a younger age and further developed her theory subsequently.

Based on her 'Theory of Different Kinds of Information', Xu (2003, 2007) distinguishes between three types of information used for object information: spatitemporal, featural/ property, and kind information. Further, the author proposes two systems (the object- and the kind-based system) responsible for object individuation in adults. According to Xu (2003), the essence of the object-based individuation system is the concept object (i.e. a bounded, three-dimensional entity that moves as a whole). Within this system spatiotemporal as well as perceptual property (featural) information play a role in setting criteria used for individuation (Xu, 2003). Thereby spatiotemporal criteria take primacy because they are rather broad and hold for any physical object regardless of its kind or category membership. For example, the child who jumped off the diving board a second ago and disappeared under water cannot be the same as the one who buys ice cream at the ice cream stand next to the pool. One would even come to this conclusion that there are two children involved in the absence of featural information (e.g. the children are twins). This illustrates that spatiotemporal information is sufficient to make inferences about how many objects are in an event. In contrast, perceptual property information comes only into play when spatiotemporal information is absent and therefore, it takes a secondary role (Xu, 2003). Another characteristic of this system is that spatiotemporal information can override featural information (Xu, 2003). Examples for this phenomenon in adults are apparent motion and the tunnel effect (cf. Chapter 1, p. 16). After Xu (2003, 2007), representations of object kind do not matter in this system. Instead they are part of a second system, the kind-based system. The nature of the kind-based system is conceptual with object kind concepts such as dog, truck, ball, or person at its core (Xu, 2007; Xu and Carey, 1996). These concepts correspond to "basic-level categories". Hence, Xu (2003, 2007) suggests that this system derives from learning count nouns that map onto kinds of objects. The author refers to studies in which the original event-mapping task was applied and the objects were distinctly labeled on each emergence. Only a few repetitions of these labeled events lead 9-month-old infants to look longer at the unexpected outcome of one object than to the expected outcome of two objects. Thus, they showed the same looking pattern as 12-month-old infants in the original study (Xu, 2002). When spatiotemporal information is missing or misleading this system draws on kind information in order to individuate objects (Xu, 2003). This would be the case whenever we decide if objects we saw in a particular place before are the same ones we find there later. Although perceptual property information is kind relative in this system, i.e. not all perceptual property differences are treated equally as in the object-based system. Spatiotemporal information can override kind information just as it can override perceptual property information. The difference between the object-based individuation system and the kind-based system lies, for Xu (2003), in the way these systems track objects. Whereas the object-based individuation system makes use of spatiotemporal continuity, the kind-based system uses kind membership as the basis for its decision on how many individuals are present in an event (Xu, 2003). Thus, it can happen that the two systems settle on different solutions.

Under the terms of the ‘Theory of Different Kinds of Information’, the object-based individuation system is present at 4-months of age. At this age it represents the sortal object and it employs spatiotemporal information such as spatiotemporal discontinuous paths for object individuation (Xu, 2007). Toward the end of the first year infants start to represent other sortal concepts in addition to the sortal concept object. At 10 months of age infants include the sortal person to determine how many objects an event consists of. It is not until 12 months of age that infants conceptualize basic-level sortal concepts such as duck and ball that aid them in establishing a numerical identity (Xu, 2007). They can only do so, however, if the objects’ difference is indicative of a sotal distinction and thus, goes beyond mere property variations. For instance, two objects are inferred when one object seen at one time (e.g., a green plastic spoon at dinner) falls under one sortal concept and a second object seen at another time (e.g., a green toothbrush after dinner) belongs to a different sortal concept. The expectation that objects do not change kind membership underlies this reasoning. Xu (2007) concludes from that, that sortal distinctions underlie the success at 12 months. The adjoining theory gives a different explanation for the underlying mechanisms of object individuation.

Method

Xu’s Theory of Different Kind of Information tries to incorporate several lines of empirical work on object individuation and the study of object-based attention. Thus, her theory is not based on a specific type of methodology.

2.4 The Indexing Model

Theory

The object indexing theory by Leslie and his colleagues is a model of object representation, which has its origin in the theoretical approach to object-based visual attention in adults (e.g., Kahneman, Treisman, & Gibbs, 1992; Phylyshyn, 1989). Furthermore, it comprises considerations regarding a neurological differentiation of the “what-“ (ventral) and the “where-” (dorsal) neural system of visual processing (e.g. Haxby et al., 1991; Mishkin et al., 1983, 2000). The key notion of the object-indexing model implies that the development of the object concept is related to the development of mechanisms of object-based attention. It is reckoned that, indexing forms the basis for the infant’s object concept through its role in individuation and identification of physical objects. Individuation in this context concerns the notion of a single versus more than one object and identification establishes if the same or a different object is present. Thus, the model draws a conceptual distinction between the two mechanisms.

The central idea is that an index[12] points at an object in a specific location (Leslie et al., 1998; Scholl & Leslie, 1999). The index then is bound to an object and follows it by means of the objects’ location without representing any properties of the objects referring to. In other words the object index is an internal representation that reveals the existence of an object but does not describe it or the feature it contains. Such information must be specifically bound to the index (Leslie et al., 1998). However, an object index makes an association of featural information through examination of the properties possible. Thus, once an object is afflicted with an index other information about this particular object is easily accessible (Scholl & Leslie, 1999). Nevertheless, indexes are assigned to objects before feature binding occurs. According to this apprehension, indexing is the mechanism underlying object individuation whereas feature binding facilitates object identification (see Figure 3 for illustration).

[12] In Leslies’ model of object representation an index signifies a mechanism of selective attention. It represents a mental icon, which functions as a pointer to an object (Scholl & Leslie, 1999).

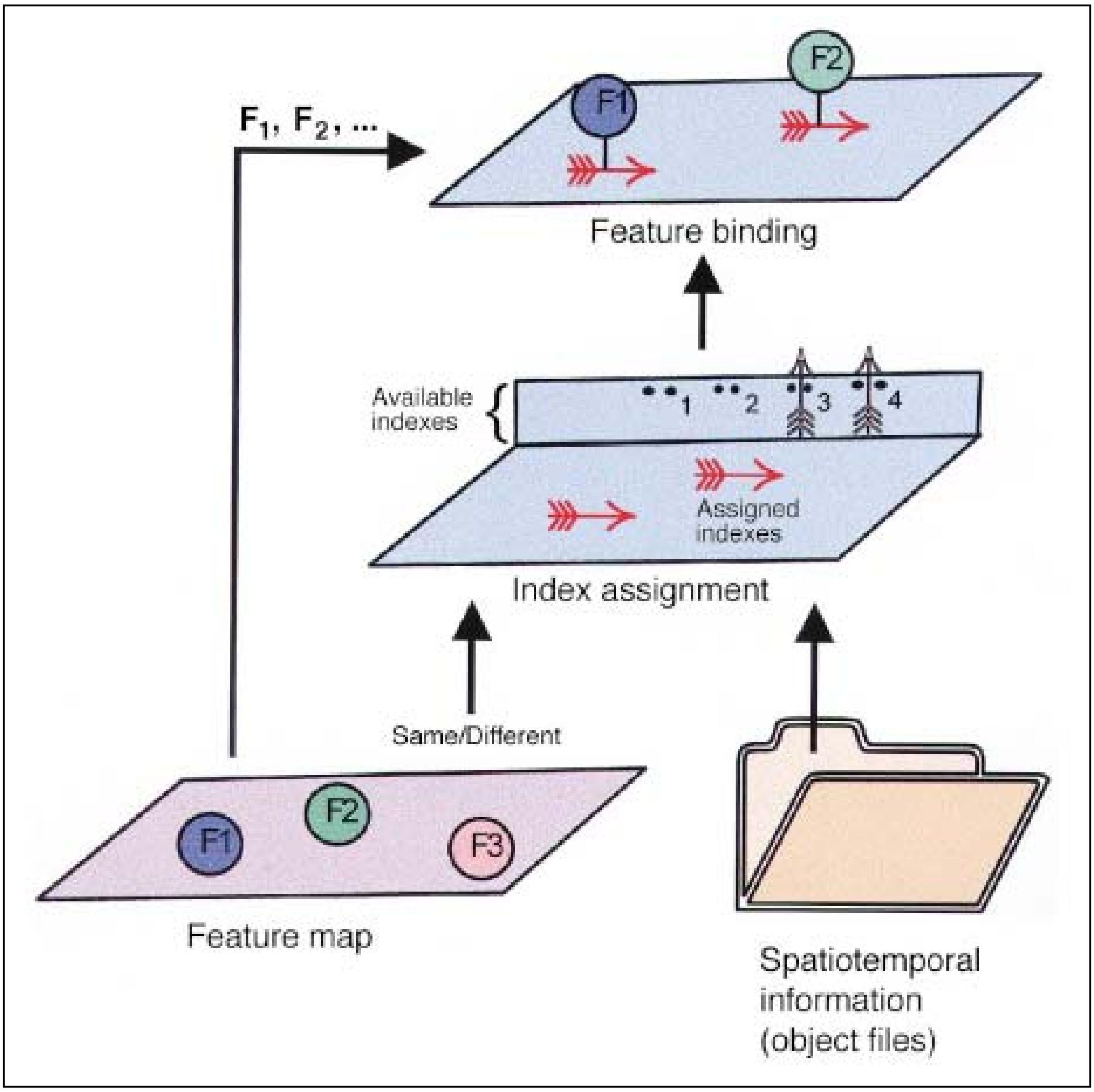

Figure 3. The object indexing system. From Leslie et al. (1998).

As aforementioned an object index serves various purposes including individuation of items based on spatiotemporal criteria such as motion and spatial gaps, continuing identity tracking of objects as they move about in the environment, and enumeration of objects (Scholl & Leslie, 1999). Thereby the object indexing system is subject to certain regulation. Because object indexing is a mechanism of selective attention, it is resource-limited, i.e. only a small number of object indexes are available. Leslie and his colleagues assume that there are four object indexes. Furthermore, the association of an index with an object takes place based on the object's location. Yet, no relationship between index and the location is formed. The association of an index with an object happens by means of basic principles. These include the following characteristics. Each definite object receives only one object index. The assignment of multiple indexes to a single object is not feasible due to the limiting number of object indexes. In contrast, several objects could be substituted under one index in conditions where object arrangements engage in the same motion or where multiple spatial arrays cannot be differentiated by additional spatiotemporal information. In case all indexes are placed with an object, an index can only be assigned to a new object when an already indexed object dismisses its index. Once an index is ascribed to an object it stays with that object even when it occluded. In the case where one object disappears behind an occluder and another one emerges, both could be tracked by the same index, because indexes point to objects regardless of object features. Indexes follow objects on the basis of separate motion and spatial gaps between objects. Hence, only when several objects are visible simultaneously in different locations at some point, separate indexes are automatically assigned to them. This makes independent tracking of the objects possible (Scholl & Leslie, 1999).

Leslie et al. (1998) linked the development from feature-blind to feature-driven object indexing to the increased integration of the “what” and “where” systems of visual processing in the brain. These systems describe neural circuits involved in the representation of objects. The “what” system processes the kind of objects present regardless of their locations and the “where” system manages the locations of objects without referring to the object identities (Sagi & Julesz, 1987; Mishkin et al., 1983, 2000). Thus, information regarding objects and their features (“what system”) and locations (“where system”) seem to be processed by distinct anatomical brain pathways (ventral and dorsal). Leslie et al. (1998, p. 11) specify them as follows:

> *“Featural information is processed mainly in circuits linking primary visual cortex, through extrastriate cortex, to the inferior temporal cortex, while information about the location of visual objects is processed mainly in a stream running from striate to partial cortex.”*

Authors in favor with such neuropsychological explanations (e.g. Leslie, 1998; Mishkin et al., 1983, 2000) the authors argue that the different results with 10 and 12-month-olds derive from the development of the connection between the two neural systems. In 10-month-old infants the object system and mechanism of object indexing are not fully connected yet. Therefore, infants are not able to use property information for object individuation at the younger age. Even though there is still work to be done regarding how these neural systems relate to the object-based attentional mechanism, the maturation and integration of these circuits may account for the changes in infant object cognition (Leslie et al., 1998; Scholl & Leslie, 1999).

Method

Besides reinterpreting results on infants' initial knowledge in the context of object indexing, Leslie and colleagues carried out studies employing an event-mapping task (Figure 4) to test their theory. The general paradigm proceeded like this: Infants were familiarized with an event in which two distinct objects were sequentially drawn from behind one side of an occluder. Each object was replaced behind the screen before the other one was brought out. Thus, the two objects were shown in the same location but never at the same time. In test trials the screen was lowered revealing either both objects shown during familiarization (expected outcome) or two identical objects from either kind of the familiar objects (unexpected outcome). Implementing this procedure Tremoulet, Leslie, and Hall (2000) investigated the distinction between object individuation and object identification. After consecutive presentation of a circle and a triangle infants were exposed to both objects (circle and triangle) side by side or to two objects of the same shape (two circles or two triangles). Longer looking to the unexpected outcome indicated that at 12 months of age infants indexed two distinct objects on the basis of shape during the familiarization phase. When color rather than shape was the differentiating feature in familiarization trials, same aged infants did not look longer at the unexpected outcomes. However, infants did expect one object after repeated exposure to same-colored objects suggesting that they attended to color and used it for individuation. Together, these results provide evidence that 12-month-old infants use shape to individuate and to identify objects through occlusion but only use color under certain conditions for object individuation (Tremoulet et al., 2000).

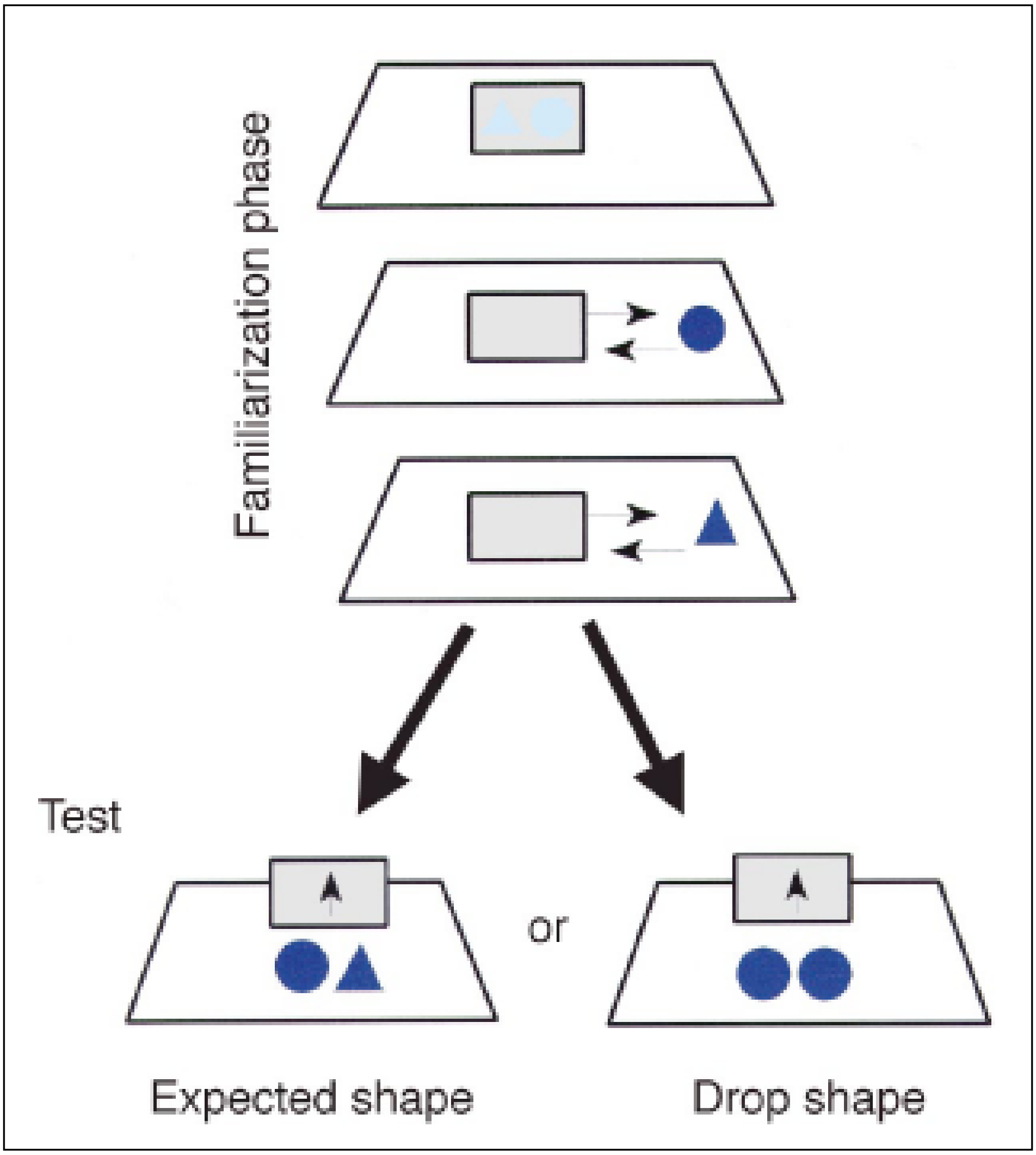

Figure 4. Infant Object Indexing by Shape: A Circle and a Triangle Are Shown Sequentially. From Leslie et al. (1998).

Using the same method, Leslie and Chen (2007) recently examined whether 11-month-old infants are able to individuate pairs of objects by means of object shape. Instead of single geometric shapes pairs composed of a circle and a triangle were displayed. The experiments provide evidence for individuation of two sequential pairs of objects at 11 months of age (Leslie & Chen, 2007). On top of it, the findings speak for an early competence of forming object pairs based on featural information as well as of representing and tracking sets. Considering the indexing theory, one explanation for such performance is that the property information for two individuals is bound to one index. This would yield two indexes tracking four objects, which in turn would reduce processing demands and make the representation of two pairs possible.

The following stance on object individuation is as complex as the object indexing theory. However the model differs from all other approaches concerned with individuation processes in respect to the impact, which it awards the meaning of object permanence.

2.5 The Identity Theory

Theory

While the major concern of the identity theory is the development of object permanence it also makes predictions about the numerical identity of objects. In this theoretical approach Meltzoff and Moore (1992, 1998, 2001; Moore & Meltzoff, 1999, 2008) take a different stand on the development of object representation. According to their model of the early representational system for maintaining object identity, infants' competence to represent hidden objects originates from the ability to signify an object's identity (Moore & Meltzoff, 1999). In order to develop the notion that objects continue to exist during an occlusion interval, infants first have to interpret the object involved in an occlusion event as a single entity (Moore & Meltzoff, 2004). That is, only when infants are able to re-identify an object, which disappeared and reappeared, as the same are they able to derive object permanence. Once the concept of permanence is developed it is then used to interpret events visible and occluded (Moore & Metlzoff, 2008). Thus, under the terms of the identity theory, object identity precedes object permanence. This implies that object permanence is not innate but rather develops during infancy out of a prior understanding of object identity (Meltzoff & Moore, 1998). Instead of possessing object permanence infants start out with what the authors call 'representational persistence'. That is, representations of objects persist and are accessible even when the object is absent from the perceptual field. In contrast to object permanence, which concerns the continued existence of a physical object in the external world, representational persistence implies that such understanding is nonessential for representations to exist in mind (Meltzoff & Moore, 1998). In other words, infants are able to possess a permanent inner image of an object without the assumption that this object persists in the environment (Meltzoff & Moore, 1998). Thus, with regard to occlusion events, infants do not necessarily expect the objects they observed disappearing behind an occluder to exist at any position thereafter.

Representational persistence derives from an evolutionary preparedness to represent and interact with objects (steady-state representations). Infants are apt to perceive middle-sized objects that comply with the inertia principle (i.e. stationary objects remain on their position and objects in motion pursue the initiated track). This capacity allows setting up representations of objects and events from perception alone (Meltzoff & Moore, 1998). In addition, representational persistence facilitates the determination of how many objects are encountered and if the same or different objects are involved. Hence, once object representations are established the question of identity arises. Meltzoff and Moore (1998, 2001) proceed on the assumption that the primary criteria for identity (also for numerical identity) are spatiotemporal ones. Specifically, such determinants include location for stationary objects and trajectory for moving entities. In their view infants interpret occlusion events based on an object's trajectory. The authors propose that infants are able to infer the initiated path of an object. In relation to occlusion events this again implies that infants anticipate where and when the object will appear on the other side of the screen. The entity that dissolves behind the occluder on one side and emerges on the other side is perceived as one if the visible trajectory is the same (Meltzoff & Moore, 1998).

Even though Meltzoff and Moore (1998, 2001) represent the view that numerical identity is determined by spatiotemporal information, the authors still do not think that features are completely irrelevant in this process. Around 5 months of age infants make additional use of qualitative criteria in form of functional and featural object properties. At this point the goal is to combine these different parts of information about a perceived object to set up a representation of its identity. The following general model on object identity can be taken from this (Figure 5). Every time infants encounter an object in the visual field and have to make a decision on its identity they compare the discovered entity to already existing stead-state representations. If a match exists between a steady-state representation and the detected object, the object is considered identical to the represented one. A new representation is established in case of a mismatch (see Meltzoff & Moore, 1998 or 2001 for a detailed description).

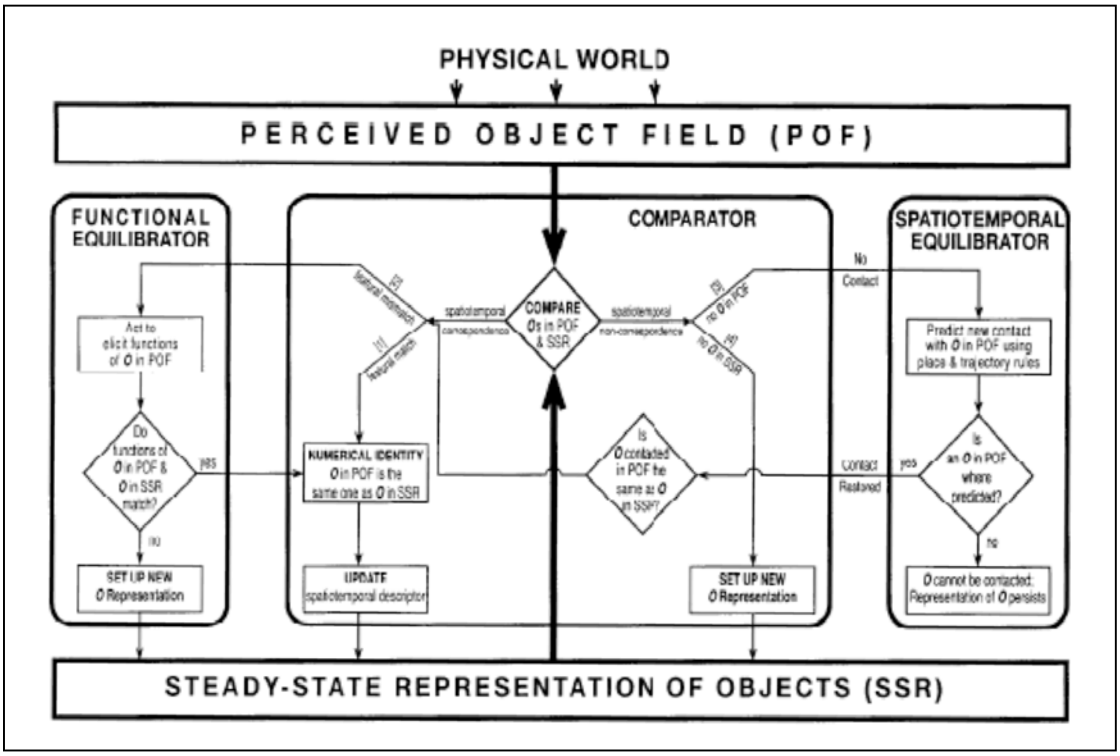

Figure 5. Model on how infants determine numerical according to the Identity Theory by Meltzoff & Moore (1998). The bold boxes indicate the five major components.

Method

The identity theory draws on conclusions from studies dealing with deferred imitation and manual search (e.g. Meltzoff & Moore, 1992; Moore & Meltzoff, 2008). The task in the manual search paradigm was to remove a screen in order to retrieve an object after watching the occluder move in front of the object in question. Two conditions were compared, one in which the object was partially visible and another where the object was completely hidden. The results showed that infants by the end of 8 months age indeed uncovered the object when partly occluded by removing the screen. However, same aged infants did not search for the object when it was completely occluded. This effect remained even in case another perceptual (auditory) cue to the object's hiding location was given (Moore & Meltzoff, 2008). Only at 10 months of age were infants able to make use of this hint. The authors concluded that partial occlusions help infants in learning about total occlusions and in establishing an identity of an object. Unless this can be done reappearing objects will be understood as new and different. Partial occlusion teaches infants through the spatial identity criterion (i.e. the location of disappearance and reappearance is the same continuously existing place) that the object continues to exit in a particular hidden location (Meltzoff & Moore, 1998). Thus, infants experience that the object continues to reside at that invisible place in the disappearance event.

Studies that look at deferred imitation are usually concerned with memory capacities of infants. Meltzoff and Moore (1992), however claim that deferred imitation[13] is not only a measure to test memory abilities but it also indicates whether they possess rules of object identity When used as a dependent variable, this kind of imitation behavior was taken as evidence that infants are able to represent actions that are no longer visible as well as people when they become unseen (Meltzoff & Moore, 1992). The authors concluded that identity plays a fundamental role in young infants' understanding about people and their actions. They further suggested that imitation subserves the identification of people by verifying their identity. Hence, imitation bears upon the object concept in a broader sense (Meltzoff & Moore, 1992).

Another theoretical formulation related to the importance of the people concept is the Human-first Hypothesis by Bonatti et al. (2002), which the following paragraph encapsulates.

2.6 The Human-first Hypothesis

Theory

Even though Bonatti et al.'s (2002) theoretical approach describes no comprehensive theory of the development of individuation, it still yields an explanatory framework for their results, which are hard to integrate in one of the existing models. Only Xu's theory on different kind of information meets this requirement. Bonatti et al.'s (2002) proposal of the Human-first Hypothesis is based

[13] This describes infants' ability to re-enact a behavior previously observed without prior engagement in the behavior and without the presence of the initial model.

on the assumption that objects belonging to ones own species are of particular importance. Hence, the authors argue that 10-month-old infants are able to use property information for object individuation when it involves typical characteristics for members of their own species. Category specific attributes are thought to enable the discrimination of various kinds. The reason for this is seen in the fundamental importance of identifying and telling member of ones species from other kinds of objects in the environment apart. In order to do so, Bonatti et al. (2002) speculate that humans are endowed with mechanisms for detecting human properties such as face and body schema (property method). To promote this presumption, Bonatti et al. (2002) draw on evidence from brain research showing that dedicated cerebral tissue handles these properties and that members of our own species, animals, and other objects are processed in different brain areas (e.g., Bertenthal et al., 1987; Kanwisher et al., 1999; Martin et al., 1996). In addition, work on infants' ability to discriminate properties suggests that complex features are singled out from early on (Bertenthal et al., 1985; Morton & Johnson, 1991; Meltzoff & Kuhl, 1994). Thereby, infants go beyond pure discrimination. They also apply different principles to various kinds of objects and such being the case, their expectations of the kinds of objects surrounding them differ (Bonatti et al., 2002). As a result, the Human-first Hypothesis claims that these cognitive mechanisms make individuation of humanlike objects in young infants possible. Due to an early representation of humans, animals, and inanimate objects, infants can use the properties of conspecifics to keep them separate from other objects (Bonatti et al., 2002). Whereas Xu and Carey (1996) claimed that infants younger than 12 months of age possess only the general sortal "physical object", Bonatti et al. (2002) in contrast suggest that at least 10-month-old infants have a more extensive knowledge of sortals.

Method

Bonatti et al. (2002) tested this prediction in a series of studies implementing Xu and Carey's (1996) event-mapping task with 10- and 12-month-old infants (cf., Chapter 2.1). In contrast, however, Bonatti et al's (2002) stimuli consisted of dolls with realistic human faces and objects deprived of humanlike features (Bonatti et al., 2002). During familiarization a doll head and an inanimate object emerged from and vanished behind an occluder interchangeably. Infants looked longer at the one-object display compared to the two-object display when the occluder was removed. The results indicated successful object individuation by 10 months of age. Thus, infants younger than 12 months were capable individuating diverse object kinds by means of their properties as long as they specified characteristics of conspecifics. When exchanged with geometric shapes infants failed to apply the property method. In addition the humanlike objects had to be contrasted with other non-human ones (animal or inanimate objects) in order for infants to of establish a mental model of two objects and display the effect in test. Under circumstances where all of the objects had humanlike features 10-month-olds were unsuccessful. Taken together, the findings speak for the Human-first Hypothesis providing evidence that infants are sufficient in making use of properties common to humans for object individuation. Theoretically, Bonatti et al., (2002) took these results as evidence for the concept human being to be the underlying sortal rather than physical object, because 10-month-old infants seem to have more knowledge than the Object-first Hypothesis suggested. Consequently, the Human-first Hypothesis speaks against the claim of the Object-first Hypothesis that infants under the first year are unable to identify object on the basis of non-spatiotemporal properties. For this reason the Human-first Hypothesis lines up with the event categorization approach in granting infants more proficiencies.

The Human-first Hypothesis ends the chapter on theoretical and methodological approaches concerned with the development of object individuation. Within this area of investigation researchers came to partly conflicting results and ideas explaining how this development occurs and what object properties infants include in their judgment. How can these be theoretically reconciled?

2.7 Resolution of Disputes

This section attempts to specify overlaps und contrasts of the particular theories presented in the last chapter with the purpose to find a common ground for the present work.

Xu and Carey (1996) explored when and on what basis infants comprehend the existence as well as the number of objects behind a screen introducing infants to an event-mapping task. In a typical experiment, infants were habituated to sequences in which two objects, differing in their perceptual properties and in their categorical kind, were taken from and then replaced behind an occluder one at a time. Following these events, the occluding screen was removed to reveal either one object (unexpected outcome) or both objects (expected outcome). Under conditions of event-mapping (see p. 25) only 12-month-old infants showed surprise when one object was visible in the outcome display. The authors concluded that the failure to individuate objects on the basis of property/ kind information at a younger age results from an inability to represent and use this information and formulated the Object-first Hypothesis.

Although the negative finding, Xu and Carey obtained with 10-month-old infants, has been confirmed in additional experiments (e.g. Van de Walle et al., 2000; Wilcox & Baillargeon, 1998; Wilcox & Chapa, 2002, 2004; Wilcox et al., 2003), their interpretation of this finding has been questioned. Researchers who applied simpler event-monitoring tasks to investigate the use of featural information in individuation cast doubts upon the conclusion that infants under the age of 12 months incorrectly interpret the different-object occlusion events (Kaldy & Leslie, 2003; Needham & Baillargeon, 2000; Wilcox & Baillargeon, 1998 a, b). Following these authors, the occlusion task carried out by Xu and Carey (1996) was too demanding to test this ability at the younger age, because infants had to compare the representation of an event that contained an occluder with the representation of an event in which the occluder was missing. Thus, Wilcox and Baillargeon (1998b) as well as their colleagues made task difficulties responsible for the failure of the 10-month-old infants. In their view, instead of a conceptual deficit at that age, event-mapping hinders younger infants to succeed. That is because it involves the representation of the familiarization trials as an event and the evaluation of its progress in test trials (Wilcox & Chapa, 2002). In studies in which infants were required to monitor one single continuous event only they showed the ability to individuate before they completed the first year of life. Recent evidence from studies by Kaldy and Leslie (2003) supports this objection. They provided evidence that 9-month-olds exert feature information (i.e. shape) to individuate and identify objects. The more over, infants as young as 3 months utilize size to detect discrepancies between a hidden object and its occluding screen (Aguiar & Baillargeon, 2002; Baillargeon & Brueckner, 2000). Shape is in addition to size used at 4.5 months of age (Spelke et al., 1992; Wilcox, 1999), texture by 7.5 months, and color by 11.5 months (Wilcox, 1999). Thus, when the amount of information the infants need to include in their representation of the occlusion situation is reduced infants make correct inferences about various object features that are partially or completely hidden behind an occluding screen (Wilcox & Baillargeon, 1998b). Therefore, event-monitoring tasks appear to be especially suitable for younger infants. The underlying account of this research is that infants group physical events into categories such as occlusion, containment, and support and then access their knowledge of the category selected (Baillageon, 1995, 2000). This knowledge specifies the variables identified as relevant to that category and determines which are included in the event representation. By evaluating these variable (e.g. size, object shape, pattern, or color) infants are able to detect violations of their expectations. Hence, the construction of event categories leads to the perception of the event as a whole without necessarily attending to the particular objects that are part of it (Baillargeon, 2004a; Baillargeon & Wang, 2002; Mandler, 2000).

One problem with some event-monitoring tasks, however, is the presence of unintended spatiotemporal information in the paradigm, which nevertheless refers to the number of objects. For instance, when infants look longer in the narrow-wide screen experiments realizing that the combined width of the objects exceeds the size of the narrow occluder, the surprise might be based on the spatiotemporal premise that two distinct solid objects cannot occupy the same space at the same time. This interpretation would speak for the use of spatiotemporal knowledge instead of featural information. Xu et al. (2001) provided additional alternative explanations for the results obtained with the event-monitoring paradigm. For instance, they explained the findings of Wilcox and Baillargeon's (1998b) narrow/ wide screen experiments with the tunnel effect (Burke, 1952; see p. 16 for explanation). Based on this phenomenon, infants might have interpreted the ongoing in the narrow-screen event as a box turning into a ball behind the screen. The reason for this was that the narrow screen provided unambiguous and strong spatiotemporal evidence for a single object (Xu, 2003). In contrast, infant's percept was not influenced by spatiotemporal information in the wide-screen condition. On this alternative account, 4.5-month-old infants looked longer at the narrow-screen event because they found it interesting or anomalous that the object with box properties turned into an object with ball attributes during occlusion. This interpretation is supported by data from adults who were asked how they apprehended the displays used in Wilcox and Baillargeon's (1998b) experiment

(Xu et al., 2001). The results indicate that in the narrow-screen event adults either did not notice anything impossible or they described the event as an object changing it properties as predicted by the literature on the tunnel effect (Xu et al., 2001). Furthermore, even though Wilcox's (1999) work showed that infants starting at age 4.5 months detect property changes in size shape, surface pattern, and color, "the longer looking in these experiments reflected which property changes were salient and interesting to the infants, but it did not bear on the question whether infants established a representation of two distinct objects behind the occluder using perceptual property differences (Xu, 2003, p. 178)." According to Xu (2003), this issue can only be addressed with an experimental method, which presents one- and two-object test displays directly to infants.

Although the tunnel effect can elucidate the narrow/wide screen experiments, it does not account for the single-trajectory experiments (Wilcox & Baillargeon, 1998b, Experiments 8). These studies provide evidence that infants could show their ability to use perceptual property or kind information for object individuation at an earlier age, when information-processing demands are reduced by using simple geometric forms as opposed to more complex multi-parted functional objects and by applying a less complicated experimental procedure with no reversal of the objects along their path of motion (Xu, 2003). What leads to this earlier success in Wilcox and Baillargeon's (1998b) studies? In her analysis of the factors that influenced the performance of infants, Xu (2003) argues that the difference in methodology might not be as critical as proposed by Baillargeon and her colleagues. After all, manual search tasks such as the one employed by Van de Walle et al. (2000) found the same developmental shift as Xu and Carey (1996) who used a violation-of-expectation looking time measure. Further, the complexity of the objects is unlikely to be responsible for it, because even when the procedure of Xu and Carey (1996) was implemented with simple objects (e.g., box and cylinder), Bonatti et al. (2002) replicated the failure at 10 months. A long these lines, Bonatti et al. (2002) objected that high task demands alone account for the failure at 10 months of age. In their studies infants succeeded in an event-mapping task with complex stimuli whereas they failed when provided with simple geometric forms that are less complex. Therefore, they came to the conclusion that certain objects are special in an infant's world and hence their properties are available early on for object individuation (Bonatti et al., 2002). At the same time could this familiarity be the reason why this might not be a complex task for younger infants and thus solved earlier. This however, remains an open question for further research.

Taken together, Xu (2003) arrived at the conclusion that the inconsistency of the results originated from the complexity of the procedure introduced. Confirming evidence for this resume comes from Xu and Baker’s (2005) work in which the authors tested whether 10-month-old infants searched more persistently in a manual-search task after retrieving an object that was different from the original object (switch trials) than after retrieving the original object (no-switch trials). As predicted, infants used the differences between a toy car and a toy duck to conclude that two distinct objects were inside the box. As a result they searched more persistently on the switch trials compared to the no-switch trials. From these results it could be concluded that the complexity of the procedure was likely to be responsible for the success or failure at different age groups in various studies. Indeed, infants succeed in event-mapping tasks at a younger age when the events are pared down so that the object on each side of the screen present a single, left-right trajectory. Infants’ performance is deteriorated if one or both of the objects undergo one or more reversals (Wilcox & Baillaregon, 1998b). Hence, even younger infants can show their ability to use featural information under conditions where complexity is reduced. Instead, when information-processing demands are high, infants draw upon kind representations. The connection between higher information-processing demands and kind representations can thus be summarized as follows:

> *“In this view, the relatively late success in Xu and Carey (1996) and Van de Walle et al. (2000) may reflect the emergence of kind representations whereas the basis of the relatively early success in Wilcox and Baillargeon (1998b) may reflect the use of perceptual property representations (Xu, 2003, p. 179).”*

Xu (2007) represents this point of view also in her further developed Theory of Different Kind of Information. According to this approach, the relative strength of the various sources of information, which are available for object individuation, can account for the observed differences in infants’ performance (Xu, 2007). Thus, the simplified tasks, in which property information may be the only source of evidence available, might tap on an early sensitivity to use featural information, hence, producing evidence for the usage of property information. On the other hand, even though the more complex tasks are designed in a way to exclude spatiotemporal information, it might be that younger infants posit one object with changing properties. In this case spatiotemporal information might override property information just like in the perceptual phenomena of apparent motion or the tunnel effect. Hence, it is not until 12 months of age when infants over come the strong spatiotemporal evidence for one object and represent two objects with the aid of the developing sortal concepts (Xu, 2007).

Similarly to Xu's theory of different kinds of information as well as the Object-first Hypothesis, the object indexing theory proceeds on the assumption that infants at first dispose of more general knowledge and conceptions about objects in their environment. It is not until later that infants develop more complex and detailed object concepts, which include information about properties and kind. In contrast to these theories, Leslie and colleagues hold other mechanisms accountable for this development. The key construct of the object indexing theory is, as its name implies, the object index – a mental finger that points at an object in the world and allows rapid access to the object and its descriptive information. Hence, an index forms the core of the object representation that an infant constructs in working memory while attending to a physical object. This allows tracking it as it moves even if occluded in the course of it (Leslie et al., 1998; Scholl & Leslie, 1999). Applied to Xu and Carey's (1996) results, the development of feature binding is exemplified. In terms of the object-indexing framework, infants' performance at 10 months of age reflects 'feature-blind object indexing' (Scholl & Leslie, 1999, p. 56). This entails that 10-month-old infants infer the existence of two objects only on the basis of spatiotemporal information. The simultaneous observation of both objects in two separate locations at the beginning of the familiarization phase leads to the assignment of two object indexes (Scholl & Leslie, 1999). Because these indexes stick to the objects in and out of sight infants track the objects individually and expect two. Therefore, infants showed increased attention to the one-object outcome in this condition. Ten-month-old infants failed to individuate, however, when both objects were not simultaneously visible in different locations. This means that despite distinct property/ kind condition the object system did not track the existence of the second object (Scholl & Leslie, 1999). The reason for this is that only a single index was assigned to the objects. As the first object emerged from behind the occluder an index is designated to it. The index then tracks the object and continues to point to it when it returns behind the screen. When the second object appears thereafter the ‘feature-blind system’ treats it as the originally indexed object (Scholl & Leslie, 1999). Hence, no additional new index is established for the second object but rather the old index is reassigned. Therefore both objects are tracked by the same index suggesting one object. Thus, even under circumstances in which the second object differs in its features and is of a discriminative kind the indexing system cannot track it without contradicting spatiotemporal information. It is not until the feature-driven indexing develops around 12 months of age that featural variations drive index assignment in situations where spatiotemporal information is ambiguous or absent. In such events the presence of property information is registered and stored on a feature map. Novel features on the feature map indicate a distinct object. Due to this developmental change 12-month-old infants conclude “objecthood” from both sorts of information (Scholl & Leslie, 1999). This explains why infants succeed in the spatiotemporal condition but fail in the property/ kind one in Xu and Carey’s (1996) experiments. However, Xu (2007) points out that the task in object identification studies is to bind object features to locations. Therefore, the number of objects is kept constant. This implicates that infants are not directly asked whether they expect one or two object in an event. In addition, this account cannot elucidate the results by Bonatti et al. (2002) in that 10-month-old infants seem to attribute two indexes when humanlike and non-humanlike are contrasted even in the absence of spatiotemporal cues. In order to explain the results the indexing theory would have to make special provisions for systems that treat members of the same species as special objects (Bonatti et al., 2002). Nevertheless, the object-indexing framework contributes an important conceptual distinction between object individuation and object identification in addition to offering an interesting approach for explaining the development of object individuation and its underlying mechanisms.

The identity theory adopts the primacy of spatiotemporal information in accord with the object indexing theory, the Object-first Hypothesis, and the theory of different kind of information. However, concerning individuation on the basis of the difference in properties Meltzoff and Moore (1992, 1998, 2001) take the same view as Baillargeon and Wilcox (1998b). They state that featural information plays an important role for object individuation even during the first half of the first year of life. The more over similarly to the Human-first Hypothesis the identity theory integrates a special treatment of humanlike objects through the inclusion of human beings as objects in their theoretical reflections. In addition, the theory incorporates well the distinction between object identification and object individuation as proposed by Leslie et al. (1998). Besides these numerous overlaps Meltzoff and Moore's (1992, 1998, 2001) model differs entirely from all the others in the meaning they ascribed to object permanence. They proposed that infants are evolutionarily prepared to represent objects without the understanding of object permanence. Object identity is a prerequisite for object permanence in their view. According to this are infants able to represent objects in their mind but at the same time they have no knowledge about the objects' existence in the world (Meltzoff and Moore, 1992, 1998, 2001). Even though Meltzoff and Moore's discussions are well argued and their theory is able to and reinterpret empirical findings such as the draw bridge results by Baillargeon (1987) many results cannot be accounted for without the ability to perceive objects as permanent (e.g., Baillargeon & DeVos, 1991; Arguiar & Baillargeon, 2002). Thus, it seems difficult to acknowledge the theory as a broad and general account (Krojgaard, 2002).

2.8 Summary

The previous chapter brings home the message that despite a vast number of studies, research has not yet definitive clarified to what extent the infantile object concept embeds knowledge about possible and impossible object transformations. Even though today most researchers agree that spatiotemporal information has an early and superior relevance in the setup of distinct object representations, disagreement prevails concerning the application of featural or kind information, respectively.

Only Xu's Theory of Different Kinds of Information is able to combine the different lines of empirical work concentrating on the development of object individuation. Xu (2007) distinguishes between various kinds of sortals such as physical object, person, and basic-level objects, which infants represent at different times during the first year of life. This growing understanding correlates with infants' performance in object individuation tasks. In connection with this, their proficiency depends on information processing demands and on what information a paradigm presents. Based on a large number of studies, it seems undoubtedly that younger infants are well capable of making use of featural information to interpret occlusion events with different objects involved. Infants' ability to use this type of reference can just be observed, though, under conditions where they cannot rely on spatiotemporal information (i.e., there is only one trajectory reversal) and property information is the only evident source of information available (Xu, 2007). However, the environment in which we grow up offers a rich array of information providing infants with the most complex task. Under such conditions it is not until 12-month of age that infants make use of adult-like representations resulting in adult-like reactions (Xu, 2007). Thus, when interested in infants' apprehension of the number of objects in an event Xu and Carey's (1996) original paradigm seems to be the most direct one to investigate this matter.

Even so, up to now only static object features have been considered within the scope of this object individuation task. This is striking since events are dynamic in principle, which means that the activities constituting an event are carried out in a particular order governed by causal and conventional relations. Further, research on motion perception, biological motion, categorization, and agency suggests that motion information plays a crucial role in early cognitive development. According to work in these areas, motion gives rise to an understanding of goals, intentions, and psychological causes – competencies which infants show during the first year of life. Still the influence of dynamic characteristics has not been taken into account in the field of object individuation. However, conceptual event knowledge should include the comprehension of dynamic aspects the kinds of objects engage in and the kinds of actions that bind events together. One form of early knowledge that is used as particular source of dynamic information is the manner in which objects engage in self-motion (Mandler, 2004). Although there exists a remarkable amount of research on infants' inferences about self-propelled motion, contingent motion, and agent-patient roles, this research has typically been carried out outside the context of objects associated with these activities (e.g., Gergely & Csibra, 1994; Rochat et al., 1997; Schlottmann & Surian, 1999). The next chapter illustrates the role motion plays in the formation of concepts about object kind and how children come to understand the distinction between animate being and inanimate object.

CHAPTER 3

MOTION INFORMATION AS KIND INFORMATION

Human infants have been found to be sensitive to motion. Numerous studies on infant motion perception has shown that infants detect motion information readily even when their visual activity for static displays is still rather low. Infants not only attend to motion but also use corresponding information to make inferences about the surrounding world (Banks & Salapatek, 1981; Gibson, 1987; Gibson & Gibson, 1991). They both use and depend on motion information provided to specify the nature and properties of objects (Haith & Campos, 1977; Freedland & Dannemiller, 1987).

The following chapter will elucidate that motion information not only is a highly salient and crucial factor when perceiving objects but also has an essential impact on the establishment of object concepts. After a brief outline of the influence motion information has on object perception in general, the second part of the chapter will describe the impact of motion as domain-specific knowledge on the formation of object concepts.

3.1 Motion Perception in Early Childhood

Information concerning movement takes up a central role in object perception during infancy (Bertenthal, 1993; Burnham, 1987; Kellman, 1984; Slater, 1989). Since motion information is only evident when something moves, it relies on objects for its perceptual manifestation (Burnham, 1987). Moving objects or moving object parts are highly captive and attract infants' attention from early on (Gibson, 1969). For instance, newborn infants are already able to discriminate between static and dynamic displays. They clearly prefer to fixate moving stimuli over stationary ones (Burnham, 1987; Slater, 1989). Between 7 and 21 weeks of age infants will pick out a moving object among stationary entities and look significantly longer at it (Dannemiller, 2000). From birth on, infants have the ability to perceive various types of movement such as lateral, approaching, and receding motion (Burnham, 1987). By

8 weeks of age infants differentiate rotating objects (Burnham & Day, 1979) and track faster moving objects better than objects in slow motion (Burnham & Dickinson, 1981). Infants as young as 4 months of age distinguish biological from mechanical motion (Bertenthal, Profitt, & Cutting, 1984) and 5-month-olds discriminate between rigid and non-rigid motion transformations (Gibson et al., 1978). Due to the presence of these very early abilities it seems like there are innate structures for the registration of movement. Nevertheless, infants' processing abilities have first been described as limited, and movement information has been made accountable for suppressing object perception in young infants (Bower, 1971). Meanwhile this claim has been rejected due to studies that provided evidence that motion information facilitates not only the detection of objects over a distance but also the perception of object features. Burnham and Day (1979) showed that infants younger than 20 weeks are able to perceive the color and shape of objects rotating in various ways. Hartlep (1979) found that 11-week-old infants looked longer at a rotating cube than at a rotating sphere. Thus, provided that the movement is neither too complicated nor too fast, it facilitates the perception of the structure of certain types of objects (Burnham, 1987; Owsley, 1984; Ruff, 1982). Supporting this claim, Kellman and Spelke (1983) as well as Kellman, Spelke, and Short (1986) reported that 4-month-old infants perceived a partly occluded object only as whole when its ends moved in a common translation behind the occluder[14]. Infants did not conclude that there was one object involved when its perceptible parts were stationary. Neither did infants make the inference of one object upon color or forms of surfaces (Kellman & Spelke, 1983). This suggests that infants interpret object unity when two surfaces undergo a common rigid motion. Kellman (1993) takes these results as evidence for the assumption that motion information is fundamental for the development of perception. According to his view, abilities that are based on information given by spatiotemporal changes (kinematic information) form the foundation for an important contact with the environment in the first months of life (see also Arterberry, Craton, & Yonas, 1993 as well as Burnham, 1987). Thus, movement is a dominating stimulus that takes a priority role in

[14] The general method in these experiments was to habituate infants to an occlusion display in which the center of an object was hidden behind a nearer object. In one condition the two visible parts of the object underwent common motion. Infants' perception of object unity was then tested by presenting a display with two separate pieces (broken rod) and one with a single, connected object (complete rod) shown on alternating trials (Kellman & Spelke, 1983). This general method was additionally used to test a variety of relationships between the two unblanked portions such as alignment of edges or similarity of color and lightness.

processing. Additionally, motion information is relevant for the early perception of particular characteristics of objects such as object unity and kind. Research on biological motion[15] has illustrated that motion is not only an object feature it self, but also matters for the definition of identity (e.g., Bertenthal et al., 1984; Butterworth, 1989; Johansson, 1973). In studies investigating an understanding of biological motion infants are presented with displays containing point light figures, which are created by placing small lights or reflective patches on characterizing locations of an object (e.g., head, shoulders, elbows, wrists, hip, and knees on a person) covered in black and moving in the dark (Maas, Johansson, & Jansson, 1971). Point light displays present motion patterns without providing the surface information. Hence, recognition of the figures is only possible if the perceiver is sensitive to the motion patterns viewed and is able to link then to a representation of the underlying form (Moore et al., 2007). Developmental research shows that 4- to 6-month-old infants are sensitive to biomechanical motion specified by point light displays (Butterworth, 1989). They discriminate a point light walker from an upside-down one as well as random movement with the same number of dots (Bertenthal et al., 1985). Temporally or spatially scrambled lights lead to a complete loss of the perceptual effect. This suggests that the motion information is only carried in the dynamic transitions of coherent moving presentations. Stationary point light displays are rarely recognized and therefore, do not transport the essential information (Bertenthal et al., 1987). Biological motion contains common properties expressed by spatiotemporal patterns. Early perception captures these transitions and assembles a unified manifestation of a matter in motion (Butterworth, 1989) to the extent that 6-month-old infants are able to categorized dynamic point-light displays showing only motions of animals and vehicles (Arterberry & Bornstein, 2002, see Chapter 3.3 for further specification).

As a result for the work at hand, it remains to be said that motion is an extremely salient source of information for object perception during infancy. On top of this, movement seems to be of great importance for early concept formation. The early sensitivity to biological motion sets an example for the influence of motion information on later conceptual development, for example in the way in which children conceive what is alive. Even children at 3–5 years of age make false attributions as to living and non-living things based on movement (e.g., clouds).

[15] Biological motion incorporates mechanically complex, animate movements as found in humans and animals (Butterworth, 1989). It expresses movement with ecological significance.

Research provides evidence that specific patterns and aspects of motion might play a role in the formation of object representations (Rakison & Poulin-Dubois, 2001). Thus, over the course of development infants attend selectively to the types of movement important for object identification and motion that is not. This distinction will be amplified in the next section.

3.2 Contribution of Motion to the Animate – Inanimate Distinction

Besides its impact on general object perception some aspects of motion appear to play an important role in characterizing animate and inanimate entities (e.g., Gelman & Spelke, 1981, Mandler, 1992; Pauen, 1999). Even though both types of object kinds share physical dimensions (e.g., size, shape, and color) and underlie similar physical transformations such as occlusion and displacement they greatly differ in various ways that are more or less obvious. For instance, they vary with respect to perceptual components and more importantly with regard to behavior as well as internal processes and structures (Gelman & Spelke, 1981; Rakison & Poulin-Dubois, 2001). Animate objects are self-propelled; they are able to initiate actions in a causal event, engage in interactions and act in goal-directed ways as agents. Inanimate objects, on the contrary, do not have the capacity to behave in self-initiated and intentional ways. Their transformations and functions depend mostly on outside sources and they can only be acted on. Continuing, animate objects have the ability to grow, perceive, think, incorporate knowledge and communicate these things whereas inanimate objects lack the capacity for any mental representation or process. Internal functions like motivation, learning, and emotion are only common to animates (Gelman & Spelke, 1981; Mandler, 2004; Rakison & Poulin-Dubois, 2001). Thus, in order to identify animate and inanimate objects we not only rely on physical properties, but also focus on actions and reactions of objects in relation to their environment. Although some of these concepts (e.g., non-observable biological information such as growth, reproduction, and theory of mind) are not comprehended and used for classification until the preschool age (Carey, 1985; Gelman, 1990; Gelman & Markman, 1986; Simons & Keil, 1995), infants already posses knowledge about core characteristics that determine living and non-living entities. What these entail is discussed next.

The foundation for the animate – inanimate distinction is mainly seen in the way motion is initiated (Gelman & Spelke, 1981; Mandler, 2004; Premack, 1990; Rakison & Poulin-Dubois, 2001). According to Premack (1990), infants classify the world in self-initiated objects, which set in motion and stop moving on their own and non-self-starting objects, which need an external cause in order to move. Premack’s theory describes an innately specified system, which interprets the change from rest to motion (or vice versa) as intentional and most movement changes of non-self-propelled objects as causal (Premack, 1990). This implies that biological patterns of motion activate infants’ perception of objects as agents with goals and desires (Premack, 1990). Thus, Premack’s view is consistent with a number of other approaches (e.g., Carey, 1985; Gelman & Spelke, 1981). Leslie’s theory of causality is likewise associated with these basic assumptions and discusses infants’ developing understanding of entities in terms of agency as well (Leslie, 1984, 1988, 1994, 1995). However, Leslie claims that agency is not tied to motion but rather the enduring properties of objects, which include mechanical, intentional, and cognitive characteristics. According to the author, specific modules cause infants to attend to and interpret certain events in certain ways.

Mandler (1992, 1998, 2000, 2003, 2004) linked different types of causality to different types of motion. In addition to Premacks’ (1990) differentiation, the investigator describes characteristic types of motion as basis for the formation of the global concepts animate and inanimate in early childhood. In her theory of conceptual development and the origins of thought, Mandler proceeds on the assumption that “people judge motion to be animate on the basis of perceptual characteristics which they are not aware” (Mandler, 1992, p. 593). Like Premack (1990), Mandler distinguishes between self-instigated and caused motion and states that infants differentiate early between entities that start moving without any force acting on it and something that is made to move (Mandler, 1992, 2004). Further, the author postulates three so-called *image-schemas*[16] for several motion attributes, which are sufficient for the primarily distinction of animates and inanimates during the first year of life. These are the origin of motion, the characteristics of the trajectory that moving

[16] According to Mandler (1992, 2004), image-schemas lie at the core of understanding. They represent foundational meaning elements used to form accessible concepts during the first year of life. Image-schemas result from an innate perceptual-analysis mechanism, a process in which the infant extracts and abstracts meaningful connections from perceptual input. That is a redescription of perceptual input into image-schema. These in turn provide the grounding for symbolic representations and concepts (Mandler, 1992, 2004).

objects follow, and the nature of motion contingency between objects (Figure 6). People and animals excel by moving self-propelled, following an irregular, non-linear trajectory, and by interacting over a distance (Mandler, 1992, 2004). In contrast, inanimate objects need an external source that sets them in motion. They typically pursue a linear path of motion, and are subject to the contact principle (Spelke, 1990). Based on such perceptual dynamic information infants acquire their first conceptual ideas concerning the essential characteristics of animates and inanimate objects through visual image-schema. The gradual acquisition of image schemas provides infants with knowledge about the "kinds of things" there are (Mandler & McDonough, 1993).

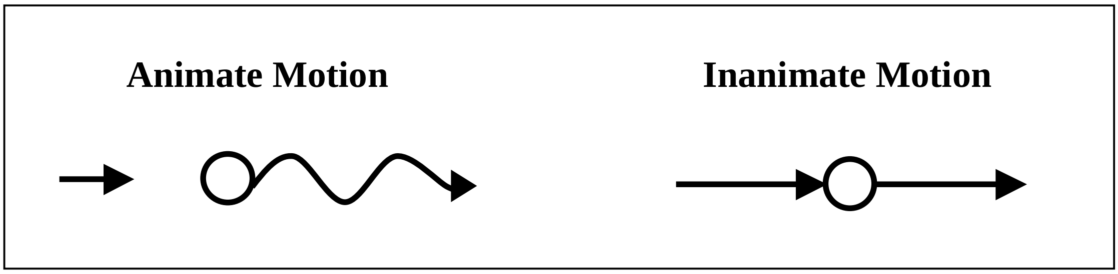

Figure 6: Motion image-schemas for animate (self-propelled, irregular path, induce action at a distance) and inanimate (caused motion, linear path, action from contact) objects. From Mandler (1992).

A number of studies provide empirical evidence for these assumptions. For instance, Poulin-Dubois and Shultz (1988) present findings showing that infants relate different types of onsets of motion with different types of objects. In their study the investigators demonstrate 8- and 13-month-olds novel events in which a female stranger and an inanimate object such as a ball or a chair moved without any external forces acting on them. The looking times for 8-month-old infants decreased significantly for both events. In contrast, 13-month-old infants looked only less in the stranger event. These results indicate that by 13 months of age infants know that inanimates are not capable of self-motion. A further test of infants' knowledge showing that the origins of movement differ across ontological categories came from a study by Spelke, Philips, and Woodward (1995). In the habituation phase 7-month-old infants saw an object move from the left side of a stage disappearing behind a central occluder. After a brief delay a second object that was partially visible on the right side of the occluder started to move following the same trajectory as the original object. The object vanished out of sight at the right side of the stage. During test infants were presented with a scene in which either two objects made contact before the second object began to move or had no contact before the second object started to move. Compared to a condition in which people instead of inanimate objects participated in the event, 7-month-old infants looked longer in the no contact condition. These findings demonstrate that 7-month-old infants expect inanimate objects to only move upon contact with another object. Further, launching events[17] look also at the form of causal action at a distance versus action from contact. Studies using this procedure demonstrate that infants at 9 to 10 months of age are able to discriminate between action from contact and action at a distance (e.g., Oakes & Cohen, 1990; Schlottmann & Surian, 1999). In the Schlottmann and Surian (1999) study infants were habituated to a red square moving non-rigidly toward a green square. At no time was there contact between the squares. Then one group of infants saw the green square starting to move before the red square came to a halt whereas another sample watched the green square beginning to move shortly after the red square had stopped. Infants who were familiarized to the first event dishabituated when the causal roles were reversed (the green square moved toward the red). These results suggest that infants at 9 months of age acknowledge the red square as an agent with the ability to cause action at a distance. Leslie (1984) as well as Pauen and Träuble (2004) offer additional empirical evidence for the association of causality with specific objects. According to Leslie's experiments (1984) infants between 4.5 and 7.5 months of age are able to perceive direct launching as events with internal structure in which one object causes another to move through collision. Pauen and Träuble (2004) examined young infants' causal thinking about the motions of animate and inanimate objects with a new paradigm. Infants were shown two objects involved in three events: In the first part they showed two motionless objects (a ball and a toy animal with a furry body and a face) side by side. In the next trial, an ambiguous[18] motion scene (familiarization phase), both objects were connected and moved together in a contingent self-propelled manner on an irregular path. In a final test trial, the animal and ball again were placed motionless in separate locations. Testing 7-

[17] In causal launching events the observer sees an event involving two objects. One object approaches a second object and causes it to move through collision. Thereby, spatial and temporal continuity act as cues to causality (e.g., Michotte, 1963).
[18] No external cause of the motion was identifiable.

month-old infants with this task, Pauen and Träuble (2004) were able to provide evidence for the use of previously acquired knowledge about causal behavior of animals and inanimate objects guiding infants' interpretation of an ambiguous sequence of moving objects. Seven-month-old infants looked longer at the animal in test compared to baseline, suggesting that, during familiarization, they parsed the ball and the animal into two separate objects and attributed the objects' common self-propelled motion to the animal. This assignment in turn suggests that 7-month-old infants appreciate that animals, but not artifacts, can move on their own. Thus, they look longer at objects for which they anticipate being the source of the motion and which they expect to start moving again (Markson & Spelke, 2006). At the same time these results provide suggestive evidence for an early sensitivity to the property of self-propelled motion. They accessorily suggest that 7-month-olds activate kind knowledge about static and dynamic attributes to form expectations regarding the future behaviors of objects involved in an event when provided with property/ feature information AND motion information at the same time. On top of this, these studies debilitate the objection of some researchers that infants possibly link self-induced motion in particular with humans. Markson and Spelke (2006) come to the same conclusion. In a set of studies they investigated 7-month-old infants' ability to learn about the self-propulsion of an object. Infants observed one wind-up toy animal move on its own and a second wind-up toy animal being moved by a hand. Thereafter, both wind-up toy animals were presented stationary side by side. In this stationary preference test infants looked reliably longer at the wind-up toy animal that previously moved on its own. These results suggests that infants not only learn and remember the mapping of objects and their motions but more importantly that they attribute self-propelled motion as a property to an object which in turn leads to their anticipation that this object starts moving again (Markson & Spelke, 2006). Infants did not show this preference when vehicles or nonsense objects undergoing translatory motion were used during familiarization. Thus, 7-month-old infants rapidly learn about self-propelled motion of an object with animal features and biological motion. Follow-up studies implementing the same method provided evidence however that learning about self-propelled motion is not restricted to the domain of animals (Shutts, Babocsai, Markson, & Spelke, 2004). These experiments speak for a rather broad ability to learn about self-propelled objects. Even when they observed novel toys, which lacked specific animate features or characteristic movements infants distinguished self-propelled from passive motion as long as the motion was more complex than rigid translation. Under these circumstances infants are capable to map self-propulsion to any object and treat it as animate even in the absence of biological motion and animate features (Shutts et al., 2004). Thus, together with previous findings these results demonstrate that infants differentiate between self-propelled and passive motion, associate self-propulsion with animate, expect animate but not inanimate objects to move on their own, and look longer at an object that had previously done so (Markson & Spelke, 2006; Leslie, 1988; Pauen & Träuble, 2004; Woodward, Phillips, & Spelke, 1993).

Even though other investigators agree with the domain-specific approach on motion as well as the importance of movement information for the animate-inanimate distinction, they albeit doubt that it is the only foundation for a knowledge-based differentiation of living and non-living things. For instance, Gelman (1990, 2002) claimed that motion alone is insufficient for the distinction because the information can be ambiguous. For example people can also be the recipient of actions. Thus, the author proposed that innate domain-specific causal principles (so-called innards principles for animates and external-agent principles for non-living objects) are crucial because they channel attention to information about the energy source and material of an object. These conceptual schemes help to direct and interpret information relevant to animates and inanimates. In a very recent study the assumption that children distinguish between internal and external properties and use this knowledge for inferences about an object’s behavior was supported. Newman et al. (2008) tested whether the appreciation that internal features are vital to how an animate being moves and behaves might be present in infancy. In their set of studies they familiarized 14-month-old infants with two animated cats that were identical in appearance except that one had a red stomach and a red hat and the other had a blue stomach and a blue hat. Each cat exhibited a different style of self-generated motion. Thereby they learned an association between feature color and a particular type of movement. Subsequent to this familiarization phase infants viewed a novel exemplar, which had the internal feature (stomach) similar to one cat and the external feature (hat) that the other cat signified. Infants looked significantly longer when the novel cat moved congruently with its external feature than when it moved matching its internal attribute (Newman et al., 2008). In a second experiment same aged infant were given an object choice that checked whether infants would prioritize internal features only when those features are a potential cause of the objects behavior. In this study infants were shown an animal-like toy with green hair on top and a white box inside. Upon pressing a button the toy started to shake and make a cooing sound. In test the experimenter offered two new toys, one with green hair on top and one with a white box inside. The presence of self-generated behaviors encouraged infants to focus on the importance of the internal feature and thus, they were more likely to choose the object with the same inside. Together, these results demonstrate that already at 14 months of age infants tend to associate an object's behavior with internal, rather than external features (Newman et al., 2008). However, as discussed by the authors these findings do not speak for explicit causal theories but rather suggest that infants might possess cognitive biases that prioritize certain features over others in certain situations. Rakison and Poulin-Dubois (2001) as well posit additional characteristics besides physical principles, which they count motion information among as part of the foundation of the animate-inanimate distinction[19]. These are purpose of action (goal-directed versus without aim) and influence of mental states (intentional versus accidental). Research by Gergely, Csibra, and their colleagues is in consent with Rakison and Poulin-Dubois' notion regarding the significance of goal-directedness as well as intentionality in defining an animate being[20] (see Csibra & Gergely, 1998, 2006 and Gergely, G. & Csibra, G., 2003 as an overview; Legerstee, 1992, 2001). However, their studies among others speak against Rakison and Poulin-Dubois' (2001, see also Rakison, 2006) hypothesis that physical and psychological characteristics of the animate-inanimate distinction are acquired in the form of a correlation between salient aspects of motion such as self-propulsion and smooth movement and obvious properties of objects (e.g., large moving parts). Gergely et al. (1995) for example used geometric forms as animate and inanimate entities, which had no conspicuous parts defining the two individually. Even without a correlation between object features and motion information these studies still showed that infants 9 and 12 months of age read the actions of computer-animated figures as rational

[19] In contrast to the accounts mentioned so far, Rakison and Poulin-Dubois (2001) take a domain-general stance toward explaining the development of animate and inanimate concepts, however. The authors reckon a sensitive perceptual system coupled with a domain-general associative learning mechanism as the underlying process of infants' ability to discriminate between living and non-living entities.

[20] Even though both attributes play a considerable role in distinguishing animates from inanimates and there has been a remarkable amount of investigations done on both topics, they will not be discussed in detail here, because for the work at hand the role of motion patterns (i.e., onset of motion, path of motion, and form of action cause) is implemented.

goal-directed behavior. This provides evidence that form and motion are not weighted equally. But what exactly constitutes the relation between form and motion? The following chapter will provide an overview of how form and motion might be associated.

3.3 Form – motion association

As noticed in previous chapters, research over the past decades has established that very young infants have the ability to discriminate a wide array of object properties under a variety of requirements. Such skills are not limited to basic low-level stimulus features but rather extend to complex characteristics that allow them to uniquely single out conspecifics (e.g., Bertenthal, Proffitt, Spetner, & Thomas, 1985; Morton & Johnson, 1991; Meltzoff & Kuhl, 1994). Furthermore, these abilities are not just perceptual. Infants know something about the objects that possess those properties. Not only are infants able to discriminate animate objects from inanimate ones (e.g., Meltzoff, 1995; Spelke, Phillips, & Woodward, 1995), or animals from artifacts (e.g., Mandler & McDonough, 1993, 1998), or intentional objects from non-intentional objects (Csibra, Gergely, Biro, Koos, & Brockbank, 1999), but they can also apply different psychological principles to the objects of such classes. Infants form specific expectations about the behavior of animate and intentional objects and have ideas of how to deal with the entities presented to them (e.g., Csibra et al., 1999; Mandler & McDonough, 1998; Premack, 1990; Premack & Premack, 1995; Premack & Premack, 1997; Woodward, 1998; Woodward & Sommerville, 2000). This raises the more general question of when in development we learn to combine form and motion information in order to class objects with animates or inanimates and reason about their behavior.

As elaborated in Chapter 3.1 researchers have shown that the early developing perceptual system processes both form and motion information (e.g., Kellman & Spelke, 1983; Jusczyk et al., 1999). Additionally, infants make inferences about causality, self-propelled motion, contingent motion, and agent-patient roles (e.g., Gergely & Csibra, 1994; Leslie & Keeble, 1987), which suggests a profound understanding of the kinds of objects that would engage in animate motion. One example for such specific knowledge is, that infants associate human form but not mechanical claws with deictic activities (Woodward, 1998). However, this does not mean that infants automatically associate the form of an object with its motion. Instead, it may well be that infants need to learn that a certain form connects with a particular motion. Arterberry and Bornstein (2002a) addressed the question of how form and motion are associated by investigating 3-, 6- and 9-month-old infants' categorization abilities of animals and vehicles based on static or dynamic attributes. They used a visual habituation paradigm in which infants had to either categorize static color images of animals and vehicles or dynamic point-light displays showing only motions of the same objects. Most animals engaged in a pendular motion shown when four legs are walking. The motion common to all the vehicles was a rotary motion emerging from rolling wheels. In order to distinguish between animate and inanimate motion infants had to understand that animals but not vehicles move using pendular motion. The findings showed that all ages not only categorized the static pictures, a replication and extension of previous research (Behl-Chada, 1996; Quinn and Eimas, 1996) but also distinguished between the different kinds of movement patterns illustrated by the point-light displays. In addition, Arterberry and Bornstein (2002b) implemented a transfer task that tested 6- and 9-month-old infants who were habituated to static pictures with dynamic point-light displays and vice versa. Here the task required infants to match motion as specified by point-light displays to appropriate forms depicted in static pictures. Longer looking toward the congruent motion or form indicated matching. Infants 9 months of age who were habituated to dynamic displays succeeded in making the transfer to static forms (see also Bertenthal et al., 1985). They failed, however, in mapping static images onto dynamic motion. These directional findings are in line with conclusions coming from research on infants' motion perception, namely motion affords advantages in perception. (e.g., Bertenthal, 1993; Burnham, 1987; Gibson, 1969; Kellman, 1984; Slater, 1989). Just as consistent with these findings is research showing that infants can construct form from motion. For instance, Arterberry & Yonas (2000) showed that shortly after birth 8-week-old infants discriminated between patterns of motion that carried information about the three-dimensional objects' shape. At the same time, the difference in transfer performance from form to motion and from motion to form reported by Arterberry and Bornstein (2002) speaks against associative learning of motion and form by mere attention to the conjunction between the two. In their study described above, form information did not activate motion information about the animate-inanimate distinction (Arterberry & Bornstein, 2002b). Besides there is considerable evidence that the encoding and/ or retaining correlations between motion and form do not develop earlier than the latter part of the first year of development. In one study Rakison and Poulin-Dubois (2002) habituated 10-, 14-, and 18-month-old infants to novel, computer-generated forms consisting of ovals, triangles and star-shapes moving across a screen on a rectilinear or a curvilinear path, respectively. Both the objects as whole entities as well as the single parts that comprised these objects moved in their own unique ways. In test infants saw once more the familiar event as well as new ones in which one of the object features (either the objects' parts, the objects' body, or the objects' path of motion) appeared in a novel combination. The results revealed that movement of the object parts as well as the overall object itself helped infants of all ages to attend to functionally relevant properties around the beginning of their second year. However, it was not until the age of 14 months that infants detected the correlations between an object's parts and its motion trajectory. At 18-months of age infants noted correlations between all three features (form, parts, and motion path) but only when the parts of the object moved (Rakison & Poulin-Dubois, 2002). These findings suggest that motion is crucial in the processing of novel objects moving in novel ways. The authors reasoned that motion captures infants' attention and directs it to the relevant information. Thus, the relation between moving parts and other dynamic properties can be discovered (Rakison & Poulin-Dubois, 2002). Even though the late success of detecting novel combinations in this study might be due to the usage of non-naturalistic and unfamiliar stimuli in a lab situation, which might have placed a greater information-processing burden on infants, research with real-life stimuli confirms that dynamic aspects are more impressive than static ones. Experimental evidence provided by Bahrick et al. (2002) supports the view that dynamic events capture more attention than static objects or even faces in the context of actions. As elaborated in Chapter 2, Baillargeon and her colleagues suggest that infants can group physical events into categories such as occlusion, containment and support and then use these categories to detect violations of their expectations by evaluating the size, substance or form of the objects (e.g., Baillargeon, et al., 1995; Baillargeon & Wang, 2002). According to this argument, event categories, which among other things are defined by motion patterns, are established prior to the analysis of the details of forms. Nevertheless, attention to the properties of objects (e.g., their size and shape) is required for successful performance. Thus, it seems like motion primes perception of form whereas form-motion correlations possibly have to be learned. The formation of appropriate associations may on the one hand be challenged in that motion events may be more enduring than the form of the objects seen in the events. On the other hand however, motion may channel attention to the objects or object parts engaged in the movement, respectively, which may foster learning and reasoning about them.

3.4 Summary

Taken together, this chapter on motion information demonstrates that infants are apt to perceive and reason about information concerning the movement of objects. Motion not only helps them to perceive unitary objects and events but it also leads to distinct inferences infants make about the objects around them. Further, infants' ability to connect motion with form enables them to establish knowledge about what is animate or inanimate. Theories on the animate-inanimate distinction point clearly out that motion plays an essential role in differentiating living and non-living objects. Each of the perspectives present physical, biological, and psychological attributes, which facilitate the development of knowledge concerning animates and inanimates. Gelman & Spelke (1981) provided a taxonomy of animate and inanimate features describing inner biological attributes on which the animate-inanimate distinction rests; Premack (1990) highlighted the role of self-propelled motion in the detection of intentionality; Leslie (1995) suggested that infants possess innate modules that interpret the actions of objects as mechanical, intentional, or cognitive; and Mandler (2004) provided a detailed developmental account of the role of motion as the foundation for early representations.

Perhaps the least ambiguous of all the motion characteristics displayed by different object kinds is that of self-propulsion or onset of motion. Only animals and people tend to move without some external physical cause (Premack, 1990; Markson & Spelke, 2006; Rakison & Poulin-Dubois, 2001). As Markson and Spelke (2006), Shuts et al. (2004), as well as Pauen and Träuble (2004) showed, infants use self-propulsion to establish representations of objects in their environment. For these reasons, the concept of animacy has far-reaching consequences for complex cognitive processes such as categorization (Mandler, 2004; Pauen, 2002), causality (Leslie, 1994; Woodward, Phillips, & Spelke, 1995), agency (Csibra & Gergely, 2006), or intentionality (Premack, 1990). However, the extent to which infants use motion to individuate objects and the role it plays through the course of the development of individuation processes remain to be studied. For these reasons, the following set of experiments investigates this topic.

III EMPIRICAL PART

CHAPTER 4

RESEARCH QUESTION AND STUDY APPROACH

4.1 Objectives

The major goal of the present work is to investigate the role of kind information in the construction of object concepts by asking whether domain-specific motion patterns have an impact on the process of individuation in early childhood. This is accomplished by linking findings from research on object individuation with the recent understanding of the role motion information plays in early knowledge acquisition. In previous chapters, the major theories concerning object individuation and early knowledge about motion were outlined and controversies regarding each theoretical account were pointed out.

Referring to the subject-matter of object individuation in early infancy as elaborated in Chapter 2, work by Aguiar & Baillargeon, (1999), Baillargeon and De Vos (1991), Spelke, Breinlinger, Macomber, & Jacobson (1992) as well as by others, indicated that infants as young as 2.5 months are able to reason about hidden objects and occlusion events. Quite a few studies conducted with only slightly older infants showed that infants can distinguish the number of objects previously hidden behind an occluding screen on the basis of their featural information (e.g. Baillargeon & Wilcox, 1998; Wilcox, Schweinle, & Chapa, 2003). This early ability is mainly based on tests including spatiotemporal information or research operating with event-monitoring tasks, in which the events during familiarization and test were in terms of occlusion internally consistent. In contrast, studies that use the same general technique (violation-of-expectation paradigm) but present an occlusion-event during familiarization and a non-occlusion event in test (event-mapping tasks), demonstrate the competence to individuate not until the end of the first year of life (Leslie et al., 1998; Wilcox & Baillargeon, 1998b; Xu, 2003; Xu & Carey, 1996). Researchers holding the view that infants possess the capacity to individuate object kinds from early on have criticized event-mapping tasks for the high demands they place on the infants' information processing. Whereas the just mentioned authors (e.g. Wilcox & Baillargeon, 1998b; Wilcox & Schweinle, 2002) concluded that the absence of individuation using property information cannot completely be ascribed to a general lack of specific concepts at a preverbal age, representatives of the Object-first Hypothesis assume that the earliest individuation capacities are based on spatiotemporal information instead of conceptual knowledge about underlying object characteristics (cf. Chapter 2). According to this position, young infants seem to possess the ability to individuate objects by means of spatiotemporal information but cannot make use of kind information. Results with 10-month-old infants support this assumption (Xu and Carey, 1996). However, as evident in the sections on motion information (cf. Chapter 3), infants are equipped with certain conceptual knowledge from early on. The results of Bonatti et al. (2002) are consistent with the conjecture that infants have more extensive kind knowledge than postulated by the Object-first Hypothesis. In their set of studies infants were capable of establishing different object representations by the kind information given (human being versus object) in an object individuation task similar to Xu and Carey's (1996). Thus, it seems plausible that infants under the age of 12 months are able to apply particular kind information that is embedded in their domain-specific knowledge repertoire concerning specific concepts (e.g., animate and inanimate). Motion patterns represent kind information of this sort.

The current work, therefore, hypothesizes that underlying conceptual knowledge about objects such as motion characteristics facilitates object individuation when made available. Motion attributes are so far an unexplored source of information that might contribute to the perception of individual objects and the establishment of object representations that are necessary to solve an individuation task. This idea is based on the assumption that motion plays a key role in object individuation. Although motion was part of the Xu and Carey's experiments, the movement was not appropriate for the kind membership of objects tested. All objects (e.g., a ball, truck, duck, and elephant) were moved in the same self-initiated manner following a linear path. Hence, they displayed ambiguous motion pattern that partly revealed animate characteristics (i.e. self-initiation), and partly inanimate characteristics (i.e. following a linear path). This will be different in the proposed set of experiments: Using an adapted version of the Xu and Carey (1996) paradigm, each object performs a motion typifying a specific object kind and thus, provides domain-specific cues. It is assumed that this enables infants to draw back on real-world knowledge about animate and inanimate objects, which they in turn can apply to the individuation task. Previous studies on infant categorization have shown that preverbal infants discriminate living and non-living objects (e.g., Mandler & McDonough, 1998; Pauen, 2002). Thereby conceptual knowledge is relevant in that it provides essential aspects about the underlying differences of distinct kinds of things. One type of information that infants base the animate-inanimate distinction on is the dissimilarity in movement, that is the difference between self-initiated motion following a non-linear path and externally induced motion following a linear path (see Mandler, 1992; 2004). In Mandler's view, infants hold the conceptual animate-inanimate distinction by the time they are 9 months old (Mandler & McDonough, 1993). Research by Pauen and her colleagues indicates that even 7-month-old infants already possess some knowledge about this distinguishing mark. The infants in their studies relate motion information with information about the appearance of objects (Pauen & Träuble, 2004). Thus, it is predicted that the manner of motion provides a conceptual foundation for a notion of kind (Mandler, 2004). Further arguments strengthening the idea that motion may play a crucial role for early conceptual representations can be found in the literature: As suggested by a number of studies on the role of motion in early infancy (see Chapter 3 for an overview) even very young infants discriminate biological from non-biological movement (Arterberry & Bornstein, 2001; Bertenthal et al., 1984). This work indicates, that by 3 months of age infants have adequate knowledge of the kind of motion objects engage in. There are several reasons that account for this early understanding. Not only are differences in biological and non-biological motion perceptually salient, they are also highly relevant for survival. Only if a given species can detect other living entities and distinguish them from non-living things, will it be able to pay special attention to these objects and respond adequately to their presence. Hence, it seems only natural that biological motion takes up important significance in brain processes (Beauchamp et al., 2003).

The aim of the planned set of studies is to illuminate how motion information contributes to and/or refines object individuation. Whereas the first set of studies uses natural looking material, hence providing appearance information about kind membership as well as motion information (in an domain-adequate combination), the second set of studies uses abstract figures, providing motion information without appearance information to determine the specific impact of motion on object individuation. The remarks stressed so far suggest that in the current work it can be taken for granted that infants have the competence to differentiate the motion acted out by the objects. Thereby it is assumed that infants are already able to combine knowledge about appearance and behavior of animate and inanimate objects, a process that should aid them in individuating object kinds.

4.2 Hypothesis

Following the paradigm originally introduced by Xu and Carey (1996), the present work tests whether infants are able to detect the number of objects involved in an occlusion event based on kind information. Specifically, the experiments examine infants' looking preference at displays containing one or two different objects after viewing an event in which these objects consecutively moved back and forth of a screen in their domain-specific way. According to Xu and Carey (1996), infants 12 months of age are able to individuate objects on the basis of property/ kind information. In their investigations, the older infants anticipated two objects behind the occluder and were surprised when only one object occurred past the screen's removal. Longer looking toward the one-object display was interpreted as indication of corresponding expectations. 10-month-old infants on the contrary failed to do so. In the research presented next, it is conjectured that 10-month-olds are able to set objects in an event-mapping task apart (cf. Xu and Carey, 1996) when the nature of the presented kind information bears upon important fundamental information (i.e. motion pattern) and the distinction of the objects' kind information indicates a clear difference (i.e. regarding self-generation, path of motion, or contact). If that is the case, then infants should solve Xu and Carey's 'sortal-task' (property/ kind condition, Experiment 2) before the end of the first year of life. Of course, infants would only be able to do so when they already make use of previously acquired knowledge about animate and inanimate objects in an object individuation task. After all, infants have no opportunity to learn this association during the task. If it is the case that infants individuate the two objects because of their particular domain adequate motion pattern, then infants should, the logic of the violation-of-expectation paradigm accordingly, show a preference for one object over two objects in test when corresponding information (self-initiation and path of motion) was given in motion trials (familiarization) beforehand. That implies the following primary hypothesis of the experiments:

Infants who saw an animate and an inanimate object repeatedly travel from behind a screen show a greater preference for a one-object display (unexpected outcome) than a two-objects display (expected outcome) in test compared to their initial looking pattern in baseline.

Thus, it is predicted that infants will individuate objects based on contrasting types of motion, a finding that would be consistent with Sharon and Wynn’s (1998) research on individuation of actions and Wilcox and Chapa’s (2004) research on the use of functional differences to individuate objects. Experiments 1 and 2 address this hypothesis employing the paradigm sketched out below.

4.3 Implementation of the Research Question

In order to elucidate the premise of this hypothesis a task was generated that allowed testing the influence of motion information on object individuation. The violation-of-expectation paradigm proved to be useful to determine whether infants are able to individuate objects (Baillargeon, 1998; Wilcox & Baillargeon, 1998b; Xu & Carey, 1996). According to Xu and Carey (1996), their event-mapping task admits the investigation of the role property/ kind information plays in infants’ object individuation capacity. Closely following the procedure described by the authors (cf. Xu & Carey, 1996, Experiment 2), infants are first familiarized with an event in which two different objects successively emerge from behind either side of a screen. During test trials, infants are presented with displays that comprise either one object (unexpected outcome) or both objects (expected outcome). Differing from the original study where objects showed uniform motion[21], the task to be used in the present context displays domain-specific motion patterns. Motion contains various types of information, which can be divided into path and manner information. Path information refers to the route an object takes when moving (i.e. from behind an occluder to the left side of a stage) such as depicted in the Xu and Carey experiments. Manner information on the contrary describes the way the object moves (e.g., Choi & Bowerman, 1991; Choi et al., 1999). Whereas path of motion provides location information, it is more likely that manner of motion can be used as an identifying feature of the object itself. In the current work manner information is made salient to activate conceptual knowledge about animates and inanimates in order to serves as kind information in the individuation task.

To find out whether infants deduce certain expectations from the additional kind information, revealed during the familiarization trials, looking times toward the outcome scenes are checked against initial looking preferences[22] at one-object versus two-object displays with the same objects used in test. Only if this comparison shows a significant shift in the expected direction (i.e. longer looking toward one object after familiarization) can one infer object individuation on the basis of property/ kind information that distinguished the objects. Xu and Carey (1996) as well as researchers who modeled experiments after theirs (e.g. Baillargeon & Wilcox, 1998b, Experiment 1 and 2; Bonatti et al., 2002; Surian et al., 2004) implemented this in a between subject-design. That is, they used separate groups when comparing the preference for looking between baseline and test trials. Unlike previous work, the present studies applied a within-subject design meaning the outcome displays are presented as baseline before the start of the familiarization phase within one single session. This change in method seemed necessary because some experiments detected a priori looking preferences for the two-object display whereas others did not (e.g., Surian et al., 2004). Using the same stimuli for baseline and test displays (and for the same subjects) guarantees that significant results supporting the initial hypothesis cannot be attributed to either differences in stimuli or a-priori group differences. Pauen and Träuble (2004) successfully worked with this within-subject testing method to

[21] During familiarization the objects in Xu and Carey's (1996) study were moved back and fourth on slightly visible sticks attached to the bottom of each object.
[22] In order to acquire a possible initial preference infants simply view the outcomes of the test trials without being exposed to any familiarization emergences before. This is referred to as baseline condition or baseline phase.

investigate knowledge-based reasoning. Their task was arranged in three separate scenes: A baseline scene (1) which was identical to a test scene (3) that examined the impact of a motion scene presented in second place (2). Testing 7-month-old infants, Pauen and Träuble provided evidence for the use of previously acquired knowledge about causal behavior of animals and inanimate objects guiding infants' interpretation of an ambiguous sequence of moving objects. The experiments to be described next combine aspects of the Xu and Carey procedure with the Pauen and Träuble task. More specifically, infants' preference for either one or two object displays was tested by comparing looking times during a baseline phase, which took place before the familiarization scenes with an occluder and a test phase that followed familiarization. Problematic with this approach is, however, that spatiotemporal information for two objects is given when presenting the two-object display which might result in a confounding of information available for infants to rely on. One might argue that the information provided by a within-subject baseline influences infants' reaction in test. Despite that possibility this type of design was preferred according to the reasons explained above. Due to the within-subject design in which a baseline is presented before familiarization the following experiments forego additional introductory trials.

In terms of the experimental presentation, Xu and Carey (1996) demonstrated the occlusion events live in a puppet stage and used an infant-controlled design. For the following set of studies a video presentation and a fixed-trial procedure[23] was chosen. Several reasons speak for this line of action: The first is to assure maximal standardization in that each infant views the same animate movement pattern. It would be extremely difficult to avoid variations and irregularities in a life display involving animate motion. Another reason for a film presentation is the reduction of spatiotemporal information available to influence infants' interpretation regarding the number of objects involved in the event. So if infants show a preference for one over two objects, it can be attributed to infants' knowledge about the kind of visual entities performing the movements. Thus, no additional information besides global level category membership (expressed by characteristic motion information) is supposed to be present. In addition, results offered by Seekircher (2007) support the assumption that infants of the tested age-range are able to extract information from a film presentation equally well as from a live demonstration. When demonstrated per video

[23] The fixed trial design was chosen in order to equate the task across subjects.

presentation how a certain part of an object functions, 12-month-old infants made use of the information illustrated in the movie. In a subsequent live completed categorization task with similar three-dimensional objects consisting of various functional partitions infants discriminated in accordance with the critical part shown in the films. The data of this study was comparable to results obtained by Träuble and Pauen (2006) who worked with the same material and a similar procedure with the only difference being the demonstration of the function of the critical part, which took place live (Seekircher, 2007). Not only did infants extract crucial pieces of information from video but also did they transfer newly acquired knowledge to a live task. Other studies conducted by Madole and Cohen (1995), Perone and Oakes (2006), as well as Mumme and Fernald (2003), showed that infants gather, process, and apply information from videos in a variety of contexts. Surian et al. (2004) further demonstrated that infants performed successful object individuation by utilizing a video technique. Based on these findings, it seems well justified to presume that infants of the tested age-range process information in similar ways when presented in the format of live and video displays.

The following chapters explain the design, the stimuli, the experimental setting, and the procedure of the experiments in more detail.

CHAPTER 5

METHODOLOGY AND PARADIGM

5.1 Subjects

Tested age groups

Since the goal of the present work was to provide evidence for object individuation on the basis of motion as kind information in a complex event-mapping individuation task (cf. Xu & Carey, 1996), 12- as well as 10-month-old infants were selected as suitable age groups. Xu & Carey found that 12- but not 10-month-old infants were capable of using differences in features and kinds to tell the number of objects involved in an occlusion event when keeping the movement patterns of both objects identical. The prediction in the following experiments is that both age groups are able to solve the given object individuation task if provided with information about different domain-specific motion of both objects. Thus, the sample of 12-month-old infants is supposed to replicate earlier findings using different stimuli and an adapted version of the original task whereas the group of 10-month-olds shall extend these results.

Recruitment

The studies took place in the infant laboratory of the Department for Developmental Studies at the University of Heidelberg. All infants were recruited by obtaining their birth record from town halls in Heidelberg, Dossenheim, and Eppelheim. Parents were contacted at first by mail and later by follow-up phone calls. Infants who participated in the studies came primarily from a Caucasian, middle-class background. The parents received a certificate including a picture of their child as well as information material describing research purposes and results of past studies as gratitude for their participation.

5.2 General Study Design

Equal numbers of infants participated in the following experiments. Infants were tested using a violation-of-expectation method to determine whether or not they are able to individuate objects by means of their different motion. Based on the arguments raised in Chapter 4.3 a 2 by 2 design with number of objects (one versus two) and trial (baseline versus test) as within-subject factors derived for testing the hypothesis independent of age. Trial duration and sequence of trials were fixed through out all five experiments. The order of outcomes (one-object display first (1_2) versus two-object display first (2_1))[24] and the kind of single object in the one-object displays (bunny/ ball in the one-object display versus tractor/ box in the one-object display) were counterbalanced across infants in each study. This results in four different versions of the movie each of which was presented to the same number of subjects.

5.3 Overview of the Stimuli

The stimulus material (Figure 2) for the following experiments consisted of film demonstrations, which were either animated graphic shots, involving a jumping rabbit and a rolling tractor, or PowerPoint-Presentations showing a square-shaped and a round geometric form moving in either animate (round) or inanimate (square-shaped) way. Thus, the objects differed in texture, shape, and color, as well as kind (animate-inanimate). In the animation appearance AND motion information identified kind membership, whereas movement information alone served this function in the PowerPoint-Presentations. Both entities as well as the occluder were featured against a white surface and background with the surrounding area being black.

Film animations

The animation films were produced with a Sony Camcorder including a Photoshot function to avoid the problem of adding a hand (a third object) with the two

[24] Each infant viewed one of two orders of outcomes 1212 or 2121 defining the order of the one- and two-object display as well as whether the task started out with the one- and two-object display.

target objects (compare to Surian et al., 2004). Pulling an invisible nylon string moved the inanimate object. The animate motion effects were generated by still photography of successive objects positions (i.e., placing the object against a board and moving it along the surface in the preferred pattern while taking shots with the camera using the Photoshot setup). After videotaping the scenes, the material was edited with Adobe Premier® a film-editing program[25] and thereafter the movies were burned on DVD for presentation.

PowerPoint-Presentations

The presentations for Experiments 2 were created with Microsoft Office PowerPoint®. The layout and content of the PowerPoint-Presentations was similar to the movies. In addition to the objects and the screen, two poles were inserted in the displays 6 cm to the left and the right of the occluder.

5.4 Experimental Setting and Technical Setup

The study took place in an experimental room holding a 203 cm by 203 cm screen. To ensure that there was little distraction from other parts of the room while this particular study took place, the experimenter drew two light blue curtains through the room and created a small room consisting of a screen, speakers, two cameras, a high chair and a table on which the beamer was installed (Figure 7). The projector stood across from the screen and was placed high enough behind the infant and the parent so that no shadows were projected onto the screen. The study was recorded by two dome-cameras. One of them was positioned in front of the infant; the other was located behind the infant across from the screen. Two speakers stood to the left and the right below the screen and were covered by the curtains.

[25] The photographs were animated by presenting them in succession by 24 frames per second. It was also necessary to manipulate the speed as well as the backward movement of both objects with Adobe Premier. Therefore a fast motion was used and the movie was partly played backward. In addition, the occluder was inserted and positioned in the center of the white surface area (6 cm from each side). Further, Windows XP sounds were inserted when a scene was beginning and ending.

Figure 7. Experimental Setting

All other equipment was located in an adjacent room called the observation room (Figure 8). The experimenters operated computer, program, and video recordings from here. Therefore, the room held a computer with all necessary features (e.g. DVD drive and player, Microsoft Office PowerPoint Software), a mixer, and four television screens.

Figure 8. Technical Setup

One of the two dome-cameras displayed the image of the infants' face on one of the TV screens; the other camera recorded the displays. A third TV screen showed a mixed picture of the child's face and parts of the display. The image was recorded on video for later coding. Once the movie/ program was started, the computer controlled the course of the experiment. A one-way mirror separated the experimental and the observation room.

5.5 General Procedure

The experimenter welcomed parents and infants to the laboratory and showed them both the experimental and the observation room while explaining the general course of the experiment. Each infant was positioned in a high chair placed 190 cm in front of the projection screen. The parents sat next to the infant. The experimenter gave the parents brief instructions regarding the experimental procedure. Parents were asked to refrain from speaking to the infant or directing the infant's attention to the screen in any way (e.g. by pointing). The experimenter closed the curtain to the right and turned the projector on. Then the left curtain was drawn back. The experimenter dimmed the light when she left the room to start the presentation on the computer next door. Mother and infant could be seen and heard from there at all times during the experiment.

Infants were presented an animated movie/ PowerPoint-Presentation, which had an average length of 4 min and incorporated a baseline phase, two familiarization phases, and a test phase. The baseline trials introduced the infant to the task and showed him/ her that there could be either one or two objects behind the occluder without providing the infant with a way of predicting which outcome would occur in the test trials. They further established a benchmark for each infant's interest in the displays. Baseline and test visualized identical static one- and two-object displays in sequence. Therefore, these trials allowed checking for a preference, infants might have for one of the two displays presented as well as comparing such between trials. Changes from baseline to test were attributed to effects of the intermediate familiarization phase.

During familiarization an animate or an inanimate object appeared successively from behind either the left or right side of a screen. The object traveled some distance before reversing trajectory and vanishing behind the screen again. On each trial one exemplar of contrasting global categories (i.e. animate versus inanimate) was presented successively in motion. Infants viewed a total of four familiarization trials, in which the same exemplar of each global category was used (see Appendix A and Appendix C for a more detailed illustration of stimuli and general procedure). The motion trials acquainted infants with the kind information that distinguished the objects. This was assumed to influence their looking behavior in subsequent test trials.

Test sessions usually lasted about 7 min. The experimenter oversaw the whole experiment and watched the infant through camera images on several monitors. The two dome-cameras videotaped the experimental setting. One of them recorded the infant's reactions to the display; the other camera was angled to record the screen on which the movies were presented. Appendix B and Appendix D describe the course of the experimental presentations.

CHAPTER 6

EXPERIMENT 1 – NATURAL MATERIAL

6.1 Study Concept

In Experiment 1 a variation of Xu and Carey's (1996) event-mapping task (property/kind condition) was carried out. The purpose of Experiment 1 was twofold. First, it attempted to confirm the results offered by Xu and Carey (1996) therein that 12-month-old infants individuate objects on the basis of property/ kind information. Second it seeks to find out whether 10-month-olds would be capable of recalling how many distinct kinds of moving objects were hidden behind an occluding screen by means of their appearance and their domain-specific movement. An event-mapping task was carried out to answer the question if infants 10 months of age were able to solve the problem of object individuation when given domain-specific motion patterns as property/ kind information.

6.2 Participants

A total of 54 infants participated in the study. Thereof 27 infants were 10 months of age and 27 infants were 12 months old. Seven of the 12-month-old and seven of the 10-month-old infants were tested but discarded from the final sample due to fussiness or crying (N = 14). The final sample ranged in age from 10 months, 03 days to 10 months, 26 days (mean age = 10 months, 12 days) and from 12 months, 02 days to 12 months, 27 days (mean age = 12 months, 15 days). Male and female infants were equally distributed in each age group. All were full-term healthy infants who showed typical development. One 10-month-old infant and two 12-month-old infants sat on their parents' lab for the study. None of the subjects who began the session in the infant seat had to be switched to the parent's lab during the session.

6.3 Stimuli

In Experiment 1 infants watched an animated movie with a total length of 5 minutes and 37 seconds in which a bunny and a tractor moved successively in and out from behind a center placed occluder (cf. Chapter 5.5 for a general description of the stimulus material).

The bunny had beige fur, a white cottontail, and black eyes. Its size was 3 x 4 cm in the movie, which yielded 22.5 x 30 cm when projected onto the screen. The tractor was 4 x 3 cm movie-size and measured 30 x 22.5 cm on screen. Its color was green with some orange on the side. It had a white rooftop and black wheels with a white inside. The occluder was dark blue in color and had a width of 8.8 cm and a height of 5.3 cm in the presentation and span 61.6 x 37.1 cm on screen. The background and the surface on which the objects rested were white.

6.4 Procedure

The task started out with the *baseline phase*, which was instigated by a short fade in accompanied by a sound (Windows XP login tone). The fade in was followed by the immediate descent of the uncovered occluder revealing either the bunny or the tractor or both objects standing still for 20 seconds. During this time looking time was measured. Thereafter the picture was faded out. Then the same sequence was repeated with the opposite event. Again the image faded in with the Windows XP login sound[26]. In case the movie started out with a scene of a single object, both objects turned up during the second presentation and vice versa. In the course of the task the bunny was standing on the right side whereas the tractor was positioned on the left side. In the two-object display both objects were situated at the same place 3.2 cm apart, which equals 22.4 cm on screen.

During *familiarization* the occluder stood in the middle of the display. The bunny and the tractor emerged alternately from each side of the screen. The bunny walked out form behind the occluder and then started to jump to the right side

[26] Throughout the experiment the fade in with sound initiated each new sequence with the purpose of drawing the infants' attention to the film presentation and to signal the coders the starting point of the scene (see Appendix B for a detailed overview of the film events).

covering a distance of 42 cm on screen in approximately 6 seconds. When the bunny was half way in the off it reversed its trajectory and disappeared after another 6 seconds behind the occluder again. After roughly a 4 second pause (the time it would take the bunny to travel behind the screen to the other edge of it with constant speed) the tractor emerged at the left side of the screen and rolled to the left until it was half way in the off[27]. Similarly to the bunny, the tractor returned with a backward motion behind the occluder. Distance and timing were matched to the bunny. This sequence was repeated four times, which means that the infant saw the bunny emerging four times to the right and the tractor four times to the left. The objects were never simultaneously visible to the infant.

After viewing these familiarization trials infants observed the first *test* trial in which the occluder descended (while the Windows XP login sound rang out) uncovering either one object (unexpected outcome) or two objects (expected outcome) depending on the order of outcomes in the previously presented baseline sequence. That is, infants who were presented with the bunny as a single object at first saw the bunny only also at first in test. Looking time was monitored after the screen was completely out of sight. The trial ended after 20 seconds and the image faded out. A second set of two complete familiarization emergences followed[28]. It was exactly as the above particularized familiarization sequence. Thereafter the second test trial ensued with the opposite outcome to the first. That is, when infants looked at both objects in second place during the baseline phase then two objects were pictured second in the test phase. Order of outcomes was counterbalanced across subjects. Half of the infants viewed the bunny as the kind of single object in the one-object display the other half saw the tractor by itself at this point.

[27] Research concerned with infants' memory and control of visual attention demonstrated that infants not only remember objects (Bushnell et al., 1984; Cornell, 1979) from early on but also show appreciable working memory for events and actions around 6 months of age (e.g., Bahrick et al., 2002; Gilmore & Johnson, 1995; Reznick et al., 2004). These studies provide evidence that infants are able to retain memories for seconds, minutes, or even longer. In regard to object individuation, Baillargeon & DeVos (1989) showed that 8-month-old infants occluded objects even after a 70 second delay. Thus, it is assumed that infants keep the objects in mind during the time they are out of sight. Additional evidence for this claim comes from Leslie & Kaldy (2001) as well as Wilcox & Schweinle (2003).

[28] Reason for that was to ensure infants remember the motion events. Pilot testing suggested that four additional emergences were too boring and infants became fussy. Thus, the second set of familiarization trials was reduced to two emergences of each object.

6.5 Scoring

Infants were videotaped for the purpose of off-line coding after the experiment was completed. The videotapes showed the infant and part of the display. The latter was covered during the baseline and test coding process to assure observer's impartiality to the experimental condition. The sound on the tape indicated start- and endpoint of the trials. Familiarization was scored, by simply indicating if the infant recognized each object appearance. Two independent coders measured looking times for every infant on baseline and test trials from the videotape with a stopwatch.

6.6 Data Analysis

The statistical analyses were based on a final sample of 40 infants. Only infants who saw at least one complete sequence (i.e., emergence and return of both objects) over the course of the familiarization phase were included in the final sample. The dependent measure was infant's looking time, as indexed by the cumulative duration of their visual fixation to each of the baseline and the test slides. Analyses were completed with the mean looking times of coder A and B. Inter-observer reliability for baseline and test looking times was assessed by Person r = .97, which reached significance at the 0.01 level (2-tailed)[29].

The statistical analyses aimed to find out whether there was a shift in infants' looking times to the one and two object display from baseline to test. Thereby the factor age should be insignificant, because it is hypothesized that both age groups are able to solve the object-individuation task based on motion information as differentiating kind information. This was checked in preliminary analyses. In addition, the factors gender, order of outcomes (1_2 versus 2_1), and kind of single object (bunny in the one-object display versus tractor in the one-object display) could have potential influence on results and thus, their impact was also clarified upfront.

[29] All statistical tests reported in Experiment 1 are two-tailed.

Preliminary Analyses

Preliminary analyses tested whether the factors age, gender, order of outcomes (1_2 versus 2_1), and kind of single object (bunny in the one-object display versus tractor in the one-object display) had an effect on infants' looking times to the one- and two-object display in baseline or test. No age and gender effects were revealed. Therefore 10- and 12-month-olds as well as male and female infants were combined for all further analyses. However, analyses examining the significance of the factors order of outcomes and kind of single object indicated that both factors influenced the results. In order to obtain a clearer picture of the results a subsequent analysis with order of outcomes and kind of single object as between-subject factors followed the primary analysis.

6.7 Results

Main Analysis

To address the key question of whether infants individuate objects based on their domain-specific movements, a 2 (trial) x 2 (number of objects) repeated measures analysis of variance (ANOVA) was conducted with trial (baseline versus test) and number of objects (one versus two objects) as within-subject factors. Looking times to the one- and two-object display obtained during baseline trials were compared with the ones retained during test trials. The ANOVA revealed a significant main effect for number of objects, $F(1, 39) = 23.34$, $p \leq .000$, η^2 (partial eta squared) = 0.37. The descriptive statistics (cf. Table 1) show that overall infants of both age groups looked longer at the two-object display.

Table 1: *Mean Looking Times (in seconds) and Standard Deviations of Experiment 1: Main Analysis with Trial and Number of Objects as Within-Subject Factors*

	Mean	Standard Deviation	N
Baseline 1 Object	11.29	4.03	40
Baseline 2 Objects	13.45	4.38	40
Test 1 Object	10.79	4.34	40
Test 2 Objects	13.00	4.01	40

No other main effects or interactions approached significance in this analysis. Thus, the expected interaction between trial and number of objects failed to appear in both age groups. Figure 9 illustrates the results.

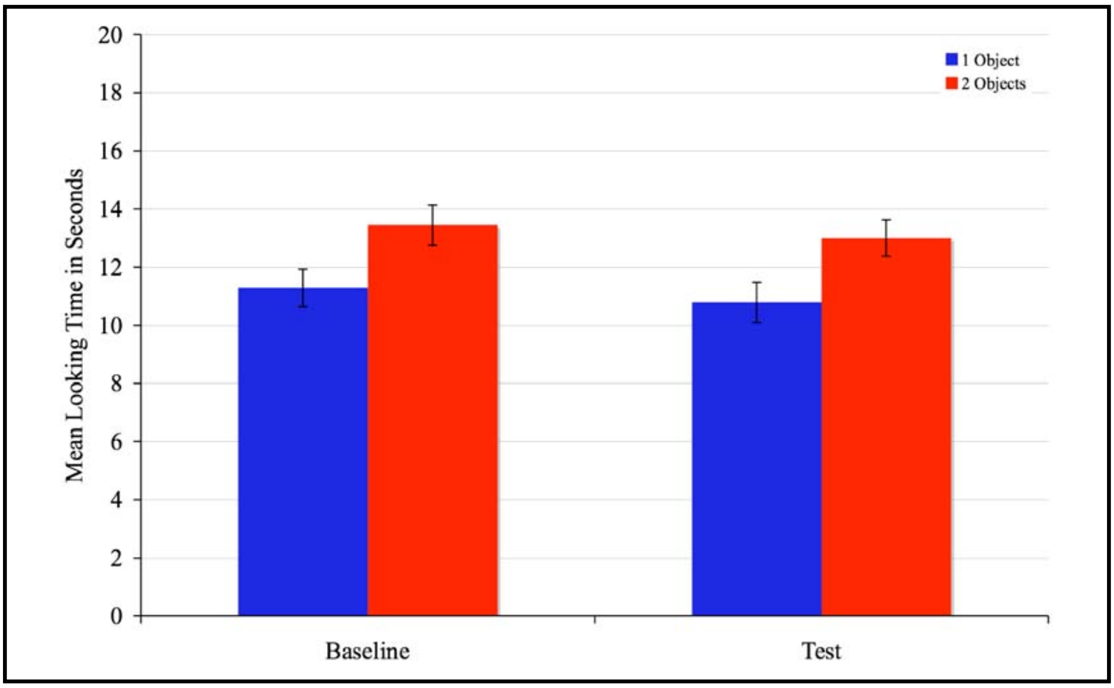

Figure 9. Results of Experiment 1 (N = 40): Mean looking times to the 1 Object versus 2 Object display in Baseline and Test

Based on preliminary analyses, which revealed an impact of the counterbalanced factors, order of outcomes and kind of single object were considered more completely in subsequent analyses.

Subsequent Analyses

Preliminary Analyses revealed that infants made different inferences depending on the order of outcomes condition (1_2 versus 2_1), and the kind of single object presented to them in the one-object display (bunny by itself versus tractor by itself). To examine the impact of these factors on 10- and 12-month-old infants' looking times to the one and two object display in baseline and test, a 2 (trial) x 2 (number of objects) x 2 (order of outcomes) x 2 (kind of single object) repeated measures mixed model analysis of variance (ANOVA) was conducted. Trial (baseline versus test) and number of objects (one versus two objects) were within-subject factors and order of outcomes (1_2 versus 2_1) as well as kind of single object (bunny in the one-object display versus tractor in the one-object display) were the between-subject factors. Besides the main effect for number of objects, $F(4, 36) = 39.64$, $p \leq .000$, $\eta^2 = 0.52$, indicating that overall infants of both age groups looked longer at the two-object display, an interaction between number of objects and order of outcomes, $F(4, 36) = 10.47$, $p = .003$, $\eta^2 = 0.23$ was found. This effect could be traced back to the following difference: Infants who viewed the two-object display before the one-object display looked significantly longer at the two-object display ($M_{1\ Object} = 19.91$, $SD_{1\ Object} = 7.77$; $M_{2\ Objects} = 27.13$, $SD_{2\ Objects} = 8.84$), $t(17) = -5.99$, $p \leq .000$, whereas infants who saw the one-object display first only showed a tendency to do so ($M_{1\ Object} = 23.86$, $SD_{1\ Object} = 7.20$; $M_{2\ Objects} = 25.88$, $SD_{2\ Objects} = 5.77$), $t(21) = -1.84$, $p = .081$. Further, there was a significant interaction between number of objects and kind of single object, $F(4, 36) = 6.99$, $p = .012$, $\eta^2 = 0.16$. Looking times to the one- and the two-object displays depended on whether the bunny or the tractor was shown as a single object in the one-object display. Surprisingly, infants in the bunny condition looked overall significantly longer at the two-object display ($M_{1\ Object} = 21.15$, $SD_{1\ Object} = 7.24$; $M_{2\ Objects} = 27.83$, $SD_{2\ Objects} = 6.98$), $t(19) = -7.47$, $p \leq .000$, compared to infants who saw the tractor as a single object and showed no such difference between the one- and the two-object display ($M_{1\ Object} = 23.01$, $SD_{1\ Object} = 8.07$; $M_{2\ Objects} =$

25.05, $SD_{2\ Objects}$ = 7.41), $t(19) = -1.45$, p = .163. One potential explanation for this result could be that the tractor was more interesting. When testing for a-priori object preferences, however, the t-test yielded no significant preference for the bunny nor the tractor (M_{Bunny} = 10.94, SD_{Bunny} = 4.09; $M_{Tractor}$ = 11.64, $SD_{Tractor}$ = 4.04), $t(38) = -0.54$, $p = .590$. This means that both objects were equally attractive to the infants when presented separately (i.e., one-object display) during baseline.

In addition to the within-subject effects, the ANOVA revealed a significant interaction of the between-subject factors order of outcomes and kind of single object, $F(4, 36) = 10.47$, $p = .003$, $\eta^2 = 0.23$. This effect suggests that the looking times vary between the conditions bunny and tractor as a single object in respect to the order of outcomes conditions. Thus, each order of outcomes condition was observed separately. When the one-object display preceded the two-object display (order of outcomes 1_2) infants looked overall longer in the condition that presented the tractor as single object, $F(2, 20) = 4.87$, $p = .039$, $\eta^2 = 0.20$. Further, infants in this condition looked overall longer at the two-object display, $F(2, 20) = 6.37$, $p = .020$, $\eta^2 = 0.24$. However, besides this main effect of the within-subject factor number of objects, the analysis revealed an interaction between the within-subject factors number of objects and kind of single object, $F(2, 20) = 11.05$, $p = .003$, $\eta^2 = 0.36$. This interaction signified that only in the condition where the bunny was the single object did infants look longer at the two-object display. When the tractor was the single object, infants looked equally long at the one- and two-object display. This explains the interaction between number of objects and kind of single object described above. In the event of order of outcome 1_2 infants actually showed an A-priori preference for the tractor. This preference continued to exist in test. Figure 10 illustrates the results for order of outcomes 1_2. In the reverse case when the two-object display came first (order of outcomes 2_1), infants looked altogether longer in the bunny condition, $F(2, 16) = 5.30$, $p = .035$, $\eta^2 = 0.25$ and preferred overall the two-object display, $F(2, 16) = 33.61$, $p \leq .000$, $\eta^2 = 0.68$. Figure 11 maps the results for order of outcomes 2_1. No other comparisons reached significance. Table 2 lists the mean looking times and the corresponding standard deviations observed in the subsequent analyses of Experiment 1.

Table 2: *Mean Looking Times (in seconds) and Standard Deviations of Experiment 1: Subsequent Analyses with Order of Outcome and Kind of Single Object as Between-Subject Factors*

	Order of Outcomes	Kind of Single Object	Mean	Standard Deviation	N
Baseline 1 Object	12	Bunny	9,63	3,97	10
		Tractor	13,59	3,40	12
		Total	11,79	4,11	22
	21	Bunny	12,25	3,97	10
		Tractor	8,71	3,13	8
		Total	10,68	3,96	18
	Total	Bunny	10,94	4,09	20
		Tractor	11,64	4,04	20
		Total	11,29	4,03	40
Baseline 2 Objects	12	Bunny	12,83	4,16	10
		Tractor	13,87	4,24	12
		Total	13,40	4,13	22
	21	Bunny	15,04	4,34	10
		Tractor	11,59	4,90	8
		Total	13,50	4,79	18
	Total	Bunny	13,93	4,29	20
		Tractor	12,96	4,53	20
		Total	13,45	4,38	40
Test 1 Object	12	Bunny	9,75	3,34	10
		Tractor	14,01	3,12	12
		Total	12,08	3,82	22
	21	Bunny	10,67	4,87	10
		Tractor	7,42	3,49	8
		Total	9,23	4,51	18
	Total	Bunny	10,21	4,10	20
		Tractor	11,38	4,60	20
		Total	10,79	4,34	40

Test 2 Objects	12	Bunny	11,85	2,31	10
		Tractor	13,00	3,92	12
		Total	12,48	3,27	22
	21	Bunny	15,95	3,73	10
		Tractor	10,73	4,50	8
		Total	13,63	4,78	18
	Total	Bunny	13,90	3,68	20
		Tractor	12,09	4,20	20
		Total	13,00	4,01	40

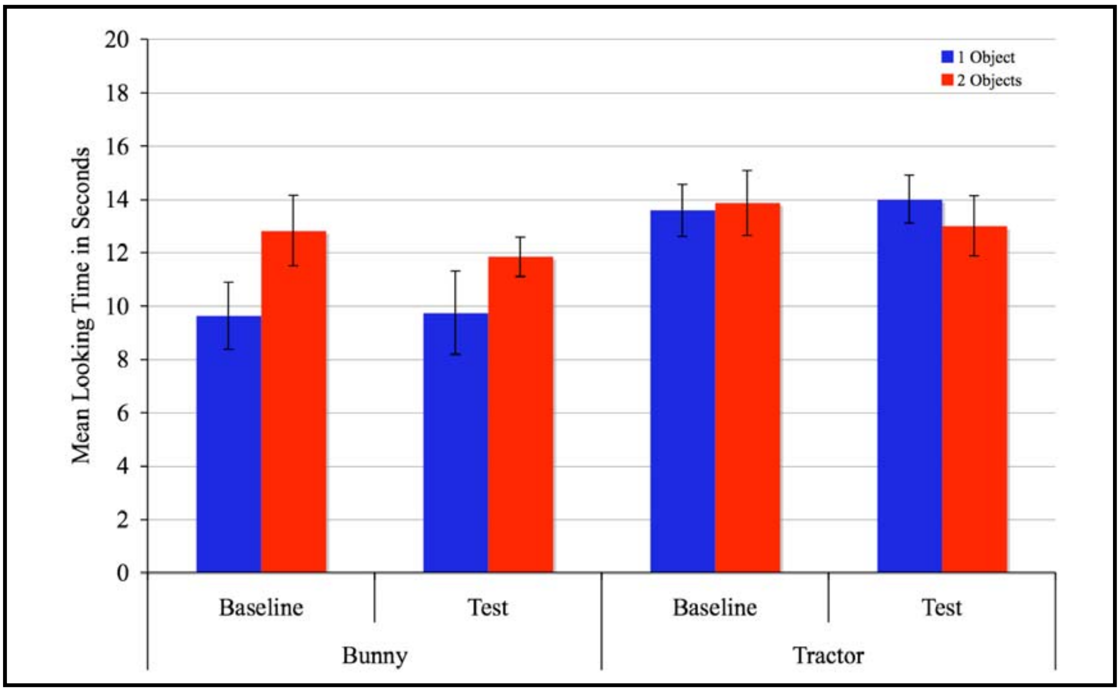

Figure 10. Results of Experiment 1 with order of outcome and kind of single object as between-subject factors (N = 40): Mean looking times to the 1-object versus 2-object display in baseline and test depending kind of single object in order of outcome condition 1_2.

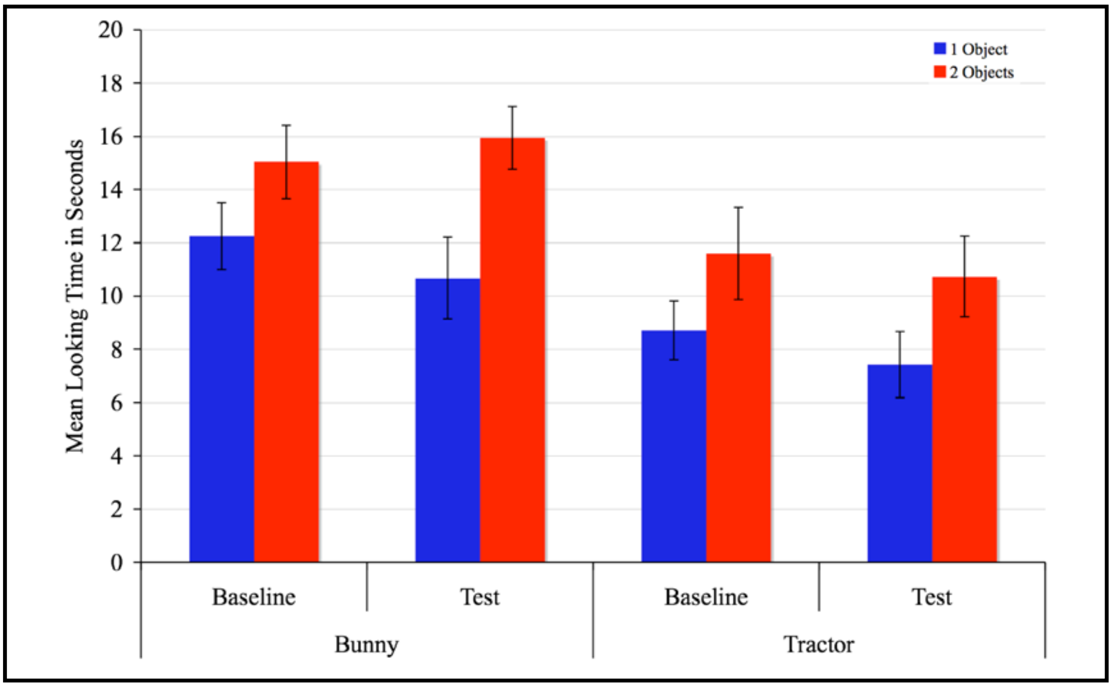

Figure 11. Results of Experiment 1 with order of outcome and kind of single object as between-subject factors (N = 40): Mean looking times to the 1-object versus 2-object display in Baseline and Test depending kind of single object in order of outcome condition 2_1.

6.8 Discussion of the Results

Both 10- and 12-month old infants showed the same looking pattern in Experiment 1. Even though no age effect was expected, contrary to the hypothesis infants of both age groups devoted overall more visual attention to the two-object display. In other words, on average, infants had a strong preference for the two-object display independent of the trial (baseline or test) it was presented in. Overall greater looking times to the two-object display indicate on the one hand that the events shown in the familiarization phase (bunny jumping from behind an occluder and a tractor emerging from behind the same occluder after the bunny had disappeared there) did not build up any expectation in infants. On the other hand it signifies, that 10- as well as 12-month-old infants failed to demonstrate that they could use the different motion pattern displayed by an animate (bunny) and an inanimate object (tractor), when emerging successively from behind the left and right side of an occluder, to infer that there must be two distinct objects behind the screen. Hence, the hypothesis that infants who saw an animate and an inanimate object repeatedly travel from behind a screen would show greater looking to a one-object display (unexpected outcome) in relation to a two-objects display (expected outcome) in test compared to their initial looking pattern in baseline could not be affirmed in Experiment 1. This is especially surprising for the group of 12-month-old infants who according to the literature should be able to individuate objects on the basis of featural as well as kind information and therefore, react with surprise indicated by longer looking to the one-object display in test (Baillargeon & Wilcox, 1998b; Surian et al., 2004; Xu & Carey, 1996; Xu 2007). In contrast, in this study 12-month-olds showed neither that they were able to use the clear featural differences between the objects (bunny and tractor) nor that they made use of the distinct kind information both objects carried in their appearance and their domain-specific motion pattern.

Preliminary analyses specified an influence of the counterbalanced factors order of outcomes and kind of single object on the variables of interest. Hence, subsequent analyses tested whether infants made different inferences depending on the order of outcomes and/ or kind of single object that was presented to them in the one-object display. One finding was that when the order of outcome was 1_2, infants in the tractor condition looked longer, whereas when the order of outcome was 2_1 infants looked longer when the bunny was the single object. The latter difference would be best attributed to a sample difference instead of a distinguished variation between groups. That is, because infants in the tractor condition demonstrated overall significantly less interest than infants in the bunny condition. Despite greater looking in the bunny condition, infants in both kind of single object groups showed a similar pattern of results, namely longer looking toward the two-object display when the order of outcome was 2_1. As to the effect in the opposite condition (order of outcome 1_2), subsequent analyses revealed that infants favored the two-object display overall, too, except here this preference only became significant when the bunny served as the single object. When the tractor was the single object in the on-object display, infants looked independent of trial equally long toward the one- and the two-object display. This pattern of results could be traced back to the tractor being more interesting. When considering both objects attentively in the static displays it is evident that the bunny lacks detail compared to the tractor. Not only are the bunny’s eyes hard to detect but also its fur is a homogeneous color. On the contrary, the tractor has several shades of color, which define various parts. Although there was no overall a-priori preference for either object, evidence for this speculation came from the descriptive statistics, which suggested an initial baseline preference when the tractor was presented first as single object compared to when the bunny was shown first as single object. Additional results obtained through the subsequent analyses correspond to the preference explanation as well. When the tractor was added to the display (two-object display) after infants saw the bunny, they observed the two-object display longer. In the case, the bunny was added to the display after infants watched the tractor no preference for the two-object display occurred. Nevertheless, even if a preference for the tractor existed it could not hold up in the condition in which both objects were presented together at first. Here infants examined the two-object display longer independent of whether they saw the bunny or tractor as kind of single object, which implies that the one-object display was less interesting when presented during the second test trial. This makes sense because not only is there less to see and examine in the display to begin with (half of the amount that is visible in the two-object display) but also when the order of outcomes was 2_1 the object in the one-object display had been part of the two-object display presented before. Hence, it is most likely that the prior examination lead to less interest or shorter processing time, which in turn interfered with any expectation for the single object during the second test trial.

More importantly, however, is the question why at least 12-month-old infants did not show object individuation. In all other individuation studies it was the case that the two-object display provided more to see and 12-month-old infants still overcame their looking time preference for two objects (e.g., Baillargeon & Wilcox, 1998b, Surian et al., 2004; Xu and Carey, 1996). Thus, is the simple argumentation that there is more to see in the two-object display sufficient to explain 12-month-olds failure? Maybe there is a more complex cause. One problem that could add to the longer looking times toward two objects is that both objects might have been perceived as self-propelled leading to the perception of two animate objects. In one important dimension for the animate-inanimate distinction, namely self-propulsion, both objects were alike. According to Mandler's (1992, 2004), animate beings distinguish oneself through moving self-propelled on a non-linear path. Even though the bunny irregularly jumping up and down implemented the later characteristic, the origin of the onset of motion was not explicit. At no point during the experiment did the infant see that the bunny started moving on its own whereas the tractor set in motion due to an external cause. Both objects came out from behind the occluder already moving and the reversal of their trajectory was concealed, too. The reasoning for such a setup was to avoid that infants see how the objects set in motion before they return behind the occluder again. This was supposed to avert that infants perceived the two objects as self-propelled. As research on the animate-inanimate distinction makes clear, infants at 7-months of age are able to remember previously moving objects and more over, expect self-propelled ones to start moving again when encountered later stationary (Markson & Spelke, 2006). However, due to the complexity of the individuation task, it might have been to complicated for infants to infer from the distinct pattern of motion the objects showed that only one of the objects could be self-propelled (the one with the irregular path of motion). Thus, it is possible that infants expected both objects to move again when they were presented stationary in test. Therefore, the expectation that two objects might move again elicited longer looking than the expectation that one entity sets back in motion. Even 12-month-old infants might prefer the two-object display over the one-object display because they wait for the two objects to move again. Hence, this anticipation might overlay the expectation that two objects were involved in the familiarization event leading to the opposite looking pattern than hypothesized. However, against this explanation speaks the fact that there is no significant difference between baseline and test trials. The expectation that one or both objects would start moving again can of course only arise after infants encountered the objects in motion. Because this was not until the familiarization phase, there should be either a variation in looking behavior between baseline and test trials or no difference between the one- and two-object display in baseline for this interpretation to count. The analyses do not show such patterns of results. Again, the latter could have been absent because of the fact that there is more to see in the two-object display. This is accompanied with another aspect that might be have contributed to the negative results in both age groups. It could be that the objects themselves are too complex and thus too interesting. It is possible that this not only distracts from the original task to determine whether one or more objects are involved in the familiarization event but more importantly it might cast a problem between the interpretation of form and motion information. As elaborated in Chapter 3.3 it is not that infants do not attend or perceive both form and motion. Research showed that young infants are able to attribute certain types of motion to particular entities (Pauen & Träuble, 2004) categorize motion (Arterberry & Bornstein, 2002), and make causal and goal attribution inferences about animate motion in absence of animate forms (Schlottmann & Surian, 1999; Csibra et al., 1999). Nevertheless, they still have difficulties tracking the kinds of motions associated with animate entities (such as expansion and contraction; Chiang & Wynn, 2000; van Marle & Scholl, 2003) and integrating form and motion when the task requires associative learning, not simply resolving structure from motion, which is readily handled via perceptual processes (e.g., Domini et al., 2002; Johnson et al., 2003; Wickelgren & Bingham, 2001). That is for instance, infants remember dynamic events after a 7-week delay but do not remember the specifics of the persons or objects shown in the events (Bahrick et al., 2002). In addition, because of infants' sophisticated knowledge about which objects engage in animate motion (see Chapter 3.2) one would reckon that they would be able to interpret the motion itself. However, despite an early detection of violations regarding object properties in occlusion, containment and support events (events that have predictable outcomes) they do not transfer animate and inanimate actions (actions that in real world situations do not have consistently predictable outcomes) to their associated forms until 9 months of age (e.g., Arterberry & Bornstein, 2001; Bertenthal et al., 1984). Using even more complex tasks (Rakison & Poulin Dubois, 2002), one can see that even in their second year of life, infants may still have difficulties coordinating form and motion information perhaps because this kind of associative learning requires several trials and is generally not accessible to later reflection (e.g., as found in implicit learning tasks).

The present procedure is a complex event-mapping task. Although the initial goal was to simplify the task for infants by providing salient domain-specific motion patterns in addition to featural kind information, it might have been the case that this added information made the task even more complex. As a result the detailed and interesting objects as well as the distinct motion pattern might have overloaded infants' information processing capacities in the, in principal, complex event-mapping task.

6.9 Summary

The major result of Experiment 1 is the failure of 10- and 12-month-old infants to show object individuation. Instead of animate and inanimate motion as kind information, infants looking times depended on the individual object or the number of objects in the displays. Thus far it is not clear whether the complexity of the objects or the expectation for the objects to move again constituted the major influencing factor. Taken together, the results of Experiment 1 lead to the conclusions that (1) the detailed realistic-looking objects are in conflict with the processing of the motion information as an individuation factor. (2) After all it cannot completely be ruled out that infants look longer at the two-object display because both objects were perceived as self-propelled and thus, generated more interest through the expectation that two objects would move again.

Given the strong preference for the two-object display, in Experiment 2 the critical content-related as well as methodological points concerning object complexity and self-propulsion were modified in order to eliminate them as causes for the missing object individuation in Experiment 1. Consequently, goal of Experiment 2 was to examine the primary hypothesis with a simplified task that followed the procedure of Experiment 1 but made use of simple yet perceptually distinct forms with very little detail. The removal of form characteristics allowed the investigation of whether 10- and 12-month-old infants process motion as an individuating factor by itself. Additionally, the ambiguity regarding the self-propulsion dimension was eliminated. The changes are specified in more detail in the next chapter.

CHAPTER 7

EXPERIMENT 2 – ABSTRACT MATERIAL

7.1 Study Concept

Experiment 2 was closely modeled after Experiment 1 but varied in the following critical aspects:

First, one way of overcoming the preference for two objects is to make the entities less interesting. Instead of using real-life miniatures with a lot of detail (e.g. fur, stripes, legs, wheels) the objects were switched to a pair of very simple geometrical objects with little characteristics but still different in color and shape. A square and a round-shaped geometric form replaced the bunny and the tractor. Concerning both objects, the only direct cue for kind membership was the animate and inanimate movement the objects engaged in, respectively. However, to emphasize animacy the ball had a pulsating inside whereas the box did not (see for example Gelman, 1990, 2002, or Newman et al., 2008 for discussion). The question was whether the absence of perceptually salient, category specific feature information would help infants to focus on the domain-specific movement pattern and therefore, would facilitate the differentiation of kind on the basis of motion.

Second, in order to better control for the influence of self-initiation two poles confined the end of the path on each side of the occluder. Contrary to Experiment 1 in which the objects traveled half way out of sight before moving back, in Experiment 2 the inanimate object reversed its trajectory by bumping against a pole whereas the animated object returned without having any external contact (see Leslie, 1995 and Spelke, 1994 for infants' expectations about contact).

Third, Experiment 2 differed methodologically in respect to the timing of baseline and test trials, namely they were presented for 15 seconds instead of 20 seconds. Pilot infants demonstrated boredom toward the end of the experimental session, which I attributed to the geometric forms with little detail. An additional distinction regarding the procedure was that after the baseline trials the experimenter calibrated. During calibration the experimenter entered the experimental room directing the infants attention to various points on and off screen. This had two functions: first, it created a break between the baseline phase and the rest of the experiment and thus, diminished a possible influence of the baseline on infants' performance in test. Second it served the purpose of pointing out the dimensions of the screen and the positions of the objects for later coding. Besides these structure variations the design and procedure were identical to Experiment 1.

7.2 Participants

A total of 45 infants participated in the study. Twenty-one of the infants were 10 months of age and 24 of them were 12 months old. Even though they were tested one 10-month-old infant and four 12-month-old infants had to be discarded from the final sample due to experimenter error (2) and fussiness or crying (3). Infants making up the final sample ranged in age from 10 months, 00 days to 10 months, 23 days (mean age = 10 months, 11 days) and 12 months, 03 days to 12 months, 29 days (mean age = 12 months, 17 days). All were full-term healthy infants who showed typical development. During the experimental session, one 10-month-old infant sat on its parents' lab for the study and one 12-month-old subject who began the study in the infant seat had to be switched to the parent's lab.

7.3 Stimuli

Four PowerPoint Presentations served as stimulus material in Experiment 2. Each presentation contained of 59 slides and was exactly the same except for variations regarding the order of outcome and the kind of single object in the one-object displays. A blue ball with a red dot in the center and a red box with a blue square in the middle represented the animate and the inanimate object, respectively. The ball had a diameter of 2 cm in the slide and 13.5 cm on screen. In the presentation the square was 2 cm high and 2 cm long; on screen its length was 12.5 cm and its width was 13 cm. When in motion the ball engaged in a jumping movement following an irregular path, which was different on the way to the side and on the return. Furthermore, it changed on every trial. Thus, the ball covered a total of 12 dissimilar routes. This was done to emphasize the liveliness of this particular object.

Additionally, for the same reason the dot that ball contained in the center pulsated two of three times as the ball landed on the ground during the jumping motion. The third time the dot remained its original size because the infant was supposed to see that this action was not always performed. This was important in regard to the stationary scenes in which both objects did not move at all. In contrast the box moved on a linear path to the side and returned in the same manner. There was no internal motion of the blue square in the center if the box. Besides the two objects the slides contained a grey occluder (slide size 4.7 cm x 5.6 cm and 35.25 cm x 42 cm screen size) and two black poles on each side of screen (slide size 3.9 x 0.5 cm and screen size 28.5 x 4 cm). The occluder covered the objects during baseline, familiarization and test while the poles served as barriers (0.25 cm from the picture margin and 3 cm from the edge of the screen). The floor on which the objects rested and moved had a dark grey color and the background was white (see Appendix C for a display of stimuli and general procedure).

The first slide of the PowerPoint Presentation was completely black containing no objects. It was projected while the infants got situated to begin the task. The following 57 slides incorporated baseline, familiarization, and test trials of the individuation task. The last slide was identical to the beginning slide. The PowerPoint-Presentation had a total length of 3 minutes and 83 seconds. Appendix D illustrates the course of presentation of the experiment.

7.4 Procedure

The order of events most closely corresponded to Experiment 1. The task started out with a black slide. A bell sound initiated the beginning of the first trial of the *baseline phase*. Either the ball or the box or both objects[30] were statically presented for 15 seconds. No screen was involved. Thereafter a black slide came on for 1 second and with the next bell sound the opposite event was shown. When the presentation started with the one-object display the two-object display turned up in the second baseline trial and vice versa. In the following the screen was introduced.

[30] The ball was situated on the left side whereas the box was positioned on the right side. In the two-object display both objects were situated at the same place 1.5 cm (11.25 cm when projected) apart. This set up was kept through out the presentation.

Accompanied by a bell sound it descended and rose back into view. This sequence was repeated.

Then the *familiarization phase* began. The occluder stood in the middle of the display. Ball and box emerged alternately from each side of the screen. The ball rolled from behind the occluder and jumped to the left side covering a distance of 6 cm in 4 seconds. Just before the pole the ball paused for a second with the red dot pulsating and then jumped on its own back behind the occluder. After roughly 2 seconds (the time it would take the ball to get with constant speed to the other edge of the screen) the box emerged at the right side of the screen. It slid to the right until it hit the pole from where it returned. It appears as if the collision caused the trajectory reversal. Distance and timing were matched to the ball. This sequence was repeated four times, which means that the infant saw the ball emerging four times to the left and the box four times to the right. The objects were never simultaneously visible to the infant.

After viewing these familiarization trials infants observed the first *test* trial in which the occluder descended (while the bell tone sounded) uncovering either one object (unexpected outcome) or two objects (expected outcome) depending on the order of outcomes in the previously presented baseline sequence. That is, infants who were presented with the ball as a single object at first saw the ball only at first in test, too. Looking time was monitored after the screen was completely out of sight. The trial ended after 15 seconds after which the occluder rose back up and a black slide came on. A second set of two complete familiarization emergences followed. They mirrored the first familiarization trials. Thereafter the second test trial ensued with the opposite outcome to the first. That is, when infants looked at both objects in second place during baseline then two objects were pictured second in test.

7.5 Scoring

Infants were videotaped for the purpose of off-line coding after the experiment was completed. The videotapes showed the infant and part of the display. The latter was covered during the baseline and test coding process to assure observer’s impartiality to the experimental condition. The sound on the tape indicated start- and endpoint of the trials. Familiarization was scored, by simply indicating if the infant recognized each object appearance. Two independent coders measured left and right looking times for every infant on baseline and test trials from the videotape with a stopwatch.

7.6 Data Analysis

The statistical analyses of Experiment 2 were as well based on a final sample of 40 infants. As in Experiment 1 only infants who saw at least one complete sequence (i.e., emergence and return of both objects) over the course of the familiarization phase were included in the final sample. The dependent measure was again infant's looking time, as indexed by the cumulative duration of their visual fixation to each of the baseline and the test slides. Analyses were completed with the mean looking times of coder A and B. Inter-observer reliability for baseline and test looking times was assessed by Person r. The reliability was r = .99 and reached significance at the 0.01 level (2-tailed)[31].

As in Experiment 1 the statistical analyses checked whether there was a shift in infants' looking times to the one and two object display from baseline to test. Again age should not have an impact, because it is hypothesized that both age groups are able to solve the object-individuation task based on motion information as differentiating kind information. Preliminary analyses examined this assumption. In addition, the factors gender, order of outcomes (1_2 versus 2_1), and kind of single object (ball in the one-object display versus box in the one-object display) could have potential influence on results (as shown in Experiment 1) and thus, their influence was screened beforehand, too.

Preliminary Analyses

As in Experiment 1 preliminary analyses were performed to check for age and gender effects. Similarly to the preliminary results in Experiment 1, both factors had no overall impact on the looking times in Experiment 2. Therefore, data from 10- and 12-month-olds as well as male and female infants were combined for all further analyses. Comparable to Experiment 1 the influence of the factors order of outcomes

[31] All statistical tests reported in Experiment 2 are two-tailed.

(1_2 versus 2_1) and kind of single object (ball in the one-object display versus box in the one-object display) was examined. These analyses indicated that both factors were again associated with some effects. Thus, as in Experiment 1 subsequent analyses with order of outcomes and kind of single object as between-subject factors followed the main analysis of Experiment 2.

7.7 Results

Main Analyses

To address our primary question of whether infants individuate simple, abstract objects based on their domain-specific movements, a 2 (trial) x 2 (number of objects) repeated measures analysis of variance (ANOVA) was conducted with trial (baseline versus test) and number of objects (one versus two objects) as within-subject factors. Looking times to the one- and two-object display obtained in baseline trials were compared with the ones retained in test trials. The ANOVA revealed a significant main effect for trial $F(1, 39) = 9.76$, $p = .003$, $\eta^2 = 0.20$ as well as number of objects $F(1, 39) = 16.28$, $p \leq .000$, $\eta^2 = 0.30$. Mean looking times displayed in Table 3 demonstrate that overall infants looked longer during test trials and preferred the two-object display.

Table 3: *Mean Looking Times (in seconds) and Standard Deviations of Experiment 2: Main Analyses with Trial and Number of Objects as Within-Subject Factors*

	Mean	Standard Deviation	N
Baseline 1 Object	7.12	2.92	40
Baseline 2 Objects	8.62	3.50	40
Test 1 Object	8.51	2.97	40
Test 2 Objects	9.93	2.88	40

In common with Experiment 1, the hypothesized interaction between trial and number of objects did not arise in the main analysis of Experiment 2. Figure 12 illustrates the results obtained through this analysis.

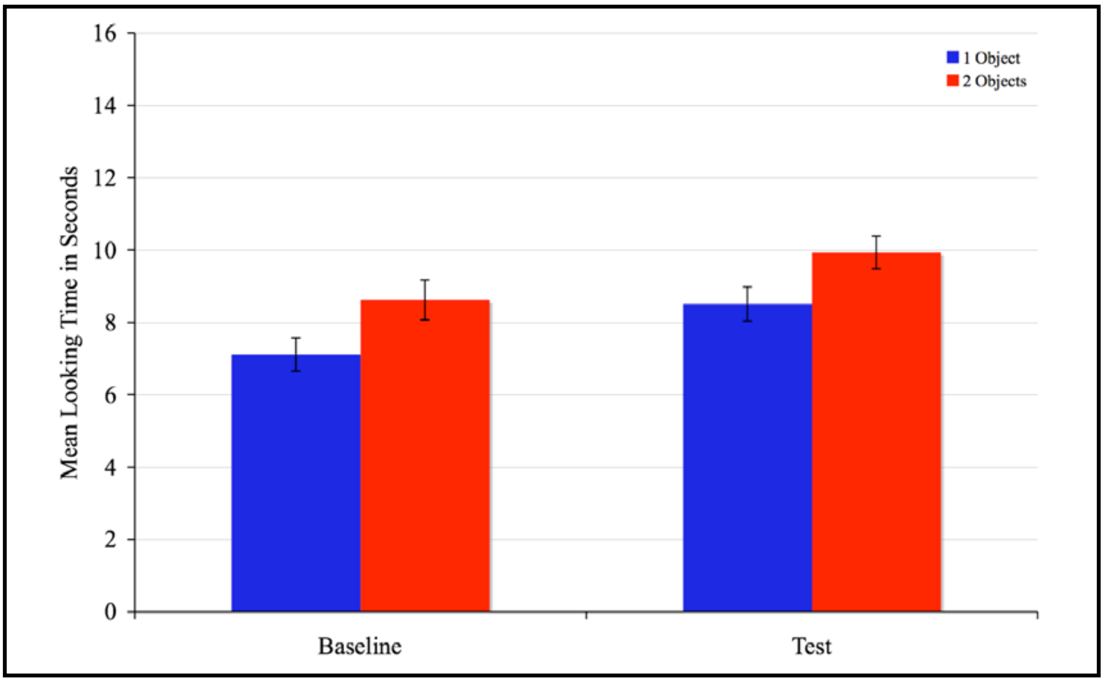

Figure 12. Results of Experiment 2: Main Analysis (N = 40): Mean looking times to the 1-object versus 2-object display in baseline and test

Preliminary analyses made aware of an impact the counterbalanced factors order of outcomes and kind of single object had on infants' looking times. Thus, corresponding subsequent analyses were carried out to get to the bottom of it.

Subsequent Analyses

The influence of the factors order of outcomes and kind of single objects was assed by a 2 (trial) x 2 (number of objects) x 2 (order of outcomes) x 2 (kind of single objects) repeated measures mixed model analysis of variance (ANOVA) with trial (baseline versus test) and number of objects (one versus two objects) as within-subject factors and order of outcomes (1_2 vs. 2_1) as well as kind of single object (ball in the one-object display versus box in the one-object display) as between-subject factors. This analysis generated two within-subject main effects, trial $F(4, 36) = 10.76$, $p = .002$, $\eta^2 = 0.23$ and number of objects $F(4, 36) = 20.53$, $p \leq .000$, $\eta^2 = 0.36$ as well as a marginal significant between-subject main effect, order of outcomes $F(4, 36) = 3.90$, $p = .056$, $\eta^2 = 0.10$. Overall, infants looked significantly longer in test and preferred the two-object display. Further, infants look reliably longer in the order of outcomes condition 2_1.

Additionally, several interactions turned out significant. In regard to the within-subject factors, trial interacted with the factor order of outcomes $F(4, 36) = 4.89$, $p = .033$, $\eta^2 = 0.12$. Follow-up T-Tests pointed out that infants only looked significantly longer in test compared to baseline when the two-object display was presented first ($M_{Baseline} = 16.10$, $SD_{Baseline} = 4.59$; $M_{Test} = 20.60$, $SD_{Test} = 3.03$), $t(19) = -3.83$, p = .001. In the condition in which infants saw the one-object display first no such difference between baseline and test looking times occurred ($M_{Baseline} = 15.40$, $SD_{Baseline} = 7.13$; $M_{Test} = 16.27$, $SD_{Test} = 4,15$), $t(19) = -0.77$, p = .454. Number of objects interacted with order of outcomes as well $F(4, 36) = 4.25$, $p = .047$, $\eta^2 = 0.11$. The T-Test comparison yielded that infants who saw the two-object display first looked significantly longer to the two-object display ($M_{1\ Object} = 16.23$, $SD_{1\ Object} = 3.26$; $M_{2\ Objects} = 20.47$, $SD_{2\ Objects} = 4.20$), $t(19) = -3.91$, p = .001, whereas infants who viewed the one-object display first showed only a tendency in that direction ($M_{1\ Object} = 15.04$, $SD_{1\ Object} = 5.75$; $M_{2\ Objects} = 16.63$, $SD_{2\ Objects} = 5.45$), $t(19) = -1.80$, p = .088. The more over, an interaction between number of objects and kind of single object reached significance $F(4, 36) = 7.78$, $p = .008$, $\eta^2 = 0.18$. Under circumstances where the box was visible in the one-object display, infants looked reliably longer at the two-object display ($M_{Ball} = 14.42$, $SD_{Ball} = 4.53$; $M_{Box} = 19.14$, $SD_{Box} = 6.08$), $t(19) = -4.99$, $p \leq .000$. This was not the case when the ball was shown in the one-object display $M_{Ball} = 16.84$, $SD_{Ball} = 4.56$; $M_{Box} = 17.96$, $SD_{Box} = 4.18$), $t(19) = -1.17$, $p = .255$. Concerning the between-subject effects, an interaction between the factor order of outcomes and the factor kind of single object was found $F(4, 36) = 5.58$, $p = .024$, $\eta^2 = 0.13$. Subsequent ANOVAs elucidated that the kind of single object presented in the one-object display tended to influence infants looking only when the displays were shown in the order 2_1, $F(2, 18) = 4.02$, $p = .060$, $\eta^2 = 0.19$. When the order of outcomes was 1_2 the kind of single object featured in the one-object display had no effect on infants looking times $F(2, 18) = 2.60$, $p = .124$, $\eta^2 = 0.13$. The results point to a favor of the box when the two-object display was presented first. All other possible effects turned out non-significant. Mean looking times and the corresponding standard deviations are shown in Table 4.

Table 4: *Mean Looking Times (in seconds) and Standard Deviations of Experiment 2: Subsequent Analyses with Order of Outcomes and Kind of Single Object as Between-Subject Factors*

	Order of Outcomes	Kind of Single Object	Mean	Standard Deviation	N
Baseline 1 Object	12	Ball	6,85	2,91	5
		Box	6,44	4,25	5
		Total	6,64	3,44	10
	21	Ball	5,18	2,01	5
		Box	6,64	2,60	5
		Total	5,91	2,32	10
	Total	Ball	6,02	2,52	10
		Box	6,54	3,32	10
		Total	6,28	2,88	20
Baseline 2 Objects	12	Ball	8,78	4,96	5
		Box	7,43	4,95	5
		Total	8,12	4,73	10
	21	Ball	6,84	2,15	5
		Box	9,40	2,82	5
		Total	8,12	2,72	10
	Total	Ball	7,81	3,75	10
		Box	8,42	3,94	10
		Total	8,11	3,75	20
Test 1 Object	12	Ball	8,69	4,30	5
		Box	6,22	2,47	5
		Total	7,46	3,56	10
	21	Ball	11,41	2,94	5
		Box	9,44	1,65	5
		Total	10,43	2,47	10
	Total	Ball	10,05	3,75	10
		Box	7,83	2,61	10
		Total	8,94	3,35	20

Test 2 Objects	12	Ball	9,50	3,03	5
		Box	8,30	0,87	5
		Total	8,90	2,19	10
	21	Ball	9,73	2,77	5
		Box	12,30	2,34	5
		Total	11,02	2,77	10
	Total	Ball	9,62	2,74	10
		Box	10,30	2,69	10
		Total	9,96	2,66	20

The following Figure 13 and Figure 14 graph the reported results.

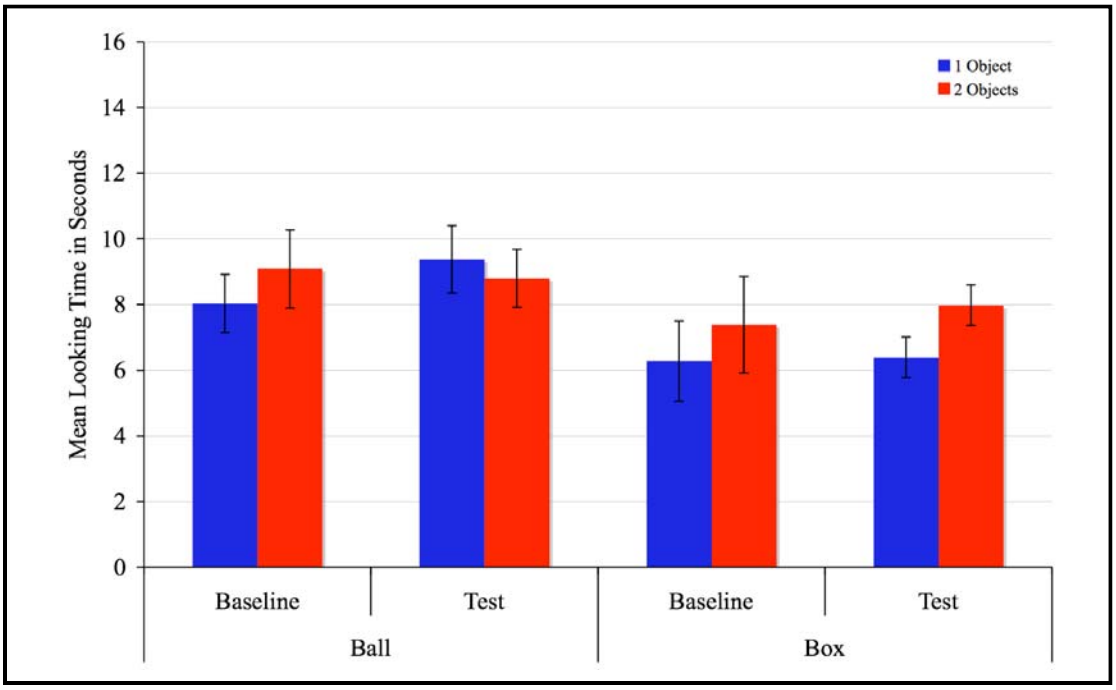

Figure 13. Results of Experiment 2: Subsequent Analyses (N = 20): Mean looking times to the 1-object versus 2-object display in baseline and test depending on the kind of single object in order of outcome 1_2.

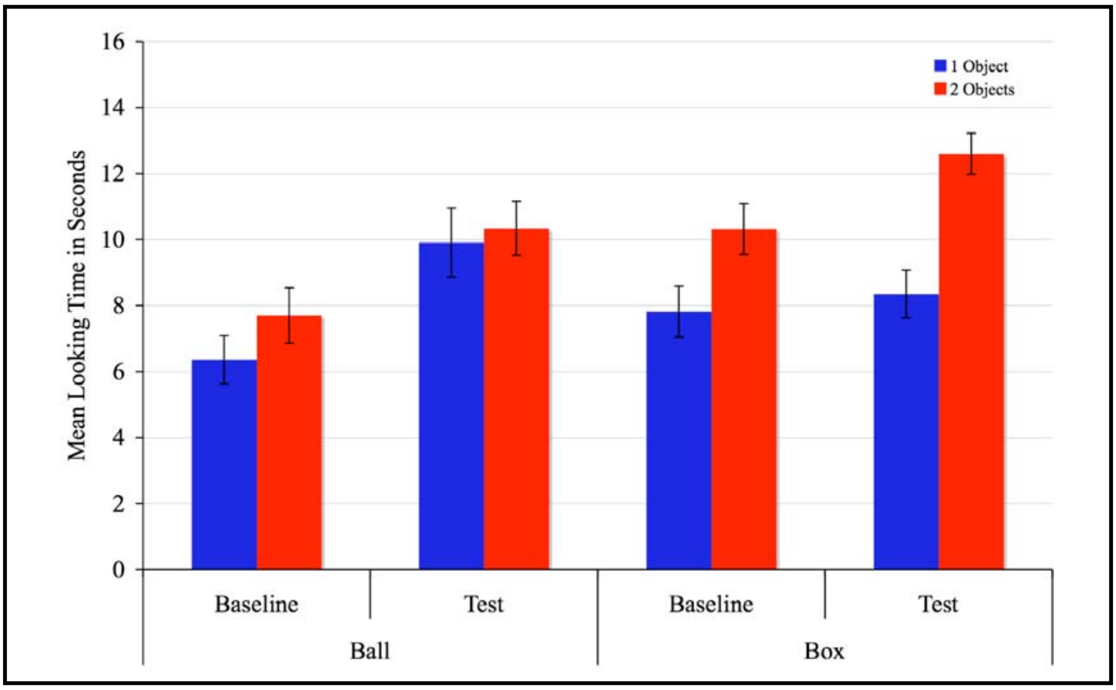

Figure 14. Results of Experiment 2: Subsequent Analyses (N = 20): Mean looking times to the 1-object versus 2-object display in baseline and test depending on the kind of single object in order of outcome 2_1.

7.8 Discussion of the Results

The question of Experiment 2 was whether infants make use of motion as kind information to establish the number of objects in an event under conditions where object complexity is reduced to a minimum and domain-specific movements are the only information for drawing conclusions regarding object kind. The results of Experiment 2 indicate no affirmation for the hypothesis that 10- and 12-month-old infants would individuate different object kinds by means of their kind distinct motion. The removal of form characteristics and the simplification of the task did not change the general pattern of results of Experiment 1.

As reported in Experiment 1, infants of both age groups looked overall longer at the two-object display in Experiment 2. Infants showed no surprise when only one object was presented in test suggesting that they did not individuate simple, abstract objects on the basis of motion patterns as kind information even when this was the most salient source of information available. The result is especially puzzling in regard to the group of 12-month-old infants. Could it be that even 12-month-old infants are unable to establish the number of simple objects by means of domain-specific motion patterns? Several previous studies demonstrated that in fact infants several months younger are able to individuate geometric forms (e.g., Kaldy & Leslie, 2003; Tremoulet et al., 2000; Wilcox & Baillargeon, 1998a, b), which makes it unlikely that the choice of objects is accountable for the missing object individuation. However, most of these studies did not use a within-subject design but implemented a between-subject design for the comparison of baseline and test trials. Hence, besides an inability of infants to solve the individuation task on the basis of motion information, it might be that the baseline presentation interferes with infants' reasoning in test. To rule out this possibility the present study is repeated without baseline trials in Experiment 3.

Nevertheless, the other main effect in this study as well as the findings of the subsequent analyses speak against a complete failure to make sense of the provided information. Besides the preference of the two-object display, the main effect trial pointed to an increased interest in the test displays. This could be partly in consequence of infants' expectancy that the objects would start moving again. While watching the motion events infants build up this expectation and thus, reacted with longer looking toward the test displays compared to the baseline presentation.

Therefore, the information displayed during familiarization had an effect on infants' reactions in test. Nevertheless, infants showed no surprise when only one object was present. One reason could be that infants' anticipation that two objects would start moving again exceeded the expectation that one object would set in motion. However, this would only be the case if infants did not make use of the box's return motion resulted from contact to the pole whereas the ball reversed its trajectory self-initiated. Research on infants understanding of the contact principle provides evidence that already 7-month-olds differentiate origins of movement, which in turn they use to reason about animacy as well as agency (e.g., Leslie & Keeble, 1987; Pauen & Träuble, 2004; Oakes & Cohen, 1990; Schlottmann & Surian, 1999; Spelke, Philips, & Woodward, 1995).

What additional reasons could be considered for this renewed failure? Subsequent analyses demonstrated that infants' looking behavior toward the one- and two-object display was affected by the order of outcomes as well as the kind of single object presented in the one-object display. Infants preferred the two-object display and looked longer in test when the order of outcome was 2_1. Why the factor order of outcome exerted influence on these findings remains speculative and must be discussed in light of the following effects. Aside from the order of outcomes, infants' favor of the two-object display was particularly evident in the box condition. Further, overall infants looked longer in the order of outcomes condition 2_1 when the box was the single object in the one-object display. Taken everything into account, infants' looking pattern could be explained as follows. It is possible that infants take the number of objects as well as the event information presented in the first test trial into account when looking at the second test trial. Concerning the number of objects, a favor of the two-object display in the order of outcomes condition 2_1 points to the explanation discussed in Chapter 6.9, namely infants look longer at the two-object display because there was more to see. Therefore, the one-object display is less interesting/ needs less processing time after the two-object display was presented. In regard to event information, infants may have different expectations in conjuncture with conceptions about animacy such as self-propulsion or agency in general. Together with the effect that order of outcomes also impacted infants' looking preference in regard to the one- or two-object display it might be possible that infants had particular expectations concerning the two-object display. One such expectation could bear on the objects behavior. Not only would it be possible to assume that the objects could start moving again but that the presumably animate object interacts with the inanimate object. Thus, infants might analyze the behavior of the previously animate and inanimate acting objects. After all, infants were taught during familiarization that one object has animate attributes (ball) and one objects represents inanimate features (box). Thus, consider the following scenarios on infants' reasoning:

In the order of outcome condition 2_1 infants might have had the expectation that the ball would either moved again or that the ball would interact with the box during the first test trial. Since both objects stayed motionless infants maintained their expectation that the ball would move again in case the ball constituted the one-object display during the second test trial, whereas they did not look for the box to move or behave in an interesting way on its own. Therefore, infants paid less attention to the one-object display containing the box. In contrast, when the order of outcome was 1_2 infants awaited the ball to move again during the first test trial, but because the ball failed to do so this expectation diminished for the second test trial in which then both objects were present. In the condition in which the box was the single object in the first test trial, infants expected no action and hence spend little time watching this display. However, when the ball was visible with the box in the second test trial infant looked longer in anticipation of something interesting (ball interacts with the box). The data adumbrates that when the one-object display preceded the two-object display in baseline and test and the ball was the single object in the one-object display infants showed a slight trend to favor the ball display in test. No such preference was apparent for this order of outcome in the box condition. On the contrary, when the two-object display came in view before the one-object display during baseline and test trials infants tended to look longer to the two-object display in test. This was especially the case in the box condition. Thus, instead of engaging in object individuation and concentrating on the number of objects present or absent, infants might be more concerned with the objects' behavior. Due to the distinct motion information, concepts such as animacy and agency might have been activated in infants. According to Mandler (2004), characteristic types of motion such as self-instigated versus caused movement, regular versus irregular path of motion, and moving without any force acting on it versus made to move are the basis for the formation of the global concepts animate and inanimate in early childhood. Hence, rather than solving an individuation task by means of domain-specific motion patterns, infants might be occupied with expectations concerning the animate-inanimate distinction. Similarly, certain motion attributes displayed by the objects might suggest intentionality (Gergely & Csibra, 2003). Particularly the internal pulsation as well as the self-initiated reversal of trajectory identifying the animate object might have contributed to the impression that the animate object is an agent (see General Discussion p. 142 for further explanation). Nevertheless, the data is only suggestive and the sample sizes of these subgroups are small (N = 10). Therefore, this should not lead to any general conclusions. In order for the interpretation that infants reason about motion instead of the number of objects to hold, further research is needed. One way to investigate whether the kind information as presented in this set of studies is hindering infants to individuate is by giving clear information regarding the number of objects (Experiment 4). However, before, let us consider one methodological control. As mentioned earlier at this point it is not clear whether the baseline influenced infants looking behaviors in test (Experiment 3).

7.9 Summary

Taken together, the removal of form characteristics and the simplification of the task did not change the trend of results observed in Experiment 1. The findings of Experiment 2 indicate that even though infants make use of the information presented during familiarization, they have difficulty to individuate the objects in the present task by means of their kind information displayed in form of motion patterns. One aspect of the study design might interfere with the actual task to establish the number of objects. Problematic with the within-subject approach is that spatiotemporal information for two objects is given when presenting the two-object display in baseline. This might result in conflicting information available for infants to rely on. To avoid possible impacts of the information given during baseline calibration was done after the baseline phase. Nevertheless, the within-subject baseline might cause carry-over effects from baseline to test and therefore, influence infants’ reaction in test. Experiment 3 investigates this possibility.

CHAPTER 8

EXPERIMENT 3 – BASELINE CONTROL

8.1 Study Concept

Experiment 3 ascertains a possible influence of the baseline presentation on infants' looking behavior in test. After all a within-subject baseline in which the one- and two-object display are presented reveals strictly speaking spatiotemporal information about the number of objects. Theoretically, however, such a potential influence should have lead infants to the assumption that two objects are involved in the event with the result of longer looking to the one-object display in test. Nevertheless, infants showed a strong preference for two objects in Experiment 1 and 2. Partly this bias for two objects was already observed in baseline. Thus, one might argue that the intrinsic preference for longer looking at two objects might have swamped the effect of infant's expectation for two objects despite a break between baseline and the rest of the experiment that was inserted in the procedure of Experiment 2. To investigate this concern Experiment 2 is repeated without the baseline trials. Besides this modification the design and procedure were identical to Experiment 2. The study was done only with 12-month-old infants, because the two previous experiments did not yield any promising results for 10-month-olds. It is more likely to find out why infants prefer the two-object display in this set of studies when an age group is tested which is assumed to solve such a task. According to the literature, infants 12 months of age are supposed to individuate objects on the basis of kind information (e.g., Surian et al., 2004; Xu, 2003, 2007; Xu & Carey, 1996). In order to find out if the within-subject baseline contributed to infants' failure to individuate in the previous experiments and whether infants are able to individuate on the basis of distinct object motion pattern the task immediately starts out with the familiarization phase followed by the test trials. For the analyses test looking times of Experiment 3 are compared between subjects to the corresponding baseline looking times of Experiment 2.

8.2 Participants

A total of 22 infants who were 12 months of age participated in the study. Two infants were discarded from the final sample due fussiness. Infants who remained in the final sample ranged in age from 12 months, 01 days to 12 months, 26 days (mean age = 12 months, 9 days). All were full-term healthy babies and had no known visual or auditory abnormalities. Two infants sat on their parents' lab for the duration of the experimental session.

8.3 Stimuli

The PowerPoint Presentations employed in Experiment 2 was used in Experiment 3 with one modification. The baseline phase consisting of the one- and two-object display was deleted and left out of the experiment. Due to the missing baseline phase the presentation contained 50 slides instead of 59 slides and had a total length of 3 minutes and 27 seconds compared to 3 minutes and 83 seconds. Thus, each of the randomized PowerPoint Presentation began with the screen introduction (see Appendix F for a detailed description of the course of the experimental presentation).

8.4 Procedure

The order of events was except for the exclusion of the baseline phase exactly the same as in Experiment 2. Thus, the task started with the introduction of the screen in which the screen moved up and down. Thereafter, the presentation proceeded directly with the *familiarization phase*, followed by the outcomes of the test trials (see Experiment 2, p. 106 as well as Appendix E). The order of outcomes (1_2 versus 2_1) as well as the kind of single object (ball versus box) was randomized between subjects.

8.5 Scoring

The coding procedure was identical to Experiment 2.

8.6 Data Analysis

The statistical analyses of Experiment 3 were based on a final sample of 20 infants. Just like in Experiment 1 and Experiment 2 only infants who saw at least one complete sequence (i.e., emergence and return of both objects) over the course of the familiarization phase were included in the final sample. The dependent measure was once more infant's looking time, as indexed by the cumulative duration of their visual fixation to each of the baseline and the test slides. Analyses were completed with the mean looking times of coder A and B. Inter-observer reliability for baseline and test looking times was assessed by Person r. The reliability for the coding times of coder A and coder B was $r = .95$ in Experiment 3, reaching significance at the 0.01 level (2-tailed)[32].

Because there was no baseline in Experiment 3, the comparison of looking times toward the one-object and the two-object displays in baseline and test trials was done by checking the test trials from Experiment 3 against the baseline trials from Experiment 2 in order to examine the hypothesized influence of a within-subject baseline. Thereby, the data was matched according to gender, order of outcomes condition, and the kind of single object that was presented in the one-object display.

Preliminary Analyses

As in the preceded experiments preliminary analyses were performed to check for gender effects, and a possible influence of the counterbalanced factors order of outcomes (1_2 versus 2_1) and the kind of single object in the one-object displays (ball in the one-object display versus box in the one-object display). Neither a gender effect was observed nor did the counterbalanced factors order of outcomes and kind of single object reveal an influence on the interesting variables in this experiment.

[32] All statistical tests reported in Experiment 3 are two-tailed.

Therefore, data of male and female infants were combined for all analyses and because the between-subject factors had no major impact on the variables of interest no subsequent analyses are reported for Experiment 3.

8.7 Results

Main Analysis

A 2 (trial) x 2 (number of objects) repeated measures analysis of variance (ANOVA) was conducted to determine if a baseline presentation affects infants expectations regarding the number of objects in an object individuation task. If this was the case, 12-month-old infants' would be expected to show a different outcome of results as in Experiment 2. By implementing a between-subject baseline-test comparison, Experiment 3 reassesses the within-subject design of Experiment 2. Trial (baseline versus test) and number of objects (one versus two objects) served as within-subject factors. Looking times to the one- and two-object display obtained in baseline trials from 12-month-old infants of Experiment 2 were compared with the ones retained in test trials of Experiment 3. The ANOVA solely revealed a significant main effect for number of objects $F(1, 19) = 15.89$, $p = .001$, $\eta^2 = 0.46$. Mean looking times displayed in Table 5 demonstrate that overall infants of both age groups preferred the two-object display.

Table 5: *Mean Looking Times (in seconds) and Standard Deviations of Experiment 3: Main Analyses with Trial and Number of Objects as Within-Subject Factors*

	Mean	Standard Deviation	N
Baseline 1 Object	7,97	2,77	20
Baseline 2 Objects	9,13	3,24	20
Test 1 Object	8,11	2,75	20
Test 2 Objects	10,55	2,66	20

No other effects reached significance. Figure 15 below plots the results obtained in Experiment 3.

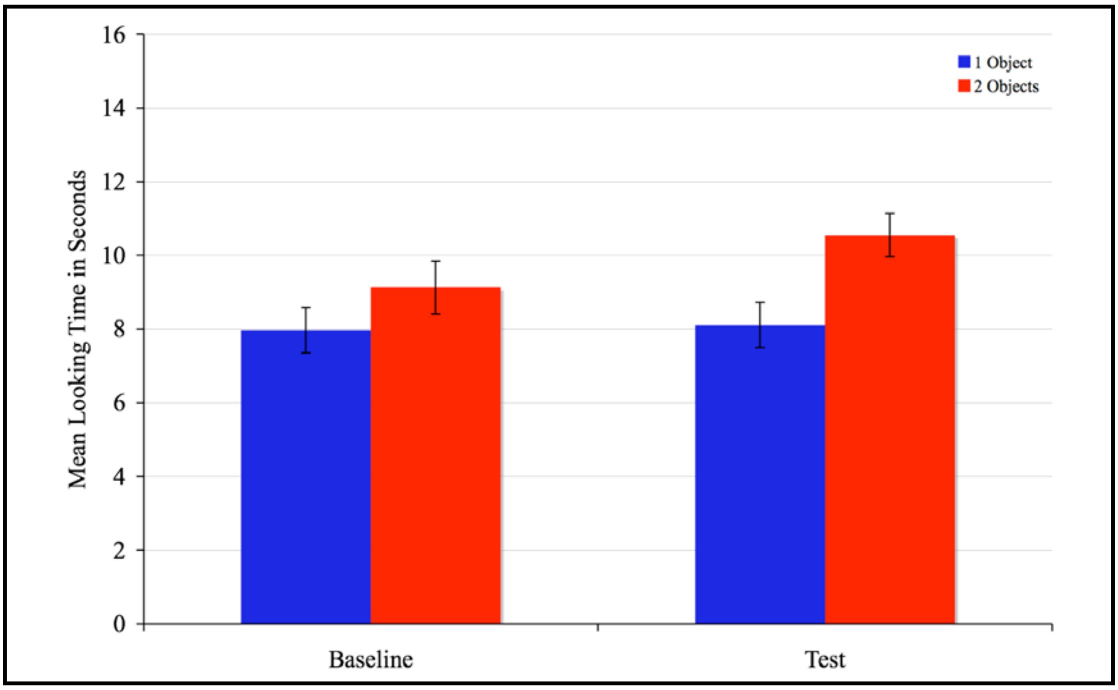

Figure 15. Results of Experiment 3 (N = 20): Mean looking times of 12-month-old infants to the 1 Object versus 2 Object display in Baseline (data from Experiment 2) and Test (data from Experiment 3)

This outcome is in accordance with the findings in Experiment 1 and Experiment 2. Additional reviewing of the test looking times toward the one-object display and the two-object display independent of any baseline trials established that the preference for the two-object display held up. A T-Test analysis of the looking times to either display in test resulted in longer looking to the two-object display ($M_{1\ Object}$ = 8.10, $SD_{1\ Object}$ = 2.75; $M_{2\ Objects}$ = 10.55, $SD_{2\ Objects}$ = 2.66), $t(19) = -4.02$, p = .001. Thus, after solely viewing the familiarization trials 12-month-old infants did not show any surprise when there was just one object presented.

8.8 Discussion of the Results

Despite a between-subject baseline, 12-month-old infants still preferred to look at the two-objects display in Experiment 3. This indicates that even without prior information about the possible number of objects behind the occluder, infants were not surprised when just one object was visible during test after viewing two objects engage in domain-specific movements. The general finding that 12-month-old infants show no sign of object individuation on the basis of domain-specific motion patterns remains even when test looking times are checked against between-subject baseline measures and thus, the analyses followed Xu and Carey’s (1996). Therefore, it can be concluded that a within-subject baseline is probably not the reason for a failure to solve the task and individuate the objects involved in the familiarization event by means of their domain-specific motion pattern. This leaves open the possibility that the stimuli facet motion pattern interferes with infants reasoning about the number of objects involved in the events. It might be that the fact that the objects engage in domain-specific movement distracts from the original task, namely establishing the number of objects, which go in and out of sight. Infants 12 months of age have been repeatedly shown to be able to solve an object individuation task in different settings and with a variety of stimuli (e.g., Baillargeon, 2004; Xu and Carey, 1996). Therefore, it might be that infants reason about motion instead of solving the individuation problem in the task at hand. One way to test this is by running a control condition in which spatiotemporal information is provided. Research has demonstrated that independent of task and stimulus material infants from as early as 3 months of age are able to individuate objects on the basis of spatiotemporal information. This question is investigated in Experiment 4.

Even though a within-subject baseline has been found to not influence infants’ reaction to the one or two-object display, the findings suggest that it leads to an influence of the counterbalanced factors order of outcomes and kind of single object. When implemented within subjects as in Experiment 1 and Experiment 2, the baseline trials seemed to trigger different expectations depending on the order of outcomes and the kind of single object used. In Experiment 3 in which no baseline trials were shown such impact could not be registered in the analyses. Nevertheless, because it depends on the sample if infants show a preference for two objects in baseline trials (see results of the main analyses in Experiment 1 and Experiment 2 a within-subject baseline procedure is not only justified but actually strongly needed. For that reason and in order to ensure comparability, Experiment 4 uses the same procedure as Experiment 2.

8.9 Summary

Experiment 3 can be summarized as follows: 12-month-old infants did not show any sign of object individuation even when they did not view any baseline trials and their looking times in test were compared to baseline measures from a different sample of infants. Successful object individuation would have been indicated by longer looking to the one-object display in test compared to corresponding looking times in baseline trials. Instead 12-month-old infants in Experiment 3 looked overall longer to the two-object display. Thus, infants 12 months of age failed to solve the individuation task in a between-subject design where their looking responses in test could have not been influenced by a baseline presentation. Hence, including a within-subject baseline does not explain the failure of 12-month-old infants to apply domain-specific motion information as an individuation factor. However, it does not seem free of influence either, because it removed most of the between-subject factors (order of outcome and kind of single object) impacts. Thus, the motion information provided might have obstructed infants to solve the individuation task. Motion is a very salient feature and might activate other cognitive processes or concepts infants reason about. Thus, Experiment 4 tests whether motion information might divert from the task. For reasons of comparability Experiment 4 maintains the general procedure even though the factors of order of outcomes and kind of single object had an influence on infants looking times in the previous studies.

CHAPTER 9

EXPERIMENT 4 – SPATIOTEMPORAL CONDITION CONTROL

9.1 Study Concept

Experiment 4 addresses the question whether 12-month-old infants are able to solve the task at hand when spatiotemporal information is given in addition to kind information. Research on object individuation showed that spatiotemporal information is the first and most important type of information that young infants base their inferences on when establishing how many objects are involved in an event. Thus, they should be able to solve this task because they do so in other studies regardless of the procedure and stimuli used. In order to test whether the so far reported failures are due to an inability to individuate objects on the basis of domain-specific motion patterns or because of methodological issues, Experiment 4 provides infants spatiotemporal information that there two distinct objects are involved in the event.

9.2 Participants

A total of 25 infants 12 months of age participated in Experiment 4. Five infants were discarded from the final sample due to experimenter error (2) and fussiness or crying (3). Infants constituting the final sample ranged in age from 12 months, 00 days to 12 months, 29 days (mean age =12 months, 17 days). All were full-term healthy babies and had no known visual or auditory abnormalities. Two infants sat on their parents' lab for the duration of the experimental session.

9.3 Stimuli

Experiment 4 used the PowerPoint-Presentations of Experiment 2 with one critical modification. In order to provide infants with spatiotemporal information a slide in which both objects appear beside the left and right side of the occluder was inserted into the presentation. After the baseline phase and the introduction of the screen the ball jumped out to the left and the box moved to the right on a linear path. This scene was repeated right before the second familiarization. The timing of ball and box movement was coordinated and both objects remained in sight for 5 seconds before a transition was made to the familiarization phase via a black slide. Due to the additional slides before each familiarization phase the presentation contained 63 slides instead of the original 59 slides and had a total length of 4 minutes and 23 seconds compared to 3 minutes and 83 seconds.

9.4 Procedure

Even though order of outcome has a hard to interpret influence on infants looking times, for reasons of comparability the order of events was the same as in Experiment 2 besides in respect to one important difference. The task started out with the baseline phase in which the one- and two-object outcomes were shown. This presentation was followed by the introduction of the screen. Thereafter, a scene in which the occluder stood in the center of the slide and both objects moved simultaneously to the left and the right of the occluder was shown (spatiotemporal information slide). After 5 seconds in which the objects remained in sight without any motion the presentation proceeded with the *familiarization phase*. After test trial one the spatiotemporal information slide was repeated before the experiment continued as described before (see Experiment 2, p. 106). The order of outcomes (1_2 versus 2_1) as well as the kind of single object (ball versus box) was randomized between subjects.

9.5 Scoring

The coding procedure was identical to Experiment 2.

9.6 Data Analysis

The statistical analyses of Experiment 4 were based on a final sample of 20 infants. As in the other experiments only infants who saw at least one complete sequence (i.e., emergence and return of both objects) over the course of the familiarization phase were included in the final sample. The dependent measure was again infant's looking time, as indexed by the cumulative duration of their visual fixation to each of the baseline and the test slides. Analyses were completed with the mean looking times of coder A and B. Inter-observer reliability for baseline and test looking times was assessed by Person r. The reliability for the coding times in Experiment 4 was $r = .98$. This correlation is significant at the 0.01 level (2-tailed) [33].

Preliminary Analyses

As in the preceded experiments preliminary analyses were performed to check for gender effects, and a possible influence of counterbalanced factors in the design (order of outcomes (1_2 versus 2_1) and the kind of single object in the one-object displays (ball in the one-object display versus box in the one-object display). Again no gender effects[34] were found. Preliminary analyses checking the impact of the counterbalanced factors revealed an influence of both factors, which subsequent analyses will examine.

9.7 Results

Main Analysis

A 2 (trial) x 2 (number of objects) repeated measures analysis of variance (ANOVA) was conducted to determine if the provision of spatiotemporal information affects infants expectations regarding the number of objects in an object individuation task. If this was the case 12-month-old infants' would be expected to show a different pattern of results as in Experiment 2. Trial (baseline versus test) and number of

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[33] All statistical tests reported in Experiment 3 are two-tailed.
[34] Thus, male and female infants were combined for all analyses.

objects (one versus two objects) served as within-subject factors. Looking times to the one- and two-object display obtained in baseline trials were compared with the ones retained in test trials. The ANOVA revealed a significant main effect for trial $F(1, 19) = 15.35$, $p = .001$, $\eta^2 = 0.45$ and one for number of objects $F(1, 19) = 19.33$, $p \leq .000$, $\eta^2 = 0.50$. Overall, infants watched the test trials longer compared to the baseline trials and preferred to look at the two-object display altogether (cf. Table 6 and Figure 16). This outcome is in accordance with previous findings in this set of studies.

Table 6: *Mean Looking Times (in seconds) and Standard Deviations of Experiment 4: Main Analyses with Trial and Number of Objects as Within-Subject Factor*

	Mean	Standard Deviation	N
Baseline 1 Object	6,28	2,32	20
Baseline 2 Objects	7,79	3,34	20
Test 1 Object	8,13	2,73	20
Test 2 Objects	10,59	3,91	20

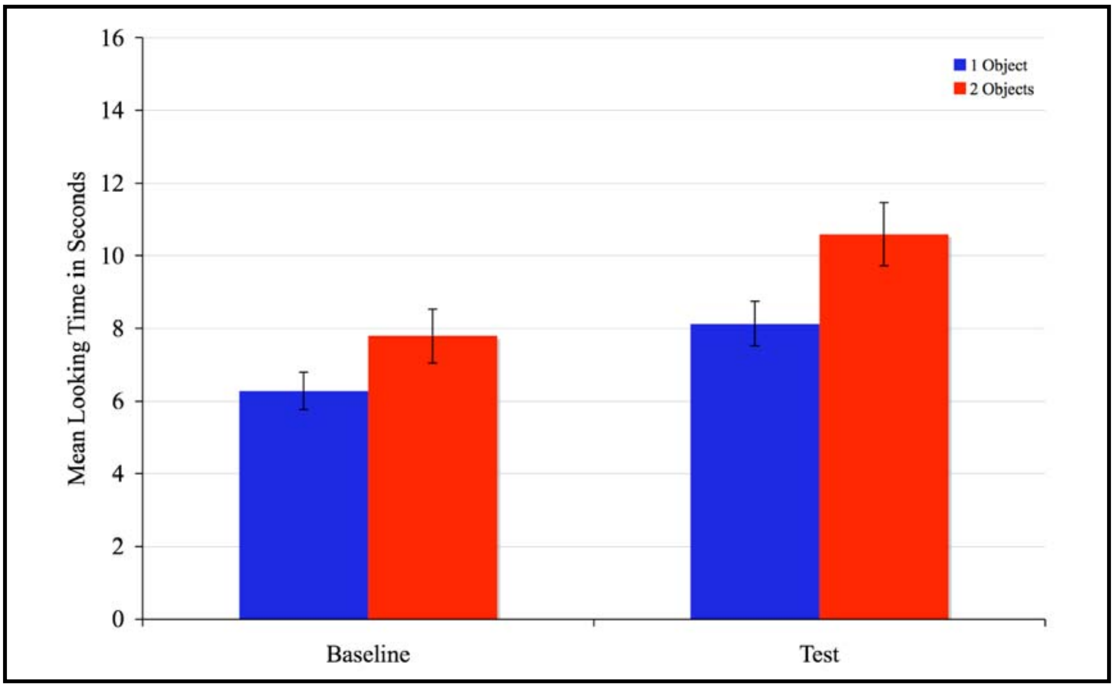


Figure 16. Results of Experiment 4 (N = 20): Mean looking times of 12-month-old infants to the 1 Object versus 2 Object display in Baseline and Test

Subsequent Analyses

The influence of the factors order of outcomes and kind of single object was assed by a 2 (trial) x 2 (number of objects) x 2 (order of outcomes) x 2 (kind of single object) repeated measures mixed model analysis of variance (ANOVA) with trial (baseline versus test) and number of objects (one versus two objects) as within-subject factors and order of outcomes (1_2 versus 2_1) as well as kind of single object (ball in the one-object display versus box in the one-object display) as between-subject factors. In addition to the main effects of trial $F(4, 16) = 14.99$, $p = .001$, $\eta^2 = 0.48$ and number of objects $F(4, 16) = 19.44$, $p \leq .000$, $\eta^2 = 0.55$ this calculation generated a marginal three-way interaction between trial, number of objects, and order of outcomes $F(4, 16) = 3.54$, $p = .078$, $\eta^2 = 0.18$. Follow up T-Tests suggested that infants looked longer at the two-object display in test when the order of outcome was 2_1. Table 7 shows mean looking times and standard deviations for these analyses.

Table 7: *Mean Looking Times (in seconds) and Standard Deviations of Experiment 4: Subsequent Analyses with Trial and Number of Objects as Within-Subject Factors and Order of Outcomes and Kind of Single Object as Between-Subject Factors*

	Order of Outcomes	Single Object Kind	Mean	Standard Deviation	N
Baseline 1 Object	12	Ball	6,49	2,00	5
		Box	5,30	1,25	5
		Total	5,89	1,69	10
	21	Ball	8,72	2,37	5
		Box	4,61	1,52	5
		Total	6,67	2,87	10
	Total	Ball	7,60	2,38	10
		Box	4,95	1,36	10
		Total	6,28	2,32	20
Baseline 2 Object	12	Ball	7,33	3,02	5
		Box	8,26	4,92	5
		Total	7,80	3,88	10
	21	Ball	9,49	2,60	5
		Box	6,06	2,22	5
		Total	7,78	2,91	10
	Total	Ball	8,41	2,89	10
		Box	7,16	3,78	10
		Total	7,79	3,34	20
Test 1 Object	12	Ball	8,43	2,45	5
		Box	7,34	1,73	5
		Total	7,88	2,08	10
	21	Ball	10,12	2,63	5
		Box	6,64	3,29	5
		Total	8,38	3,35	10
	Total	Ball	9,27	2,56	10
		Box	6,90	2,50	10
		Total	8,13	2,73	20

Test 2 Objects	12	Ball	9,36	4,74	5
		Box	8,33	2,89	5
		Total	8,85	3,74	10
	21	Ball	13,23	2,21	5
		Box	11,46	4,37	5
		Total	12,34	3,39	10
	Total	Ball	11,29	4,04	10
		Box	9,90	3,86	10
		Total	10,59	3,91	20

The following Figures 17 and 18 chart the findings of Experiment 4's subsequent analyses.

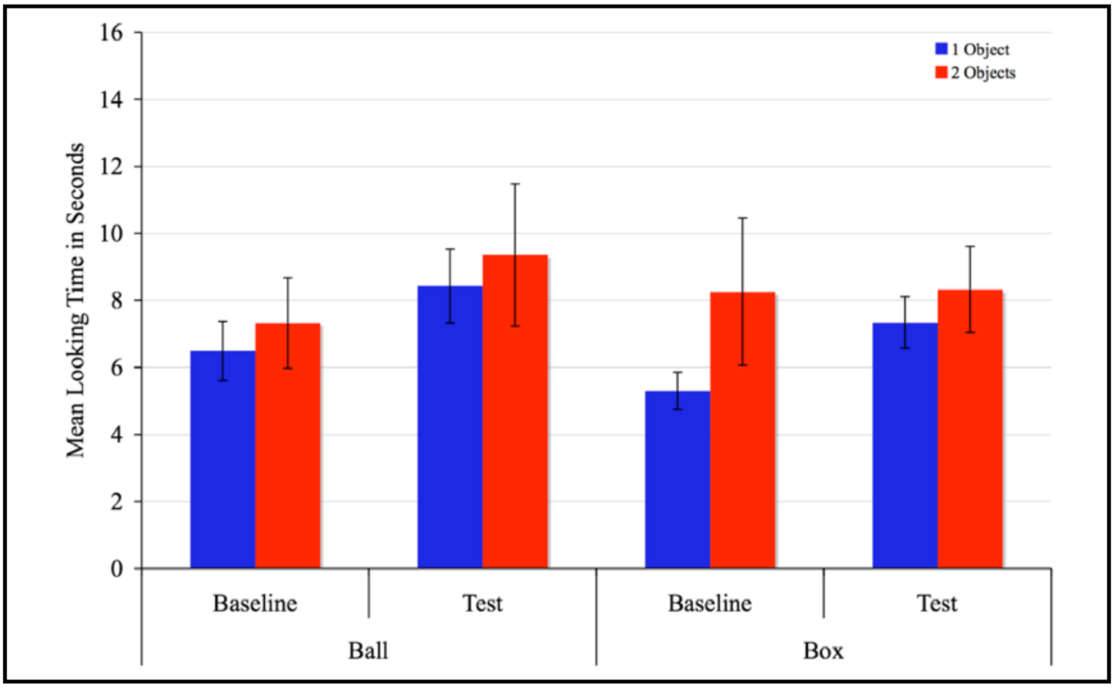


Figure 17. Results of Experiment 4 with order of outcome and kind of single object as between-subject factors (N = 20): Mean looking times of 12-month-old infants to the 1 Object versus 2 Object display in Baseline and Test depending on kind of single object in order of outcome 1_2.

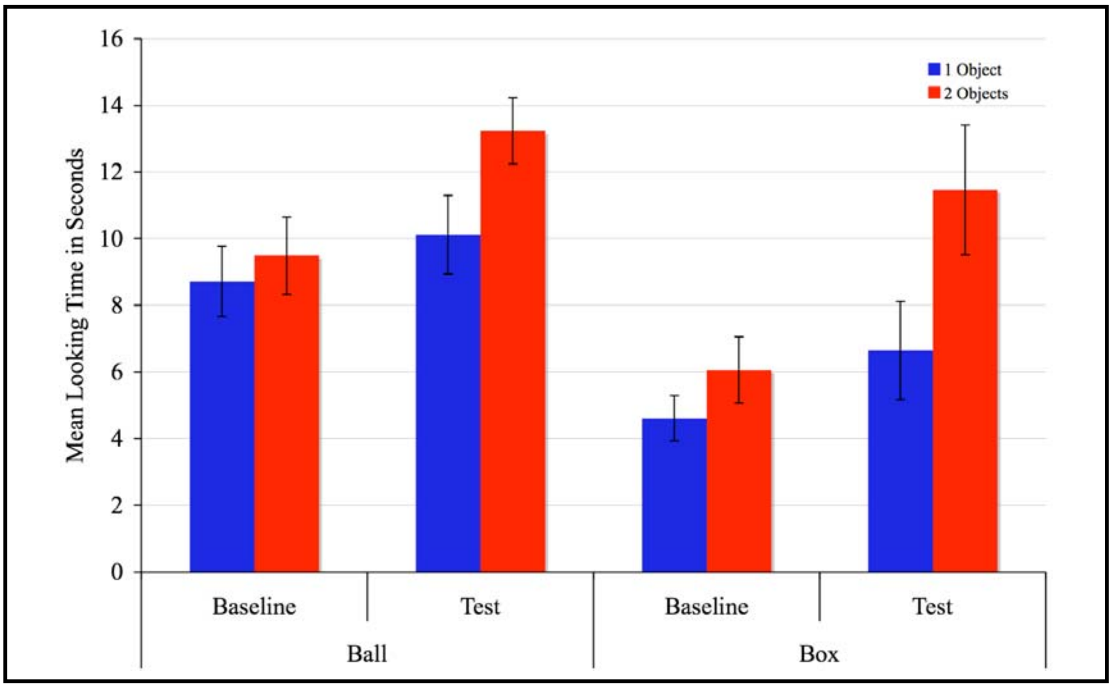


Figure 18. Results of Experiment 4 with order of outcome and kind of single object as between-subject factors (N = 20): Mean looking times of 12-month-old infants to the 1 Object versus 2 Object display in Baseline and Test depending on kind of single object in order of outcome 2_1.

Besides these within-subject effects the between-subject factor kind of single object reached marginal significance $F(4, 16) = 3.857$, $p = .067$. Overall, infants tended to look more when the ball rather than the box constituted the single object in the one-object display.

9.9 Discussion of the Results

The findings of Experiment 4 make clear that even when spatiotemporal information is provided 12-month-old infants do not solve the individuation task at hand. Consistent with the previous experiments, infants prefer to look overall longer at the two-object display instead of showing surprise when only one object is present. In light of the literature on object individuation it is unlikely that infants cannot use the spatiotemporal information given in this task. When presented with spatiotemporal information provided by seeing two objects simultaneously before the familiarization emergences began in Xu and Carey's (1996) event-mapping task both 10- and 12-month-old infants succeeded. A wealth of studies differing in stimulus material and procedure provide evidence that infants as young as 3.5 months of age are able to establish the number of objects participating in an event by means of spatiotemporal information (e.g., Aguiar & Baillargeon, 2002; Spelke, et al., 1995; Wilcox, Schweinle, & Chapa, 2003). How can this failure be explained then? The speculative assumption that infants do not engage in object individuation but rather process the information under the aspect of animacy/ agency might not be as false after all. The absence of longer looking times to the one object display in test could hint that the domain-specific motion information expressed through the objects' distinct external and internal movements overrides the intended individuation task. Instead of being concerned about the number of objects present infants might reason about animate-inanimate relations. The familiarization phase might not build up the expectation that there are two objects involved in the motion event, which in turn would lead to a surprise in case only one object is present behind the screen. Rather the motion sequences might lead to expectations about animate and inanimate objects. The following general discussion will take up this idea again and present research in favor for this hypothesis as well as methodological considerations that might likewise lead to the existent pattern of results.

9.10 Summary

Twelve-month-old infants did not show any sign of object individuation in Experiment 4. Thus, even under circumstances where spatiotemporal information is provided infants who normally individuate objects at this age and with the information given were not bale to do so in the present task. Possible reasons for the obtained results are discussed alongside with conclusions and future directions in the following chapter.

IV INTERPRETATIONAL PART

CHAPTER 10

GENERAL DISCUSSION

The purpose of the present work was to investigate 10- and 12-month-old infants' application of domain-specific motion patterns in the process of object individuation. The main question concerned whether infants could use kind information, i.e. animate and inanimate motion characteristics to guide their identification of the number of entities involved in an event. In particular, the hypothesis implied that 10- and 12-month-old infants' would show the ability to individuate objects on the basis of kind information if such information taps on underlying conceptual knowledge about objects and thus, provides essential aspects about the subjacent differences of distinct kinds of things. The assumption that infants as young as 10 months of age are able to determine the number of objects in an event by means of their domain-specific motion patterns was based on the central role of motion information for object perception as well as its relevance for the conceptual distinction of animate and inanimate objects from early on. Xu and Carey's (1996) results indicated that infants under the age of 1 year are unable to identify objects on the basis of non-spatiotemporal properties. This in turn is viewed to be the reason why infants fail to exploit property changes for the purpose of object individuation. However, since motion activates concepts about object kinds already under the age of 1 year (cf. Chapter 3.2), it could be that younger infants assign kind information about animate and inanimate objects to entities they experience in events. Hence, the relation between animate-inanimate motion features and the distinction of living and non-living entities should guide 10- and 12-month-old infants' looking behavior to a one- or two-object display depending on the information available about the objects.

10.1 Discussion of Results

In sum, the results of the present set of studies do not speak for a contribution of motion information to the individuation capacity of 10-month-old infants. Surprisingly, neither upon the presentation of a combination of featural appearance and domain-specific movement properties in form of distinct moving realistic looking toy replicas (Experiment 1) nor under conditions in which motion alone represented the critical kind difference (Experiment 2) did 10- and 12-month-old infants prove that they were able to establish the number of objects involved in the motion sequences. Both age groups failed to demonstrate successful object individuation in the present task. The discussion of Experiment 1 lead to the conclusion that object complexity put constrains on infants information-processing capacities. Thus, in order to diminish distraction, object features were reduced to a minimum in Experiment 2 by removing animate and inanimate form attributes. Kind information was solely presented through movements, typifying animate and inanimate entities. Self-propulsion, irregular path, and pulsating inside were the hallmarks for the animate object. Onset of motion upon contact, linear path, and motion less inside were the properties signifying the inanimate object. Besides the variations in motion characteristics, no additional information was given that allowed conclusions regarding object kind. Especially in Experiment 2 the ability to individuate simple objects according to their domain-specific kind information represented by distinct motion characteristics should have become apparent at least in 12-month-old infants. However, just like in Experiment 1, 10- and 12-month-old infants showed an overall preference for the two-object display. The assumption that the presentation of the one- and two-object display during the baseline phase might have adversely affected infants' looking behavior during test trials, was weakened by Experiment 3. Even without the presentation of the baseline outcomes 12-month-old infants preferred to look at the two-object display in test. Further, the looking patterns did not change under conditions of a between-subject comparison. This does not rule out, however, that a baseline preference for the two-object outcome as evident in some experiments influences infants' ability to individuate objects (Xu & Carey, 1996). It is possible that infants do use domain-specific motion information for object individuation but they have difficulties to demonstrate object individuation in the present experiments. Consistent with this reasoning are the results of Experiment 4: the application of spatiotemporal information did not alter infants' reaction to the test outcomes. Maybe the method implemented here was not sensitive enough to measure the application of motion kind information in object individuation. Particularly, infants' failure to make use of spatiotemporal information in Experiment 4 could be an indication for methodological problems leading to a theoretical explanation concerning the utilization of motion information as kind information in this task. Several lines of argumentation consisting of reasons that potentially account for the results obtained in the set of studies are proposed. These arguments focus on methodological as well as theoretical aspects. The following questions need to be answered: Did the task test what it intended to test? Do these results show that infants are unable to individuate objects by means of domain-specific motion information? What additional data might be needed to sufficiently answer this question? These issues are consecutively discussed in the following section.

Above all, let us point to some procedural difficulties and limitations of the method used in the current study, which may have contributed to the absence of results conform to the hypothesis. The methodological argumentation is two-fold and addresses issues of (1) experimental procedure, and (2) task-demands. First, as discussed in Experiment 3 it is unlikely that the within-subject baseline caused the failure of infants to individuate the objects. Even without prior information about the possible number of objects behind the occluder, infants were not surprised when just one object was visible during test after viewing two objects engage in domain-specific movements during a motion event. On top of this, there was no shift in looking time toward the unexpected one-object outcome in a between-subject comparison. However, strong order of outcomes effects through out the series of experiments might point to an influence of the information given during the first test trial on infants' looking times in the second test trial. The second familiarization phase might have been not sufficiently long enough to avoid such an influence. Previous studies by Xu and her colleagues or Wilcox and Baillargeon and their fellows did not report such order of outcome effect (e.g., Xu & Carey, 1996; Wilcox & Baillargeon, 1998b). Several reasons could account for this. One is that some of these studies presented and compared different outcomes between subjects (e.g., Wilcox & Baillargeon, 1998b). This eliminates the impact of the order of outcomes factor. In the studies on hand both outcomes are presented to infants. More importantly though motion information as specified in the current studies was not involved in other investigations. As discussed below, the special motion attribute in this line of research might have caused certain expectations that were either fulfilled in the first test trial or not. Depending on the outcome infants' prospects regarding the second test trial might have changed (see p. 144 for further explanation).

Second, the current set of studies researched the role of kind-specific motion information on object individuation in an event-mapping task. Despite concerns of high-processing demands this type of task was chosen for this investigation because the goal of the studies was to test the role of conceptually relevant kind information (domain-specific motion characteristics) on the process of object individuation. The event-mapping task proved to measure such sources of information (e.g., Krojgaard, 2007; Surian et al., 2004; Wilcox & Baillargeon, 1998b, Experiment 2; Xu, 2007; Xu & Carey, 1996). It has been discussed elsewhere (Xu, 2007) that simplified tasks although less demanding tap on other sources of information for individuation (i.e., spatiotemporal information and property information), which were not in question in the current set of studies. If any spatiotemporal evidence for one object (usually generated by the illusion of an oscillating single trajectory)[35] was given in the present task should have been overcome at least by 12 months of age due to kind concepts that strongly suggest two objects (Xu, 2007). Nevertheless, infants might have been overwhelmed or even confused by the amount of information available considering the complexity of the task itself as well as the significant volume of additional information (i.e., appearance (property/ featural) and/ or motion (kind) information) available. One way to simplify the task without changing it to an event-monitoring task is to reduce the reversals of trajectory (Wilcox & Baillargeon, 1998b). Instead of presenting four reversals per object it might be sufficient to only have one or two reversals per object. Nevertheless, in contempt of all the changes between the four experiments a rather stable pattern of results occurred which suggests contingencies. Continuity of this kind speaks either for a (1) complete failure to apply the information provided during familiarization and to solve this task or (2) it points to divergent processing of the obtainable information. The subsequent theoretical

[35] The distinct motion patterns/ paths of the objects in the present task might have reduced the illusion of an oscillating single trajectory. However, on the other hand one cannot rule out the possibility that by directing attention to the path of motion such a perception might have been increased. Infants could have perceived the two objects as one object that changes its motion behind the screen. See arguments against this possibility and further explanation below.

discussion centers around these two possibilities and focuses on problems the nature of kind information, implemented in these experiments, involves.

Could it be that infants do not distinguish the objects? Maybe strong spatiotemporal evidence for the presence of one-object that comes with complex tasks overrides the featural/ property information carried by the objects? Even though an investigation of this alternative remains to be done for the material used in the experiments on hand, other work controlled for this possible variant. For instance, Xu and Carey (1996, Experiment 3) directly tested whether infants noticed the property differences between the objects employed in their task. They found that infants detected the perceptual difference between each pair of objects. Apart from studies on object individuation, there is a vast number of investigations concerned with object perception, object discrimination, or object categorization that provide evidence that from early on infants successfully differentiate and categorize both simple forms as well as complex entities (see Goswami, 2008; Pauen, 2006 for overviews). Still in Xu and Carey's study infants failed to use this information to infer that there were two objects behind the screen. The authors claimed that differentiating objects by noticing property variations is a conceptual different task than setting up representations of numerically distinct individuals (Xu & Carey, 1996). Hence, it seems natural to think that infants showed a similar inability to make use of the information in the present task. However, Wilcox and Baillargeon (1998 a, b) chose simple stimulus material (a ball and a box) in their studies and provided evidence for object individuation and thus, object discrimination in infants as young as 4.5 months. According to the authors infants based their reasoning on featural differences between the objects. Instead of being unable to use property information, Wilcox and Baillargeon (1998b) held task demands accountable. Nonetheless, even though an inability to make use of specific sources of information might not only hold for perceptual information, it might be applicable to conceptual information about object kind. In the present experiments, infants could have had trouble connecting motion information made available in the task and previously acquired knowledge about animate and inanimate objects which would lead to the conception of two objects and thus, to a violation of expectation in case only one object is displayed. Experimental evidence provided by Bahrick et al. (2002) supports the view that properties of objects are less well encoded than the events in which they are presented. In their study they showed that memory for dynamic aspects (actions) of events is more enduring than memory for static ones such as the objects used for carrying out the actions, which 5.5-month-olds did not remember. For example, infants did not seem to notice if the actor was shown brushing her hair with the bubble wand instead of the hairbrush originally used. However, same aged infants discriminated and remember various actions such as brushing hair, brushing teeth, or blowing bubbles (Bahrick et al. 2002). This indicates that infants represented the event but not the details of the objects used in the events. Thus, these findings give rise to the hypothesis that infants may remember activities differently than objects or forms. Thereby memory may depend on whether they have categorized the activities and/ or the objects. Thus, when dynamic displays are used in infant tasks, it is possible that infants construe the events in a somewhat holistic fashion without attending to the particulars of the objects in the events (Mandler & McDonough, 1998, 2000). In a follow up study Bahrick and Newell (2008) tested an additional salience hypothesis. They found that discrimination for action was more robust in 5- and 7-month-old infants compared to dynamic faces. Faces were discriminable but actions were more salient and therefore competed for attention, which lead to the failure of discriminating and remembering faces and objects in the context of actions as demonstrated by Bahrick et al. (2002). A variety of studies speak to the contrary, though. Research on conceptual development demonstrate that during the second half of their first year of life, infants not only to reason about their environment based on acquired knowledge, but also use conceptions to make inferences about object properties, object relations, and object behaviors (e.g., Goswami, 2008 for an overview; Mandler, 2004; Träuble & Pauen, 2004; Pauen, 2002). Besides, instead of showing humans in action, the studies on hand featured simple events in which the objects performed the actions themselves. Further, two findings in the present line of studies point to a discrimination of the stimuli as well as the usage of information. One is the observation that some infants jumped up and down in the highchair during the motion events when the ball was visible. They remained still in the box sequence. It is unclear what motivated infants to do so[36], but in any case they only expected the animate object to jump and thus, not only discriminated the objects but applied a specific behavior to only one of the objects. The other finding is the different looking pattern depending on the factor of order of outcomes hint at infants' application of the familiarized information.

[36] It could be that infants learned that the animate object jumps and expected it to do so again.

But in what way did infants use certain cues in test? Did they focus on the number of objects present or were they distracted by the objects' motion directing them to expectations about animacy. As a package the studies raise doubts on the validity of the task. It is possible that not object individuation was measured with the procedure employed but rather infants' expectations about object motion, animacy, or agency. According to Goswami (2008) animacy is most strongly perceived when objects change direction or speed of motion. Speed of motion was constant in the present experimental procedure. However, the animate object changed direction by reversing its trajectory without an external cause. While form of motion (self-propulsion) as well as from of action cause (external or internal causation) are important criterions when distinguishing animates from inanimates (and thus, such actions were purposely designed), they might bring about the expectation that this object will move again at a later point in time. As evaluated in Chapter 3.2 self-propelled motion is one of the most powerful signs for animacy (Gelman & Spelke, 1981; Mandler, 2004; Premack, 1990; Rakison & Poulin-Dubois, 2001). On top of this, researchers proposed that self-initiated movement changes are seen as intentional and that they activate the perception of objects as agents with goals and desires (Leslie, 1994; Premack, 1990). Hence, apart form being perceived under aspects of animacy, perceptual displays can also be seen as causal and intentional. The notion of agency entails an understanding of intention and goal-directedness (Leslie, 1994, Gergely et al., 1995).

Is there evidence for this ability in 12-month-old or even younger infants? Can we assume that infants capable of goal attribution to non domain-specific, abstract material? Two views regarding the early reasoning about goals prevail. One account suggests that infants' ability to attribute goals develops as a result of their experiences with human agents (e.g., Meltzoff, 1995, 2002; Tomasello, 1999; Woodward, Sommerville, & Guajardo, 2001). Initial studies reported that 9-, 6-, and in some cases 3-month-old infants already perceive actions as goal directed (e.g., Woodward, 1998; Kamewari, 2005; Somerville et al., 2005). However, although young infants have the competence to assign goals, they only do so to human agents and it is not until later that they gradually extended their knowledge to other non-human agents. For instance, 9- and 6-month-old infants successfully encode aspects of actions that are relevant to the goals of a human agent. Under certain circumstances, namely early action experience even 3-month-old infants are able to detect the goal structure of actions supporting them in their interpretation of an agent's goals (Somerville et al., 2005). Therefore, this early goal attribution competence is according to this research restricted to human or human-like agents (Kamewari, 2005; Woodward, 1998). The second approach proceeds on the assumption that goal attribution is rooted in a specialized system of reasoning that is activated whenever infants encounter entities they, based on appropriate features such as self-propulsion, contingent interaction, or non-rigid movements identify as agents (Baron-Cohen, 1995; Gergely et al., 1995; Johnson, 2000, 2003; Leslie, 1995; Luo & Baillargeon, 2005; Premack, 1990). Thus, ascribing agency is independent of familiarity with actors and actions but rather depends on whether or not evidence for the presence of an agent is available (teleological stance, see Csibra, 2008). Luo and Baillargeon (2005) tested these two notions by familiarizing 5-month-old infants with a self-propelled box approaching consecutively one of two objects. In test the target of action was changed and infants' recovery to the events was measured. The results demonstrated that infants looked reliably longer to the new- than the old-goal event when given clear evidence (here through self-initiated motion) that the actions were internally caused and thus, signalized the presence of an agent (Luo & Baillargeon, 2005). Studies by Gergely et al. (1995) as well as Csibra (2008) extended these findings to other motion cues such as expansion and contraction, as well as goal-directed spatial behavior. Whereas the studies on hand used motion characteristics to represent objects as animate and inanimate kinds in order to examine infants ability to individuate, Gergely and his colleagues incorporated simple motion cues to test infants' attributions of agency. The researchers showed that 12-month-old infants generated expectations about the particular actions (approaching, retreating, jumping and contact with another object) an assumed agent was likely to perform to achieve a desired goal. Further, when tested on these expectations infants applied them in a way that speaks for their intentional causal analysis of the initial display. In a very recent article, Csibra (2008) reported that even infants 6.5 months of age attributed goals to an inanimate box if it shows variability of behavior. The results illustrate that featural identification of agents is not a necessary precondition of goal attribution in young infants and that the single most important behavioral cue for identifying a goal-directed agent is choice of action (Csibra, 2008; Johnson et al., 1998; Luo & Baillargeon, 2005). Together, these studies provide support for the teleological stance, i.e. that from an early age infants assign goals to any entity (even an inanimate geometric object) as long as information is provided that allows them to identify the object as an agent. Hence, motion contributes not only to the distinction of living and non-living kinds, it also tells agents apart from other physical objects, enabling adults as well as infants to attribute goals to movements and mental causes for goal-directed behavior, even if the displays consist of simple moving cartoon figures or geometric shapes (Csibra, 2008; Gergely et al., 1995; Tremoulet & Feldman, 2000, and Scholl & Tremoulet, 2000 for evidence in adults). Thus, infants perceive animate beings as having intentional mental states that govern certain behaviors but also represent their features such as self-initiated movement or variability in action as cues for agency. In relation to the present research, infants might have analyzed the events under the premise of agency. The variability in jumping behavior, the self-initiated change of path, as well as the expansion and contraction of the ball's inner part might have given rise to the presumption that the animate object is an agent. Instead of reasoning along the lines of a mere animate-inanimate distinction, infants might have applied an "intentional stance" to the ball's behavior. Looking at the findings of the current set of studies this could be the case for the Experiments, which used the abstract material depending on order of outcomes condition. In the order of outcome 1_2 infants might have expected the ball but not the box to move again. Thus, infants would make use of the difference in onset of motion and discriminating the different motion patterns, which in turn are attributed to animate and inanimate behavior. In the opposite condition (2_1) this might have been overshadowed by the fact that the two-object display came first, which might have resulted in reduced expectation for the single object to move again after both objects did not move. However, there seemed to be an anticipation that something might happen when both objects appear together first in test. If the concept agency was triggered during familiarization and infants might have expected the animate objects to act on the inanimate object instead of looking for both to move again.

Still such a sophisticated interpretation is highly speculative and requires further testing. Besides, whereas this explanation works well for the results of Experiment 2 and 4 it does not work out exactly in the same way for the findings of Experiment 1. The looking pattern in the order of outcomes 1_2/ tractor condition does not correspond with the ones in Experiment 2 and 4. While overall infants looked significantly longer to the two-object display in the condition where the bunny served as the single object when taking the factor kind of single object into account supporting an animacy/ agency hypothesis, when the tractor made up the object in the on-object display infants look equally long at the displays in the order of outcomes condition 1_2. This speaks to the contrary because it does not show an expectation that something would happen in case both objects were present. However, Experiment 1 contained natural/ complex material thought and thus, object form and detail might have had an influence on infants looking results as well. Although, infants just viewed the bunny engage in an interesting movement (jumping), which should have made up for differences in form, the bunny lacked detail compared to the tractor and therefore might have been less interesting in the static displays. Considering the results under the aspects of animacy and agency again, it might also be that due to the ambiguous onset of motion, both objects were viewed as self-propelled and thus animate. This in turn could have given rise to the expectation that both objects would have the ability to move again in test. Discrepancies of this sort, demonstrate that in spite of the overall consistency of the results, it is not conclusive at this point whether a failure to individuate can be attributed to methodological shortcomings and/ or reasoning about animacy, agency, or a combination of everything. The following chapter proposes a range of studies that would certainly be helpful for the interpretation of the results on hand and could contribute to a better understanding of the influence of motion on processes such as object individuation.

10.2 Future Directions and Conclusions

The former discussion alludes to several topics that are worth investigating in future research about the kind of information available for object information as well as the role of motion in such processes. Topics that were addressed in the previous discussion part are adopted and studies that cater to those issues are proposed.

First of all, it has to be stressed that the implementation of the simple material as well as a clear characterization of self-propulsion were important changes from Experiment 1 to Experiment 2. These modifications eliminated featural complexity and ambiguity regarding the animate-inanimate distinction as factors that could influence infants looking and reasoning, thus, allowing a clear differentiation of the objects by means of motion cues instead of featural characteristics. Nevertheless, many cues remained that added variance to the task. One way to get closer to a solution of what infants reasoning is to repeat Experiment 4 in which spatiotemporal information was provided but have the objects both move in a linear fashion and take away the remaining animate cues (internal pulsation and self-propulsion). If infants reason about animacy/ agency, looking times to the two-object display should be less apparent under these conditions. In fact, 12-month-old infants should be able to solve the individuation task because cues that indicate animacy or agency were removed permitting infants to focus on the question how many objects are involved in the event.[37] To further disentangle the concepts animacy and agency an experiment would have to be conducted which either does not provide agency cues at all or meets infants' expectations about particular actions of objects. Using the method of Experiment 2 such experiments could look like this. Either one removes the internal pulsation and emphasizes onset of motion, path of motion, and form of action cause or the animate object moves in test. The later possibility has to be carefully planned and elaborated because movement always offers the problem of catching interest. One would have to think of a compensation for display in which no motion is present. On the other hand, since such investigations move away from the original individuation question, it would be possible to leave the problem of object individuation aside and compare a test display in which the animate object interacts with the inanimate object after the occluder descented (expected outcome) with a test version in which the animate object does not interact upon removal of the screen (unexpected outcome). Despite the attraction due to motion infants should according to the violation-of-expectation paradigm prefer the unexpected outcome above the expected.

At this point let us come back to object individuation, which was the original concern of the present investigations and consider methodological improvements. Taken everything into account, it might be a difficult endeavor to test the influence of domain-specific motion characteristics on object individuation with the task implemented here. Motion information alone seems to interfere with the individuation process. As pointed out by Xu (2007) success or failure in establishing the number of objects in an event might be dependent on the source of information available. Thus, it is quite possible that infants concentrate on the most salient source of information available, which in the present case is motion. Because this type of information is not directly related to the object information task, expectations about the objects'

[37] This possibility is tested right now with the according experiment being under way.

movements and/ or behaviors might particularly overlay computations about individuation in the present procedure. Further, the experiments revealed that the order of outcomes had an eminent effect on the results. Thus, for further research of that kind it is advisable to eliminate any impact of this factor. In order to realize this, one has to change the design layout. One option would be to carry out the task with two groups of infants and compare the reactions to the one- and two-object display in test between groups. An experiment would look as follows. Independent of the information provided during familiarization, one group of infants sees the one-object display in baseline and test whereas another group of infants views the two-object display in baseline and test. The expectation would be that there is a greater increase in looking in the one-object display condition from baseline to test compared to the two-object display condition. With regard to the method, one could call the film presentation into question after all. So far this possibility did not appear in the discussions because a vast number of research provides evidence for infants' ability to make use of film presentations (e.g. Madole & Cohen, 1995; Mumme & Fernald, 2003; Perone & Oakes, 2006; Seekircher, 2007; Surian et al., 2004). In this case, however, it could be argued that three-dimensional information might have been vital in transferring information. Besides Surian et al.'s (2004) study, all object individuation studies are presented live in a puppet stage. The substitution of three-dimensional material through two-dimensional images might have lead to insufficient encoding of the familiarization sequences, which in turn made it harder for infants to set up stable expectations. In this regard, Csibra (2008) discusses that two-dimensional animations might hinder infants from applying specific knowledge that would have been required for the evaluation of events. Thus, the pictural form of presentation might have impeded the activation of conceptual relevant prior knowledge about animate and inanimate objects in the present series of experiments. Findings by Pauen and Träuble (2002) speak for such an interpretation. The authors showed that 7-month-old infants differentiate three-dimensional toy replicas of animals and furniture only under conditions where they are able to visually analyze them as real objects. When presented as images infants fail to do so. Other categorization studies, however, provides evidence for a successful application of picture (e.g., Quinn & Eimas, 1996). No movement was involved in those studies, though. Johnson and Aslin (1996) demonstrated that young infants recover depth information through relative motion and occlusion, aspects that were part of the present experiments. In general, literature on the use of depth information reveals that the implementation of pictural cues to infer depth on two-dimensional images starts to mature around 6 months of age (Arteberry, Bensen, & Yonas, 1991). In order to completely rule out that infants might be missing pieces of information in the two-dimensional video displays used in the experiments on hand the create a two-dimensional “stage” which suggest three-dimensionality because of perspective cues and shadows (see Csibra, 2008 for an example). In either case this would enhance the transfer of cues necessary for reasoning about motion events without minimizing standardization and accuracy in the procedure.

In conclusion, despite the conflicting results, the present set of experiments makes valuable contributions to the study of infant cognition. The experiments on hand once more elucidate the immense importance of motion cues in early childhood. As pointed out in the discussion, motion characteristics contribute to a wide range of cognitive process such as object segregation (e.g., Kellman & Spelke, 1983), object categorization (e.g., Mandler, 2004) reasoning about intentionality (Premack, 1990), causality (e.g., Leslie, 1994; Woodward, Phillips, & Spelke, 1995; Träuble, 2004), or agency, (e.g., Csibra, 2008; Gergely & Csibra, 2006). Thus, it can be concluded that motion is one of the most important information available to infants. It guides their perception and their understanding of events in the world and it seems to have the ability to override other information be it featural or kind information. Even though the role of movement on the object individuation process remains an open question at this point and requires further investigation, the notion that motion information is so powerful leaves exciting possibilities for future research on cognitive development.

In addition, the present work not only sets a starting point for further promising studies but more importantly it points out how absolute essential detailed analyses and specifications of the employed information are. Sometimes less is more when it comes to the information available for making inferences. Thereby, simply reducing task demands and then demonstrating capabilities at an even younger age does not necessarily bring us closer to the underlying processes of cognitive abilities nor does it provide us with a better understanding of how they develop. Different mechanisms might be at work and various sources of information might contribute to an infants’ reaction/ behavior. Certainly, however, clear definitions of the information and tasks with which certain competences can be measured will help design experiments that will answer the questions of developmental psychologists. As research on early cognition shows, infants are able to represent physical laws such as cohesion, solidity, continuity, and contact, as well as spatial relations and occlusion events. Besides, they judge objects' numerical, causal, and animate relations, and they reason about events, others' actions, intentions, and mental states (see Goswami, 2008 for an overview). Still there are many open questions about the underlying processes of these phenomena and how they interact. Continuous investigation through cleverly designed behavioral experiments as well as neuroscience approaches will not only bring us closer to explaining processes such as object individuation but also to understanding the origins of thought and human development in general.

REFERENCES

Aguiar, A., & Baillargeon, R. (1999). 2.5-month-old infants' reasoning about when objects should and should not be occluded. *Cognitive Psychology, 39*, 116-157.

Aguiar, A., & Baillargeon, R. (2002). Developments in young infants` reasoning about occluded objects. *Cognitive Psychology, 45*, 267-336.

Arterberry, M. E., & Bornstein, M. H. (2001). Three-month-old infants` categorization of animals and vehicles based on static and dynamic attributes. *Journal of Experimental Child Psychology, 80*, 333-346.

Arterberry, M. E., & Bornstein, M. H. (2002a). Variability and its sources in infant categorization. *Infant Behavior and Development, 25*, 515-528.

Arterberry, M. E., & Bornstein, M. H. (2002b). Infant perceptual and conceptual categorization: the roles of static and dynamic stimulus attributes. *Cognition, 86*, 1-24.

Arterberry, M. E., & Yonas, A. (2002). Perception of three-dimensional shape specified by optic flow by 8-week-old infants. *Perception & Psychophysics, 62*, 550-556.

Arterberry, M. E., Bensen, A. S., & Yonas, A. (1991). Infants' responsiveness to static-monocular depth information: A recovery from habituation approach. *Infant Behavior and Development, 14*, 241-251.

Arterberry, M. E., Craton, L. G., & Yonas, A. (1993). Infants` sensitivity to motion-carried information for depth and object properties. In C. E. Granrud (Ed.), *Visual perception and cognition in infancy* (pp. 215-234). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Atkinson, J., Braddick, O., Anker, S., Curran, W., Andrew, R., Wattam-Bell, J., & Braddick, F. (2003). Neurobiological models of visuospatial cognition in children with Williams Syndrome: Measures of dorsal-stream and frontal function. *Developmental Neuropsychology*, *23*, 139-172.

Bahrick, L. E., & Newell, L. C. (2008). Infant discrimination of faces in naturalistic events: Actions are more salient than faces. *Developmental Psychology, 44*, 983-996.

Bahrick, L. E., Gogate, L. J., & Ruiz, I. (2002). Attention and memory for faces and actions in infancy: The salience of actions over faces in dynamic events. *Child Development, 73*, 1629-1643.

Baldwin, D. A, Markman, E. M., & Melartin, R. L. et al., (1993). Infants' ability to draw inferences about nonobvious object properties: Evidence from exploratory play. *Child Development, 64*, 711-728.

Baillargeon, R. (1986). Representing the existence and the location of hidden objects: Object permanence in 6- and 8-month-old infants. *Cognition, 23*, 21-41.

Baillargeon, R. (1987). Young infants` reasoning about the physical and spatial properties of a hidden object. *Cognitive Development, 2*, 179-200.

Baillargeon, R. (1987). Object permanence in 3½- and 4½-month-old infants. *Developmental Psychology, 23*, 655-664.

Baillargeon, R. (1991). Reasoning about the height and location of a hidden object in 4.5- and 6.5-month-old infants. *Cognition, 38*, 13-42.

Baillargeon, R. (1993). The object concept revisited: New directions in the investigation of infants` physical knowledge. In C. E. Granrud (Ed.), *Visual perception and cognition in infancy* (pp. 265-315). Hillsdale, NJ: Erlbaum.

Baillargeon, R. (1994). How do infants learn about the physical world? *Current Directions in Psychological Science, 3*, 133-140.

Baillargeon, R. (1995). Physical reasoning in infancy. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 181-204). Cambridge, MA: MIT Press.

Baillargeon, R. (1998). Infants' understanding of the physical world. In S. Michel, C. Fergus, & R. Michèle (Eds.), *Advances in psychological science: Vol. 2. Biological and cognitive aspects* (pp. 503-529). Hove, England: Psychology Press.

Baillargeon, R. (1999). Young infants' expectations about hidden objects: A reply to three challenges. *Developmental Science, 2*, 115-132.

Baillargeon, R. (2000). How do infants learn about the physical world? In D. Muir & A. Slater (Eds.), *Infant development: The essential readings* (pp. 195-212). Malden, MA: Blackwell Publishing.

Baillargeon, R. (2002). The acquisition of physical knowledge in infancy: A summary in eight lessons. In U. Goswami (Ed.), *Blackwell handbook of childhood cognitive development* (pp. 47-83). Malden, MA: Blackwell Publishing.

Baillargeon, R. (2004a). Infants' Physical World. *Current Directions in Psychological Science, 13*, 89-94.

Baillargeon, R. (2004b). Infants' reasoning about hidden objects: Evidence for event-general and event-specific expectations. *Developmental Science, 7*, 391-424.

Baillargeon, R., & Aguiar, A. (1998). Toward a general model of perseveration in infancy. *Developmental Science, 1*, 190-191.

Baillargeon, R., & Brueckner, L. (2000). 3.5-month-old infants' reasoning about the width of hidden objects. Paper presented at the biennial International Conference on Infant Studies, Brighton, UK.

Baillargeon, R., & DeVos, J. (1989). Location memory in 8-month-old infants in a non-search AB task: Further evidence. *Cognitive Development, 4*, 345-367.

Baillargeon, R., & DeVos, J. (1991). Object permanence in young infants: Further evidence. Child Development, 62, 1227-1246.

Baillargeon, R., & Graber (1987). Where's the rabbit? 5.5-month-old infants' representation of the height of a hidden object. *Cognitive Development, 2*, 375-392.

Baillargeon, R., & Wang, S. (2002). Event categorization in infancy. *Trends in Cognitive Sciences, 6*, 85-93.

Baillargeon R., Kotovsky, L., & Needham, A. (1995). The acquisition of physical knowledge in infancy. In D. Sperber, D. Premack, & A. J. Premack (Eds.), *Causal Cognition: A Multidisciplinary Debate* (79-116). Oxford: Clarendon Press.

Baillargeon R., Needham, A., & DeVos, J. (1992). The development of young infants' intuitions about support. *Early Development & Parenting, 1*, 69-78.

Baillargeon, R., Spelke, E. S., & Wasserman, S. (1985). Object permanence in five-month-old infants. *Cognition, 20*, 191-208.

Baillargeon, R., Graber, M., DeVos, J., & Black, J. (1990). Why do young infants fail to search for hidden objects? *Cognition, 36*, 255-284.

Banks, M. S., & Salapatek, P. (1981). Infant pattern vision: A new approach based on the contrast sensitivity function. *Journal of Experimental Child Psychology, 31*, 1-45.

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind*. Cambridge, MA: MIT Press.

Beauchamp, M. S., Lee, K. E., Haxby, J. V., & Martin, A. (2003). fMRI responses to video and point-light displays of moving humans and manipulable objects. *Journal of Cognitive Neuroscience, 15*, 991-1001.

Behl-Chadha, G. (1996). Basic-level and superordinate-like categorical representations in early infancy. *Cognition, 60*, 105-141.

Bertenthal, B. I. (1993). Infants` perception of biomechanical motions: Intrinsic image and knowledge-based constraints. In C. E. Granrud (Ed.), *Visual perception and cognition in infancy* (pp. 175-214). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Bertenthal, B. I., Proffitt, D. R., & Cutting, J. E. (1984). Infant sensitivity to figural coherence in biomechanical motion. *Journal of Experimental Child Psychology, 37*, 213-230.

Bertenthal, B. I., Proffitt, D. R., Kramer, S. J., & Spetner, N. B. (1987). Infants' encoding of kinetic displays varying in relative coherence. *Developmental Psychology, 23*,171-178.

Bertenthal, B. I., Proffitt, D. R., Spetner, N. B., & Thomas, M. A. (1985). The development of infant sensitivity to biomechanical motions. *Child Development, 56*, 531-543.

Bogartz, R. S., Shinskey, J. L., & Speaker, C. J. (1997). Interpreting infant looking: The event set x event set design. *Developmental Psychology, 33*, 408-422.

Bonatti, L., Frot, E., Zangl, R., & Mehler, J. (2002). The human first hypothesis: Identification of conspecifics and individuation of objects in the young infant. *Cognitive Psychology, 44*, 388-426.

Bornstein, M. H. (1985). Habituation of attention as a measure of visual information processing in human infants: Summary, systematization, and synthesis. In G. Gottlieb & N. A. Krasnegor (Eds.), *Measurement of audition and vision in the first year of postnatal life* (pp. 253-300). Westport, CT: Ablex.

Bornstein, M. H., Ferdinandsen, K., & Gross, C. G. (1981). Perception of symmetry in infancy. *Developmental Psychology, 17*, pp. 82–86.

Bower, T. G. R. (1971). The object in the world of the infant. *Scientific American, 225*, 30-38.

Bower, T. G. R. (1974). *Development in infancy*, San Francisco, CA: W. H Freeman and Company.

Bower, T. G. R. (1979). *Human Development*. San Francisco, CA: W. H. Freeman and Company.

Bower, T. G. R. (1982). *Development in infancy* (2nd ed.). San Francisco, CA: W. H Freeman and Company.

Bower, T. G. R., Broughton, J., & Moore, M. K. (1971). Development of the object concept as manifested in changes in the tracking behavior of infants between 7 and 20 weeks of age. *Journal of Experimental Child Psychology, 11*, 182-193.

Bremner, J. G. (1985). Object tracking and search in infancy: A review of data and a theoretical evaluation. *Developmental Review, 5*, 371-396.

Burke, L. (1952). On the tunnel effect. *Quarterly Journal of Experimental Psychology*, *4*, 121-138.

Burnham, D. K. (1987). The role of movement in object perception by infants. In B. E. McKenzie & R. H. Day (Eds.), *Perceptual Development in Early Infancy* (pp. 143-172). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Burnham, D. K., & Day, R. H. (1979). Detection of color in rotating objects by infants and its generalization over changes in velocity. *Journal of Experimental Child Psychology*, *28*,191-204.

Burnham, D. K., & Dickinson, R. G. (1981). The determinants of visual capture and visual pursuit in infancy. *Infant Behavior and Development*, *4*, 359-372.

Butterworth, G. (1989). Events and encounters in infant perception. In A. Slater & G. Bremner (Eds.), *Infant Development* (pp. 73-83). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Carey, S. (1995). On the origins of causal understanding. In D. Sperber, D. Premack, & A. J. Premack (Eds.), *Causal Cognition: A Multidisciplinary Debate* (268-308). Oxford: Clarendon Press.

Carey, S., & Xu, F. (2001). Infants` knowledge of objects: beyond object files and object tracking. *Cognition, 80*, 179-213.

Chakraborti, S. R., Barnes, G. R., & Collins, C. J. S. (2002). *Experimental Brain Research, 144*, 152-158.

Chiang, W.-C., & Wynn, K. (2000). Infants` tracking of objects and collections. *Cognition, 77*, 169-195.

Choi S., & Bowerman, M. (1991). Learning to express motion events in English and Korean: The influence of language-specific lexicalization patterns. *Cognition, 41*, Special issue: Lexical and conceptual semantics. 83-121.

Choi, S., McDonough, L., Bowerman, M., & Mandler, J. (1999). Comprehension of spatial terms in English and Korean. *Cognitive Development, 14,* 241-268.

Craton, L. G. (1996). The development of perceptual completion abilities: Infants' perception of stationary, partially occluded objects. *Child Development, 67,* pp. 890-904

Crichton, M. T., & Lange-Küttner, C. (1999). Animacy and propulsion in infancy: tracking, waving and reaching to self-propelled and induced moving objects. *Developmental Science, 2,* 318-324.

Csibra, G. (2008). Goal attribution to inanimate agents by 6.5-month-old infants. *Cognition, 107,* 705-717.

Csibra, G., & Gergerly, G. (1998). The teleological origins of mentalistic action explanations: A developmental hypothesis. *Developmental Science, 1,* 255-259.

Csibra, G., & Gergely, G. (2006). Social learning and social cognition: the case for pedagogy. In Y. Munakata & M. H. Johnson (Eds.), *Processes of change in brain and cognitive development. Attention and performance XXI* (pp. 249–274). Oxford: Oxford University Press.

Csibra G., Gergely, G., Biró, S., & Koós, O., & Brockbank, M. (1999). Goal-attribution without agency cues: The perception of 'pure reason' in infancy. *Cognition, 72,* 237-267.

Dannemiller, J. L. (2000). Competition in early exogenous orienting between 7 and 21 weeks. *Journal of Experimental Child Psychology, 76,* 253-274.

Day, R. H., & Burnham, D. K. (1981). Infants' perception of shape and color in laterally moving patterns. *Infant Behavior and Development, 4,* 341-357.

Domini, F., Vuong, Q. C., & Caudek, C. (2002). Temporal integration in structure from motion. Domini, *Journal of Experimental Psychology: Human Perception and Performance, 28,* 816-838.

Fantz, R. L. (1961). The origin of form perception. *Scientific American, 204,* 66-72.

Fantz, R. L. (1963). Pattern vision in newborn infants. *Science 140,* 296-297.

Fantz, R. L. (1964). Visual experience in infants: Decreased attention familar patterns relative to novel ones. *Science, 146,* 668-670.

Feigenson, L., Carey, S., & Hauser, M. (2002). The representations underlying infants` choice of more: Object files versus analog magnitudes. *Psychological Science, 13*, 150-156.

Freedland J. L., & Dannemiller, R. L. (1987). Detection of stimulus motion in 5-month-old infants. *Journal of Experimental Child Psychology, 47*, 337-355.

Geach, P. (1962). *Reference and Generality*. Ithaca, NY: Cornell University Press.

Gelman, R. (1990). First principles organize attention to and learning about relevant data: Number and the animate-inanimate distinction as examples. *Cognitive Science: A Multidisciplinary Journal, 14*, 79-106.

Gelman, R. (2002). On animates and other worldly things. In N. L. Stein, P. J. Bauer, & M. Rabinowitz (Eds.), *Representation, Memory, and Development: Essays in Honor of Jean Mandler* (75-87). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Gelman, R., & Spelke, E. (1981). The development of thoughts about animate and inanimate objects: implications for research on social cognition. In J.H. Flavell & L. Ross (Eds.), *Social cognitive development. Frontiers and positive futures* (pp. 43-66). Cambridge, MA: Cambridge University Press.

Gelman, S. A., & Gottfried, G. M. (1996). Children`s causal explanations of animate and inanimate motion. *Child Development, 67*, 1970-1987.

Gelman, S. A., & Markman, E. M. (1986). Categories and induction in young children. *Cognition, 23*, 183-209.

Gelman, S. A., & Opfer, J. E. (2002). Development of the animate-inanimate distinction. In U. Goswami (Ed.), *Blackwell Handbook of Childhood Cognitive Development* (151-166). Malden, MA: Blackwell Publishing.

Gergely, G., & Csibra, G. (1994). On the ascription of intentional content. *Cahiers de Psychologie Cognitive/Current Psychology of Cognition, 13*, 584-589.

Gergely, G., & Csibra, G. (2003). Teleological reasoning about actions: the naïve theory of rational action. *Trends in Cognitive Sciences, 7*, 287–292.

Gergely, G., Nádasdy, Z., Csibra, G., & Bíró, S. (1995). Taking the intentional stance at 12 months of age. *Cognition*, Vol. 56, No. 2., 165-193.

Gibson, E. J. (1969). *Principles of perceptual learning and development*. New York: Appelton-Century-Crofts.

Gibson, E. J. (1987). Introductory Essay: What does infant perception tell us about theories of perception? *Journal of Experimental Psychology: Human Perception and Performance, 13,* Special issue: The ontogenesis of perception. 515-523.

Gibson, E. J. (1991). The concept of affordances in development: The renascence of functionalism. In E. J. Gibson (Ed.), *An Odyssey in learning and perception* (pp. 558-570). Cambridge, MA: MIT Press.

Gibson, E. J., & Gibson, J. J. (1991). The senses an information-seeking systems. In E. J. Gibson (Ed.), *An Odyssey in learning and perception* (pp. 503-510). Cambridge, MA: MIT Press.

Gibson, E. J., Owsley, C. J., Johnson, J. (1978). Perception of invariants by five-month-old infants: Differentiation of two types of motion. *Developmental Psychology*, *14*, 407-415.

Goswami, U. (2008). *Cognitive development: The learning brain*. New York: Psychology Press.

Goubet, N., & Clifton, R. K. (1998). Object and event representation in 6½-month-old infants. *Developmental Psychology, 34*, 63-76.

Gratch, G. (1982). Responses to hidden persons and things by 5-, 9-, and 16-month-old infants in a visual tracking situation. *Developmental Psychology*, *18*, 232-237.

Haith, M. M. (1999). Some thoughts about claims for innate knowledge and infant physical reasoning. *Developmental Science, 2*, 153-156.

Haith, M. M., & Benson, J. B. (1998). Infant cognition. In W. Damon (Series Ed.), D. Kuhn, & R. S. Siegler (Eds.), *Handbook of child psychology: Vol. 2. Cognition, perception, and language* (5th ed., pp. 199-254). New York: Wiley.

Haith, M. M., & Campos, J. J. (1977). Human infancy. *Annual Review of Psychology, 28*, 251-293.

Haith, M. M., Wentworth, N., & Canfield, R. L. (1993). The formation of expectations in early infancy. *Advances in Infancy Research, 8,* 251-297.

Hartlep, K. L. (1979). Object perception and motion in infants. *The Journal of General Psychology, 100,* 167-174.

Haxby, J. V., Grady, C. L., Ungerleider, L. G., & Horwitz, B. (1991). Mapping the functional neuroanatomy of the intact human brain with brain work imaging. *Neuropsychologia, 29*, Special issue: Special Issue in Honor of Karl H. Pribram: Localization and distribution of cognitive function. 539-555.

Hespos, S. J., & Baillargeon, R. (2001). Infants' knowledge about occlusion and containment events: A surprising discrepancy. *Psychological Science, 12*, 141-147.

Hespos, S. J., & Rochat, P. (1997). Dynamic mental representation in infancy. *Cognition, 64*, 153-188.

Hirsch, E. (1982). *The Concept of Identity.* Oxford: Oxford University Press.

Hofstadter, M., & Reznick, J. S. (1996). Response modality affects human infant delayed-response performance. *Child Development*, *67*, 646-658.

Humphreys, G. W., & Riddoch, M. J. (2003). From what to where: Neuropsychological evidence for implicit interactions between object- and space-based attention. *Psychological Science, 14*, 487-492.

James, W. (1890/1950) *The principles of psychology.* New York: Dover.

Johannson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception and Psychophysics, 14*, 201-211.

Johnson, S. C. (2000). The recognition of mentalistic agents in infancy. *Trends of Cognitive Sciences*, *4*, 22-28.

Johnson, S. C (2003). Detecting agents. In C. Frith & D. Wolperts (Eds.), *The Neuroscience of Social Interactions: Decoding, Initating, and influencing the actions of others.* Oxford: Oxford University Press.

Johnson, S. C, Slaughter, V., & Carey, S (1998). Whose gaze would infants follow? The elicitation of gaze following in 12-month-olds. *Developmental Science, 1*, 233-238.

Johnson, S. P. (1997). Young infants' perception of object unity: Implications for development of attentional and cognitive skills. *Current Directions in Psychological Science, 6*, pp. 5-11.

Johnson, S. P., & Aslin, R. N. (1995). Perception of object unity in 2-month-old infants. *Developmental Psychology, 31*, 739-745.

Johnson, S. P., & Aslin, R. N. (1996). Perception of object unity in young infants: the roles of motion, depth, and orientation. *Cognitive Development, 11*, 161-180.

Johnson, S. P., Cohen, L. B., Marks, K. H., & Johnson, K. L. (2003). Young infants' perception of object unity in rotation displays. *Infancy, 4*, 285-295.

Jusczyk, P. W., Johnson, S. P., Spelke, E. S., & Kennedy, L. J. (1999). Synchronous change and perception of object unity: Evidence from adults and infants. *Cognition, 71*, 257-288.

Kahneman, D., Treisman, A., & Gibbs, B. J. (1992). The reviewing of object files: Object-specific integration of information. *Cognitive Psychology, 24*, 175-219.

Kaldy, Z., & Leslie, A. M. (2003). Identification of objects in 9-month-old infants: integrating ´what` and ´where` information. *Developmental Science, 6*, 360-373.

Kamewari, K., Kato, M., Kanda, T., Ishiguro, H., & Hiraki, K. (2005). Six-and-a-half-month-old children positively attribute goals to human action and to humanoid-robot motion. Cognitive Development, 20, 303–320.

Kanwisher, N., Stanley, D., & Harris, A. (1999). The fusiform face area is selective for faces not animals. *Neuroreport: For Rapid Communication of Neuroscience Research, 10*, 183-187.

Kaufman-Hayoz R., Kaufmann, F., & Stucki, M. (1986). Kinetic contours in infants' visual perception. *Child Development, 57*, 292-299.

Kavsek, M. J. (2000). *Visuelle Wahrnehmung bei Säuglingen. Gewöhnung und Informationsverarbeitung*. Lengerich: Pabst Science Publishers.

Kellman, P. J. (1984). Perception of three-dimensional form by human infants. *Perception & Psychophysics, 36*, 353-358.

Kellman, P. J. (1993). Kinematic foundations of infant visual perception. In C. E. Granrud (Ed.), *Visual perception and cognition in infancy* (pp. 121-173). Hillsdale, NJ: Erlbaum.

Kellman, P. J., & Spelke, E. S. (1983). Perception of partly occluded objects in infancy. *Cognitive Psychology, 15*, 483-524.

Kellman, P. J., & Spelke, E. S. (1987). Object and observer motion in the perception of objects by infants. *Journal of Experimental Psychology: Human Perception and Performance, 13*, Special issue: The ontogenesis of perception, 586-593.

Kellman, P. J., Spelke, E. S., & Short, K. R. (1986). Infant perception of object unity from translatory motion in depth and vertical translation. *Child Development, 57*, 72-86.

Koechlin, E., Dehaene, S., & Mehler, J. (1998). Numerical transformations in five month old human infants. *Mathematical Cognition, 3*, 89-104.

Köhler, S., Moscovitch, M., & Melo, B. (2001). Episodic memory for object location versus episodic memory for object identity: Do they rely on distinct encoding processes? *Memory & Cognition, 29*, 948-959.

Krojgaard, P. (2003). Object individuation in 10-month-old infants: Manipulating the amount of introduction. *British Journal of Developmental Psychology, 21*, 447-463.

Krojgaard, P. (2004). A review of object individuation in infancy. *British Journal of Developmental Psychology, 22*, 159-183.

Krojgaard, P. (2007). Comparing infants' use of featural and spatiotemporal information in an object individuation task using a new event-monitoring design. *Developmental Science, 10*, 892-909.

Legerstee, M. (1992). A review of the animate-inanimate distinction in infancy: implications for models of social and cognitive knowing. *Early Development and Parenting, 1*, 59-67.

Legerstee, M. (2001). Domain specificity and the epistemic triangle: the development of the concept of animacy in infancy. In F. L. C. von Hofsten & M. Heimann (Eds.), *Emerging cognitive abilities in early infancy* (pp. 193-212). Mahwah, NJ: Lawrence Erlbaum Associates.

Leslie, A. M. (1984). Spatiotemporal continuity and the perception of causality in infants. *Perception, 13*, 287–305.

Leslie, A. M. (1988). The necessity of illusion: Perception and thought in infancy. In Weiskrantz (Ed.), *Thought without language* (pp. 185-210). New York: Clarendon Press/Oxford University Press.

Leslie, A. M. (1994). ToMM, ToBy, and Agency: Core architecture and domain specificity. In L. Hirschfeld and S. Gelman (Eds.), *Mapping the mind: Domain specificity in cognition and culture* (pp. 119–148). New York: Cambridge University Press.

Leslie, A. M. (1995). A theory of agency. In D. Sperber, D. Premack, A. J. Premack (Eds.), *Causal cognition: A multidisciplinary debate* (pp. 121-149). New York: Clarendon Press/Oxford University Press.

Leslie, A. M., & Chen, M. L. (2007). Individuation of pairs of objects in infancy. *Developmental Science, 10*, 423-430.

Leslie, A. M., & Kaldy, Z. (2001). Indexing individual objects in infant working memory. *Journal of Experimental Child Psychology, 78*, Special issue: Reflections, 61-74.

Leslie, A. M., & Keeble, S. (1987). Do six-month-old infants perceive causality? *Cognition, 25*, 265-288.

Leslie, A. M., Xu, F., Tremoulet, P.D., & Scholl, B.J. (1998). Indexing and the object concept: developing ´what` and ´where` systems. *Trends in Cognitive Sciences, 2*, 10-18.

Lowe, E. J. (1989). What is a criterion of identity? *The Philosophical Quarterly, 39*, 1-21.

Luo, Y., & Baillargeon, R. (2005). Can a self-propelled box have a goal? Psychological reasoning in 5-month-old infants. *Psychological Science, 16*, 601–608.

Maas, J. B., Johansson, G., & Jansson, G. (1971). *Motion Perception, Parts 1and 2* (Films). Boston: Houghton Mifflin.

Macnamara, J. (1987). *A Border Dispute: The Place of Logic in Psychology*. Cambridge, MA: MIT Pres.

Madole, K. L., & Oakes, L. M. (1995). The role of object parts in infants' attention to form-function correlations. *Developmental Psychology, 31*, 637-648.

Madole, K. L., & Oakes, L. M. (1999). Making sense of infant categorization: Stable processes and changing representations. *Developmental Review, 19*, 263-296.

Mak, B. S. K., & Vera, A. H. (1999). The role of motion in children`s categorization of objects. *Cognition, 71*, B11-B21.

Mandler, J. M. (1992). How to build a baby: II. Conceptual primitives. *Psychological Review, 99*, 587-60.

Mandler, J. M. (1997). Development of categorization: Perceptual and conceptual categories. In G. Bremner, A. Slater, G. Butterworth (Eds.), *Infant development: Recent advances* (pp. 163-189). Hove, England: Psychology Press.

Mandler, J. M. (1998). Representation. In D. Kuhn & R. S. Siegler (Eds.), *Handbook of Child Psychology: Vol. 2. Cognition, perception, and language* (pp. 255-308). New York: Wiley.

Mandler, J. M. (2000). Perceptual and conceptual processes in infancy. *Journal of Cognition and Development, 1,* 3-36.

Mandler, J. M. (2004). *The foundations of mind: Origins of conceptual thought.* New York: Oxford University Press.

Mandler, J. M., & McDonough, L. (1993). Concept formation in infancy. *Cognitive Development, 8,* 291-318.

Mandler, J. M., & McDonough, L. (1998). On developing a knowledge base in infancy. *Developmental Psychology, 34,* 1274-1288.

Mandler, J.M., & McDonough, L. (2000) Advancing downward to the basic level: Inductive generalization in infants and young children. *Journal of Cognition and Development, 1,* 379-403.

Markson, L., & Spelke, E. S. (2006). Infants' rapid learning about self-propelled objects. *Infancy, 9,* 45-71.

Meltzoff, A. N. (1995). Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology, 31,* 838-850.

Meltzoff, A. N. (2002). Imitation as a mechanism of social cognition: Origins of empathy, theory of mind, and the representation of action. In U. Goswami (Ed.), *Blackwell Handbook of Childhood Cognitive Development* (pp. 6-25). Oxford: Blackwell Publishers.

Meltzoff, A. N., & Kuhl, P. K. (1994). Faces and speech: Intermodal processing of biologically relevant signals in infants and adults. In D. J. Lewkowicz, & R. Lickliter (Eds.), *The development of intersensory perception: Comparative perspectives* (pp. 335-369). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Meltzoff, A. N., & Moore, M. K. (1992). Early imitation within a functional framework: The importance of person identity, movement, and development. *Infant Behavior and Development, 15,* 479-505.

Meltzoff, A. N., & Moore, M. K. (1998). Object representation, identity, and the paradox of early permanence: Steps toward a new framework. *Infant Behavior and Development, 21,* 201-235.

Meltzoff, A. N., & Moore, M. K. (2001). 'Discovery procedures' for people and things-The role of representation and identity. In F. Lacerda, C. von Hofsten, & M. Heimann (Eds.), *Emerging cognitive abilities in early infancy* (pp. 213-230). Mahwah, NJ: Erlbaum.

Michotte, A. (1963). *The perception of causality*. Oxford, England: Basic Books.

Mishkin, M., & Ungerleider, L. G., Macko, K. A. (1983). Object vision and spatial vision: Two cortical pathways. *Trends in Neurosciences, 6*, 414-417.

Mishkin, M., & Ungerleider, L. G., Macko, K. A. (2000). Object vision and spatial vision: Two cortical pathways. In S. Yantis (Ed.) Visual perception: Essential readings (pp. 296-302.). New York: Psychology Press.

Moore, D. G., Goodwin, J. E., George, R., Axelsson, E. L., & Braddick, F. M. B. (2007). Infants perceive human point-light displays as solid forms. *Cognition, 104*, 377-396.

Moore, M. K., & Meltzoff, A. N. (1999). New findings on object permanence: A developmental difference between two types of occlusion. *British Journal of Developmental Psychology, 17*, 623-644.

Moore, M. K., & Meltzoff, A. N. (2004). Object permanence after a 24-hr delay and leaving the locale of disappearance: The role of memory, space, and identity. *Developmental Psychology*, *40*, 606–620.

Moore, M. K., & Meltzoff, A. N. (2008). Factors affecting infants' manual search for occluded objects and the genesis of object permanence. *Infant Behavior and Development*, *31*, 168-180.

Morton, J., & Johnson, M. H. (1991). The perception of facial structure in infancy. In G. R. Lockhead & J. R. Pomerantz (Eds.), *The perception of structure: Essays in honor of Wendell R. Garner* (pp. 317-325). Washington, DC: American Psychological Association.

Mumme, D. L., & Fernald, A. (2003). The infant as onlooker: Learning from emotional reactions observed in a television scenario. *Child Development, 74*, 221-237.

Needham, A. (1997). Factors affecting infants' use of featural information in object segregation. *Current Directions in Psychological Science, 6*, pp. 26-33.

Needham, A. (1999). The role of shape in 4-month-old infants' object segregation. *Infant Behavior and Development, 22*, pp. 161-178.

Needham, A., & Baillargeon, R. (1997). Object segregation in 8-month-old infants. *Cognition, 62*, 121-149.

Needham, A., & Baillargeon, R. (1998). Effects of prior experience on 4.5-month-old infants' object segregation. *Infant Behavior and Development*, *21*, 1-24.

Needham, A., & Baillargeon, R. (2000). Infants` use of featural and experiential information in segregating and individuating objects: a reply to Xu, Carey and Welch (2000). Cognition, 74, 255-284.

Needham, A., & Ormsbee, S. M. (2003). The development of object segregation during the first year of life. In R. Kimchi, M. Behrmann, & C. R. Olson (Eds.), *Perceptual organization in vision: Behavioral and neural perspectives* (pp. 205-232). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Needham, A., Baillargeon, R., & Kaufman, L. (1997). Object segregation in infancy. Advances in Infancy Research, 11, 1-44.

Needham, A., Dueker, G., & Lockhead, G. (2005). Infants` formation and use of categories to segregate objects. *Cognition, 94*, 215-240.

Newcombe, N., Huttenlocher, J., & Learmonth, A. (1999). Infants' coding of location in continuous space. *Infant Behavior and Development*, *22*, 483-510.

Newman, G. E., Herrman, P., Wynn, K., Keil, F. C. (2008). Biases towards internal features in infants' reasoning about objects. *Cognition, 107,* 420-432.

Oakes, (1994). Development of infants' use of continuity cues in their perception of causality. *Developmental Psychology, 30*, 869-879.

Oakes, L. M., & Cohen, L. B. (1990). Infant perception of a causal event. *Cognitive Development*, *5*, 193-207.

Quinn, & Eimas, (1996). Perceptual cues that permit categorical differentiation of animal species by infants. *Journal of Experimental Child Psychology, 63*, 189-211.

Owsley, C. (1984). The role of motion in infants' perception of solid shape. *Perception*, *12*, 707-717.

Pauen, S. (1999). Developing ontological categories of matter: Stable dimensions and changing concepts. In W. Schnotz, S. Vosniadou, & M. Carretero (Eds.), *New perspectives on conceptual change* (pp. 15-31). Amsterdam: Elsevier.

Pauen, S. (2002). Evidence for knowledge-based category discrimination in infancy. *Child Development, 73,* 1016-1033.

Pauen, S (2003). Säuglingsforschung aus einer kognitiven Perspektive. In H. Keller (Ed.), *Handbuch der Kleinkindforschung* (3rd ed., pp. 283-318). Bern: Hans Huber.

Pauen, S. (2006). *Was Babys denken: Eine Geschichte des ersten Lebensjahres*. München: Beck.

Pauen, S., & Träuble, B. (2002). *Perzeptuelle Kategorisierung mit drei bis vier Monaten – Gibt es sie wirklich?* Positionsreferat gehalten auf dem 43. Kongress der Deutschen Gesellschaft für Psychologie, Berlin.

Pauen, S., & Träuble, B. (2004). *Knowledge-based reasoning about the animate-inanimate distinction at 7 months of age: What makes the ball go round?* Manuscript submitted for publication.

Perone, S., & Oakes, L. M. (2006). It Clicks When It is Rolled and It Squeaks When It is Squeezed: What 10-Month-Old Infants Learn About Object Function. *Child Development, 77*, 1608-1622.

Piaget, J. (1954). *The Construction of Reality in the Child*. New York: Basic Books.

Poulin-Dubois, D. (1999). Infants` distinction between animate and inanimate objects: the origins of naive psychology. In P. Rochat (Ed.), *Early social cognition. Understanding others in the first months of life* (pp. 257-280). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Poulin-Dubois, D., & Shultz, (1988). The development of the understanding of human behavior: From agency to intentionality. In J. W. Astington, P. L. Harris, & D. R. (Eds.), *Developing theories of mind* (pp. 109-125). New York: Cambridge University Press.

Poulin-Dubois, D., Lepage, A., & Ferland, D. (1996). Infants` concept of animacy. *Cognitive Development, 11*, 19-36.

Premack, D. (1990). The infant`s theory of self-propelled objects. *Cognition*, *36*, 1-16.

Premack, D., & Premack, A. J. (1995). Origins of human social competence. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 205-218). Cambridge, MA: The MIT Press.

Premack, D., & Premack, A. J. (1997). Infants attribute value± to the goal-directed actions of self-propelled objects. *Journal of Cognitive Neuroscience, 9*, 848-856.

Pylyshyn, Z. W. (1989). The role of location indexes in spatial perception: A sketch of the FINST spatial-index model. *Cognition, 32*, 65-97.

Quine, W. V. (1960). *Word and Object*. Cambridge, MA: MIT Press.

Quinn, P. C., & Eimas, P. D. (1996). Perceptual cues that permit categorical differentiation of animal species by infants. *Journal of Experimental Child Psychology*, 63, 189-211.

Rakison, D. H. (2006). Make the first move: How infants learn the identity of self-propelled objects. *Developmental Psychology, 42*, 900-912.

Rakison, D. H., & Butterworth, G. E. (1998). Infants` use of object parts in early categorization. *Developmental Psychology, 34*, 49-62.

Rakison D. H., & Oakes, L. M. (2003). *Early category and concept development: Making sense of the blooming, buzzing confusion*. New York: Oxford University Press.

Rakison, D. H., & Poulin-Dubois, D. (2001). Developmental origin of the animate-inanimate distinction. *Psychological Bulletin, 127*, 209-228.

Rakison, D. H., & Poulin-Dubois, D. (2002). You go this way and I'll go that way: Developmental changes in infants' detection of correlations among static and dynamic features in motion events. *Child Development*, *73*, 682-699.

Ricard, M., & Allard, L. (1993). The reaction of 9- to 10-month-old infants to an unfamiliar animal. *The Journal of Genetic Psychology*, *154*, 5-16.

Richards, D. D., & Siegler, R. S. (1986). Children`s understanding of the attributes of life. *Journal of Experimental Child Psychology*, *42*, 1-22.

Rivera, A. M., & Zawaydeh, A. N. (2006). Word comprehension facilitates object individuation in 10- and 11-month-old infants. *Brain Research, 1146*, Special issue: Mysteries of meaning,146-157.

Rochat, P, & Hespos, S. J. (1996). Tracking and anticipation of invisible spatial transformation by 4- to 8-month-old infants. *Cognitive Development*, *11*, 3-17.

Rochat, P., Morgan, R., & Carpenter, M. (1997). Young infants' sensitivity to movement information specifying social causality. *Cognitive Development*, *12*, 441-465.

Rosander, K., & von Hofsten, C. (2004). Infants` emerging ability to represent occluded object motion. *Cognition*, *91*, 1-22.

Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M., & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology, 8,* 382-439.

Ruff, H. A. (1982). The effects of object movement on infants' detection of object structure. *Developmental Psychology, 18*, 462-472.

Sagi D., & Julesz, B. (1987). Short-range limitation on detection of feature differences. *Spatial Vision, 2,* 39-49.

Schlottmann, A., & Surian, L. (1999). Do 9-month-olds perceive causation-at-a-distance? *Perception*, *28,* 1105-1113.

Scholl, B. J. (2001). Objects and attention: the state of the art. *Cognition, 80*, 1-46.

Scholl, B. J., & Leslie, A. M. (1999). Modularity, development and 'theory of mind.' *Mind & Language, 14,* 131-153.

Scholl, B. J., & Tremoulet, (2000). Perceptual causality and animacy. *Trends in Cognitive Sciences, 4,* 299-310.

Seekircher, S. (2007). *Der Einfluss von Funktion auf die frühkindliche Kategorisierungsleistung Vergleich einer Video- gegen eine Livepräsentation von Funktion*. Diplomarbeit, Universität Heidelberg.

Sharon, T., & Wynn, K. (1998). Individuation of actions from continuous motion. *Psychological Science, 9*, 357-362.

Shutts, K. B. S., Babocsai, L., Markson, L., & Spelke, E. S. (May, 2004). *Infants' learning about self-propelled motion.* Poster presented at the 14th 'International Conference on Infant Studies', Chicago, IL, USA.

Siegler, R. S. (1993). Commentary: Cheers and lamentations. In C. E. Granrud (Ed.), *Visual perception and cognition in infancy* (pp. 333-344). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Simons, D. J. (1996). In sight, out of mind: When object representations fail. *Psychological Science, 7*, 301-305.

Simons, D. J. (1997). Reconceptualizing the origins of number knowledge: a "non-numerical" account. *Cognitive Development*, *12*, 349-372.

Simons, D. J., & Keil, F. C. (1995). An abstract to concrete shift in the development of biological thought: The insides story. *Cognition*, *56*, 129-163.

Simons, D. J., Hespos, S. J., & Rochat, P. (1995). Do infants understand simple arithmetic? A replication of Wynn (1992). *Cognitive Development*, *10*, 253-269.

Slater, A. (1989). Visual memory and perception in early infancy. In A. Slater & G. Bremner (Eds.), *Infant development* (pp. 43-71). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Slater, A., Mattock, A., & Brown, E. (1990). Newborn and older infants' perception of partly occluded objects. *Journal of Experimental Child Psychology, 49*, pp. 314-322.

Sommerville, J. A., Woodward, A. L., & Needham, A. (2005). Action experience alters 3-month-old infants' perception of others' actions. *Cognition, 96*, B1-B11.

Spelke, E. S. (1985). Preferential looking methods as tools for the study of cognition in infancy. In G. Gottlieb & N. A. Krasnegor (Eds.), *Measurement of audition and vision in the first year of postnatal life* (pp. 323-363). Westport, CT: Ablex Publishing.

Spelke, E. S. (1988). The origins of physical knowledge. In L. Weiskrantz (Ed.), *Thought without language*. Oxford, UK: Oxford University Press.

Spelke, E. S. (1990). Principles of object perception. *Cognitive Science, 14*, 29-56.

Spelke, E. S. (1991). Physical knowledge in infancy: Reflections on Piaget's theory. In S. Carey & R. Gelman (Eds.) *The Epigenesis of Mind: Essays on Biology and Cognition* (pp. 257-291). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Spelke, E. S. (1994). Initial knowledge: six suggestions. *Cognition, 50*, 431-445.

Spelke, E. S. (1998). Nature, nurture, and development. In J. Hochberg (Ed.), *Perception and cognition at century's end* (pp. 333-371). San Diego, CA: Academic Press.

Spelke, E. S. (2003). What makes us smart? Core knowledge and natural language. In D. Gentner & S. Goldin-Meadow (Eds.), *Language in Mind: Advances in the Investigation of Language and Thought* (pp. 277-311). Cambridge, MA: MIT Press.

Spelke, E. S., & Kestenbaum, R. (1986). Les origines du concept d'objet. *Psychologie Française, 31*, 67-72.

Spelke, E. S., Phillips, A. T., & Woodward, A. L. (1995). Infants' knowledge of object motion and human action. In D. Sperber, D. Premack, & A. J. Premack (Eds.), *Causal cognition: A multidisciplinary debate*. Oxford: Oxford University Press.

Spelke, E. S., Breinlinger, K., Macomber, J., & Jacobson, K. (1992). Origins of knowledge. *Psychological Review, 99*, 605-632.

Spelke, E. S., Kestenbaum, R., Simons, D., & Wein, D. (1995). Spatiotemporal continuity, smoothness of motion and object identity in infancy. *The British Journal of Developmental Psychology, 13*, 113-142.

Surian L., Caldi, S., & Piredda, E. (2004, May). *Agents motion and the development of object individuation*. Poster presented at the 14th ‘International Conference on Infant Studies’, Chicago, IL, USA.

Tomasello, M. (1999). Having intentions, understanding intentions, and understanding communicative intentions. In P. D. Zelazo, J. W. Astington, & D. R. Olson (Eds.), *Developing theories of intention: Social understanding of self control* (pp. 63–75). Mahwah, NJ: Lawrence Erlbaum Associates Inc.

Träuble, B. (2004). *Die Bedeutung von Kausalwahrnehmung für den frühen Wissenserwerb: neue Befunde aus der Säuglingsforschung*. Berlin: Logos.

Tremoulet, P. D., & Feldman, J. (2000). Perception of animacy from the motion of a single object. *Perception*, *29*, 943-951.

Tremoulet, P. D., Leslie, A. M., & Hall, D. G. (2000). Infant individuation and identification of objects. *Cognitive Development*, *15*, 499-522.

Van de Walle, G. A., & Spelke, E. S. (1996). Spatiotemporal integration and object perception in infancy: Perceiving unity versus form. *Child Development, 67*, 2621-2640.

Van de Walle, G. A., Carey, S., & Prevor, M. (2000). Bases for Object Individuation in Infancy: Evidence from Manual Search. *Journal of Cognition and Development*, *1*, 249-280.

Van Giffen, K., & Haith, M. M. (1984). Infant visual response to Gestalt geometric forms. *Infant Behavior and Development*, *7*, pp. 335–346

Van Marle, K., & Scholl, B. J. (2003). Attentive tracking of objects versus substances. *Psychological Science*, *14*, 498-504.

Wertheimer, M. (1958). Principles of perceptual organization. In D. C. Beardslee & Wertheimer, M. (Eds.), *Readings in Perception* (pp. 115-135). New York: van Nostrand.

Wickelgren E. A., & Bingham, G. P. (2001). Infant sensitivity to trajectory forms. *Journal of Experimental Psychology: Human Perception and Performance, 27*, 942-952.

Wiggins (1967). *Identity and spatio-temporal continuity*. Oxford: Basil Blackwell.

Wiggins (2001). *Sameness and Substance Renewed*. Cambridge: University Press.

Wilcox, T. (1999). Object individuation: infants` use of shape, size, pattern, and color. *Cognition*, *72*, 125-166.

Wilcox, T., & Baillargeon, R. (1998a). Object individuation in young infants: Further evidence with an event-monitoring paradigm. *Developmental Science, 1*, 127-142.

Wilcox, T., & Baillargeon, R. (1998b). Object individuation in infancy: The use of featural information in reasoning about occlusion events. *Cognitive Psychology, 37*, 97-155.

Wilcox, T., & Chapa, C. (2002). Infants' reasoning about opaque and transparent occluders in an individuation task. *Cognition, 85*, B1-B10.

Wilcox, T., & Chapa, C. (2004). Priming infants to attend to color and pattern information in an individuation task. *Cognition, 90,* 265-302.

Wilcox, T., & Schweinle, A. (2002). Object individuation and event mapping: developmental changes in infants` use of featural information. *Developmental Science, 5*, 132-150.

Wilcox, T., & Schweinle, A. (2003). Infants' use of speed information to individuate objects in occlusion events. *Infant Behavior and Development, 26*, 253-282.

Wilcox, T., & Schweinle, A., & Chapa, C. (2003). Object individuation in infancy. In H. Hayne & J. W. Fagen (Eds.), *Progress in Infancy Research* (Vol. 3, pp. 159-192). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Wilcox, T., Nadler, L., & Rosser, R. (1996). Location memory in healthy preterm and full-term infants. *Infant Behavior and Development, 19*, 309-323.

Wilcox, T., Schweinle, A., & Chapa, C. (2003). Object individuation in infancy. In H. Hayne & J. W. Fagen (Eds.), *Progress in Infancy Research* (Vol. 3, pp. 193-243). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Woodward, A. L. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition, 69*, 1-34.

Woodward, A. L., & Sommerville, J. A. (2000). Twelve-month-old infants interpret action in context, *Psychological Science, 11*, 73-76.

Woodward, A. L., Phillips, A.T., & Spelke, E. S. (1993). Infants' expectations about the motion of animate versus inanimate objects. *Proceedings of the Cognitive Science Society*. Hillsdale, NJ: Lawrence Erlbaum Assocites, Inc.

Woodward, A. L., Sommerville, J. A., & Guajardo, J. J. (2001). How infants make sense of intentional action. In B. F. Malle, L. J. Moses, & D. A. Baldwin (Eds.), Intentions and Intentionality: Foundations of Social Cognition (pp. 149-169). Cambridge, MA: MIT Press.

Wynn, K. (1992). Addition and Subtraction by human infants. Nature, 358, 749-750.

Xu, F. (1997). From Lot's wife to a pillar of salt: Evidence that physical object is a sortal concept. *Mind & Language, 12,* 365-392.

Xu, F. (1999). Object individuation and object identity in infancy: The role of spatiotemporal information, object property information, and language. *Acta Psychologica, 102*, 113-136.

Xu, F. (2002). The role of language in acquiring object kind concepts in infancy. *Cognition, 85*, 223-250.

Xu, F. (2003). The development of object individuation in infancy. In H. Hayne & J. W. Fagen (Eds.), *Progress in Infancy Research* (Vol. 3, pp. 159-192). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Xu, F. (2007). Sortal concepts, object individuation, and language. *Trends in Cognitive Sciences, 11,* 400-406.

Xu, F., & Baker, A. (2005). Object individuation in 10-month-old infants using a simplified manual search method. *Journal of Cognition and Development, 6*, 307-323.

Xu, F., & Carey, S. (1996). Infants` metaphysics: The case of numerical identity. *Cognitive Psychology, 30*, 111-153.

Xu, F., & Carey, S. (2000). The emergence of kind concepts: a rejoinder to Needham and Baillargeon (2000). *Cognition, 74*, 285-301.

Xu, F., Carey, S., & Quint, N. (2004). The emergence of kind-based object individuation in infancy. *Cognitive Psychology, 49*, 155-190.

Xu, F., Carey, S., & Welch, J. (1999). Infants` ability to use object kind information for object individuation. *Cognition, 70*, 137-166.

Younger, B. A. (1990). Infants' detection of correlations among feature categories. *Child Development, 61*, 614-620.

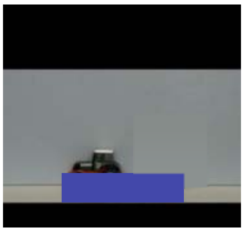
APPENDICES

LIST OF APPENDICES

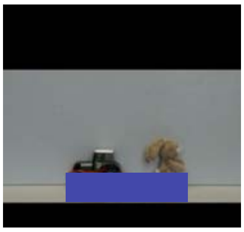
APPENDIX A – PROCEDURE EXPERIMENT 1

Baseline Phase

One-Object Display

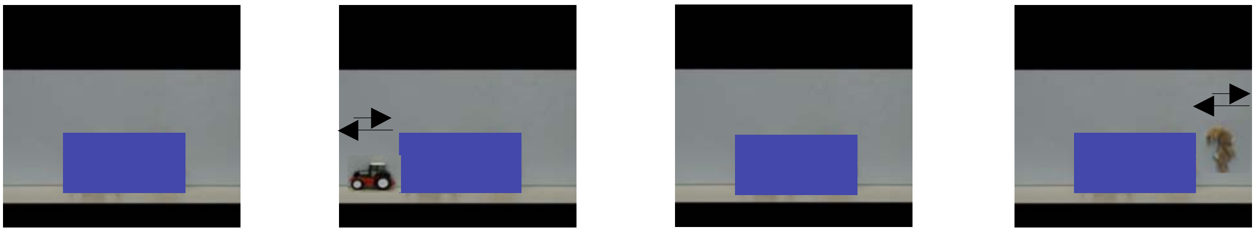


Two-Object Display



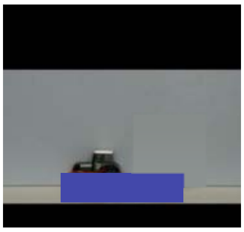
Familiarization Phase A

(4 Presentations)



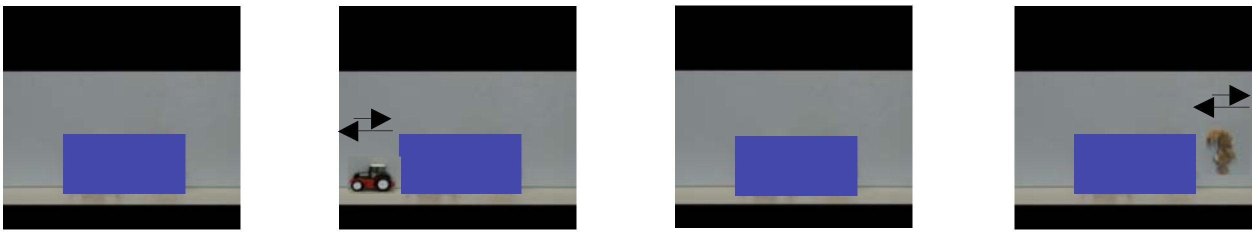
Test A

One-Object Display



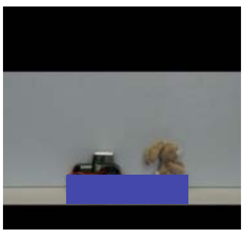
Familiarization Phase B

(2 Presentations)



Test B

Two-Object Display



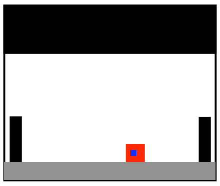
APPENDIX B – COURSE OF PRESENTATION EXPERIMENT 1

SEQUENCE	PRESENTATION	DURATION
BASELINE A	▪ Black Screen ▪ Fade in ▪ Occluder descents plus Sound ▪ Presentation of one- or two-object display ▪ Fade out	4 seconds 2 seconds 2 seconds 20 seconds 2 seconds
BASELINE B	▪ Fade in ▪ Occluder descents plus Sound ▪ Presentation of one- or two-object display ▪ Fade out	2 seconds 2 seconds 20 seconds 2 seconds
FAMILIARIZATION A	▪ Black Screen ▪ Fade in plus Sound ▪ Occluder ▪ Bunny comes out from behind the occluder and jumps to the right ▪ Bunny jumps backwards and disappears behind the occluder ▪ Occluder ▪ Tractor rolls out from behind the occluder to the left ▪ Tractor rolls back behind the occluder ▪ Occluder SEQUENCE PRESENTED 4 TIMES	4 seconds 2 seconds 2 seconds 6 seconds 6 seconds 4 seconds 6 seconds 6 seconds 4 seconds
TEST A	▪ Occluder descents plus Sound ▪ Presentation of one- or two-object display ▪ Fade out	2 seconds 20 seconds 2 seconds
FAMILIARIZATION B	▪ Fade in plus Sound ▪ Occluder ▪ Bunny comes out from behind the occluder and jumps to the right ▪ Bunny jumps backwards and disappears behind the occluder ▪ Occluder ▪ Tractor rolls out from behind the occluder to the left ▪ Tractor rolls back behind the occluder ▪ Occluder SEQUENCE PRESENTED 2 TIMES	2 seconds 2 seconds 6 seconds 6 seconds 4 seconds 6 seconds 6 seconds 4 seconds
TEST B	▪ Occluder descents plus Sound ▪ Presentation of one- or two-object display ▪ Fade out	2 seconds 20 seconds 2 seconds

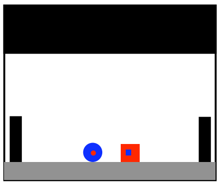
APPENDIX C – PROCEDURE EXPERIMENT 2

BASELINE PHASE

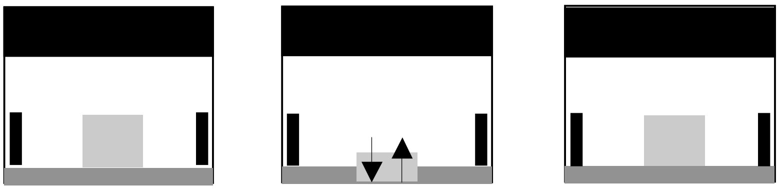
One-Object Display



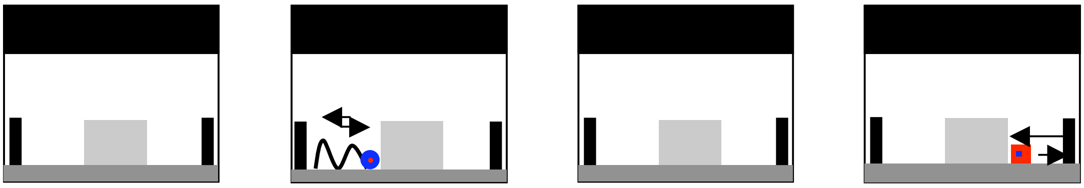
Two-Object Display



INTRODUCTION OF SCREEN

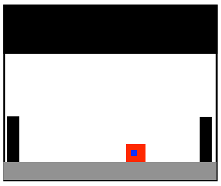


FAMILIARIZATION PHASE A
(4 Presentations)

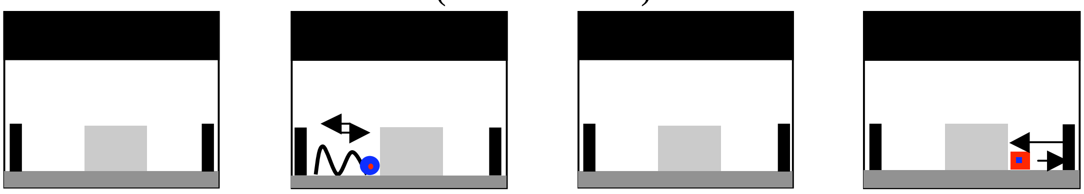


TEST A

One-Object Display

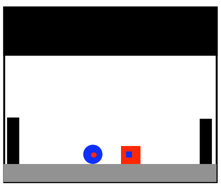


FAMILIARIZATION PHASE B
(2 Presentations)



TEST B

Two-Object Display

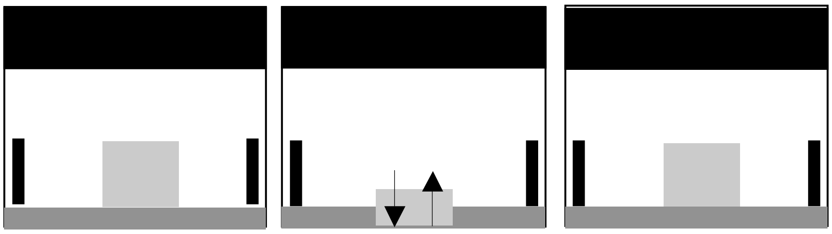


APPENDIX D – COURSE OF PRESENTATION EXPERIMENT 2

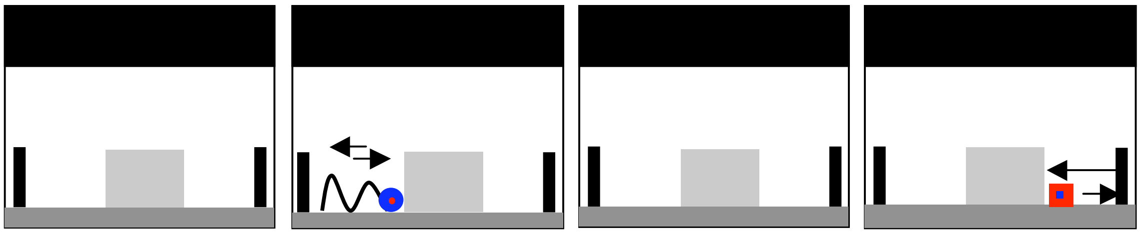
Sequence	**Presentation**	**Duration**
Baseline A	▪ Black Slide plus Sound ▪ Presentation of one- or two-object display	2 seconds 15 seconds
Baseline B	▪ Black Slide plus Sound ▪ Presentation of one- or two-object display	2 seconds 15 seconds
Introduction of Screen	▪ Black Slide ▪ Descent of Screen plus Sound ▪ Ascent of Screen ▪ Descent of Screen plus Sound ▪ Ascent of Screen	2 seconds 4 seconds 4 seconds 4 seconds 4 seconds
Familiarization A	▪ Black Slide plus Sound ▪ Occluder ▪ Ball appears to the left, pulsates, jumps further to the left, pulsates ▪ Ball jumps back toward the occluder, stops before it disappears behind the occluder ▪ Occluder ▪ Box slides out from behind the occluder and moves to the right ▪ Box hits pole and slides back behind the occluder ▪ Occluder Sequence presented 4 times	2 seconds 2 seconds 4 seconds 4 seconds 2 seconds 4 seconds 4 seconds 2 seconds
Test A	▪ Black Slide plus Sound ▪ Presentation of one- or two-object display	2 seconds 15 seconds
Familiarization B	▪ Black Slide plus Sound ▪ Occluder ▪ Ball appears to the left, pulsates, jumps further to the left, pulsates ▪ Ball jumps back toward the occluder, stops before it disappears behind the occluder ▪ Occluder ▪ Box slides out from behind the occluder and moves to the right ▪ Box hits pole and slides back behind the occluder ▪ Occluder Sequence presented 2 times	2 seconds 2 seconds 4 seconds 4 seconds 2 seconds 4 seconds 4 seconds 2 seconds
Test B	▪ Black Slide plus Sound ▪ Presentation of one- or two-object display	2 seconds 15 seconds

APPENDIX E – PROCEDURE EXPERIMENT 3

Introduction of Screen

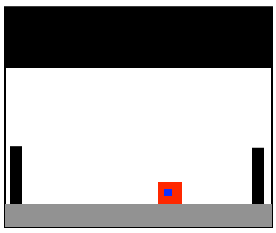


Familiarization Phase A
(4 Presentations)

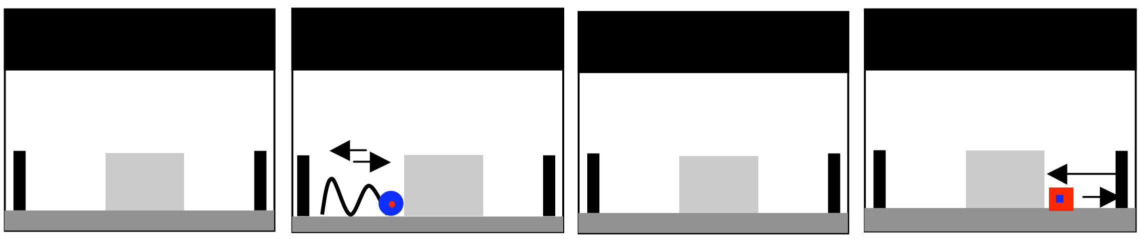


Test A

One-Object Display

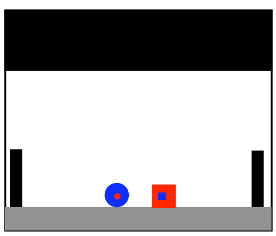


Familiarization Phase B
(2 Presentations)



Test B

Two-Object Display



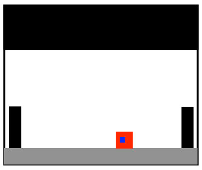
APPENDIX F – COURSE OF PRESENTATION EXPERIMENT 3

SEQUENCE	**PRESENTATION**	**DURATION**
INTRODUCTION OF SCREEN	▪ Black Slide ▪ Descent of Screen plus Sound ▪ Ascent of Screen ▪ Descent of Screen plus Sound ▪ Ascent of Screen	2 seconds 4 seconds 4 seconds 4 seconds 4 seconds
FAMILIARIZATION A	▪ Black Slide plus Sound ▪ Occluder ▪ Ball appears to the left, pulsates, jumps further to the left, pulsates ▪ Ball jumps back toward the occluder, stops before it disappears behind the occluder ▪ Occluder ▪ Box slides out from behind the occluder and moves to the right ▪ Box hits pole and slides back behind the occluder ▪ Occluder SEQUENCE PRESENTED 4 TIMES	2 seconds 2 seconds 4 seconds 4 seconds 2 seconds 4 seconds 4 seconds 2 seconds
TEST A	▪ Black Slide plus Sound ▪ Presentation of one- or two-object display	2 seconds 15 seconds
FAMILIARIZATION B	▪ Black Slide plus Sound ▪ Occluder ▪ Ball appears to the left, pulsates, jumps further to the left, pulsates ▪ Ball jumps back toward the occluder, stops before it disappears behind the occluder ▪ Occluder ▪ Box slides out from behind the occluder and moves to the right ▪ Box hits pole and slides back behind the occluder ▪ Occluder SEQUENCE PRESENTED 2 TIMES	2 seconds 2 seconds 4 seconds 4 seconds 2 seconds 2 seconds 4 seconds 4 seconds 2 seconds
TEST B	▪ Black Slide plus Sound ▪ Presentation of one- or two-object display	2 seconds 15 seconds

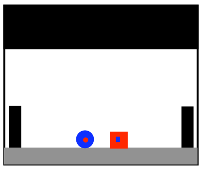
APPENDIX G – PROCEDURE EXPERIMENT 4

Baseline Phase

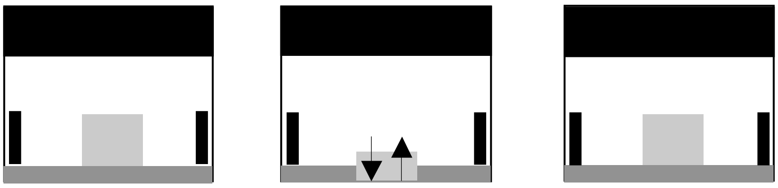
One-Object Display



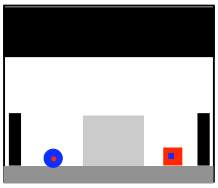
Two-Object Display



Introduction of Screen

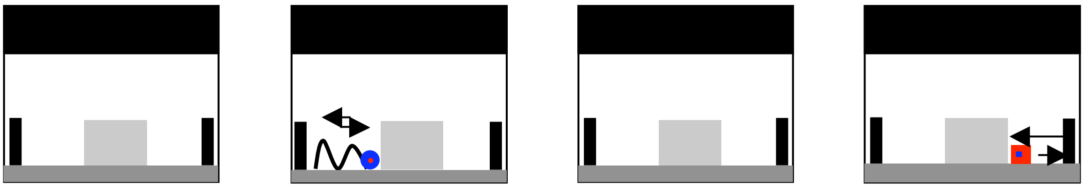


Presentation of Spatiotemporal Information



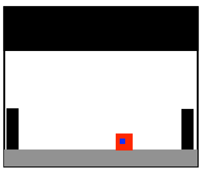
Familiarization Phase A

(4 Presentations)



Test A

One-Object Display



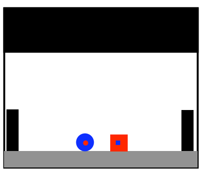
Presentation of Spatiotemporal Information

Familiarization Phase B

(2 Presentations)

Test B

Two-Object Display



APPENDIX H – COURSE OF PRESENTATION EXPERIMENT 4

SEQUENCE	PRESENTATION	DURATION
BASELINE A	▪ Black Slide plus Sound ▪ Presentation of one- or two-object display	2 seconds 15 seconds
BASELINE B	▪ Black Slide plus Sound ▪ Presentation of one- or two-object display	2 seconds 15 seconds
INTRODUCTION OF SCREEN	▪ Black Slide ▪ Descent of Screen plus Sound ▪ Ascent of Screen ▪ Descent of Screen plus Sound ▪ Ascent of Screen	2 seconds 4 seconds 4 seconds 4 seconds 4 seconds
PRESENTATION OF SPATIOTEMPORAL INFORMATION	▪ Black Slide plus Sound ▪ Presentation of both objects aside the screen	2seconds 10 seconds
FAMILIARIZATION A	▪ Black Slide plus Sound ▪ Occluder ▪ Ball appears to the left, pulsates, jumps further to the left, pulsates ▪ Ball jumps back toward the occluder, stops before it disappears behind the occluder ▪ Occluder ▪ Box slides out from behind the occluder and moves to the right ▪ Box hits pole and slides back behind the occluder ▪ Occluder SEQUENCE PRESENTED 4 TIMES	2 seconds 2 seconds 4 seconds 4 seconds 2 seconds 4 seconds 4 seconds 2 seconds
TEST A	▪ Black Slide plus Sound ▪ Presentation of one- or two-object display	2 seconds 15 seconds
PRESENTATION OF SPATIOTEMPORAL INFORMATION	▪ Black Slide plus Sound ▪ Presentation of both objects aside the screen	2 seconds 10 seconds
FAMILIARIZATION B	▪ Black Slide plus Sound ▪ Occluder ▪ Ball appears to the left, pulsates, jumps further to the left, pulsates ▪ Ball jumps back toward the occluder, stops before it disappears behind the occluder ▪ Occluder ▪ Box slides out from behind the occluder and moves to the right ▪ Box hits pole and slides back behind the occluder ▪ Occluder SEQUENCE PRESENTED 2 TIMES	2 seconds 2 seconds 4 seconds 4 seconds 2 seconds 4 seconds 4 seconds 2 seconds
TEST B	▪ Black Slide plus Sound ▪ Presentation of one- or two-object display	2 seconds 15 seconds

APPENDIX I

LIST OF FIGURES

APPENDIX J

LIST OF TABLES