PSYC 140a
Professor Frank Keil

By submitting this essay, I attest that it is my own work, completed in accordance with University regulations.—Elizabeth Rawson

Infants' Use of Kind Information in Object Individuation and Implications for Conceptual Development

by Elizabeth Rawson

Abstract

Investigation of object individuation bears on the topic of infant conceptual development. The current debate on object individuation concerns at what age infants are able to use featural or kind information to perform object individuation. Previous research has found that 10-month-olds fail to use featural/kind information in a complex object individuation task developed in Xu and Carey (1996). It has been concluded that 10-month-olds must not have kind concepts. However, infant categorization research has demonstrated that infants younger than 10 months do have the capacity to represent kind concepts. Wilcox and Baillargeon (1998) suggested that the failure to use featural/kind information in the Xu and Carey (1996) task is an artifact of the complexity of the task. I propose that infants may fail the task even though they have the relevant concepts. The proposed study combines two previously developed experimental designs in a novel way in order to demonstrate that the presence of kind concepts in 10-month-old infants does not predict the same infants' performance on the object individuation task used by Xu and Carey (1996).

Introduction

Object segregation is the process of parsing the visual scene into distinct objects. Object individuation is the process of keeping track of those objects through time and space. In principle, neither requires object identification or recognition, which is the process of

recognizing a particular object as being a member of a particular category. Object segregation is often implicitly tested in research on object individuation. Indeed, the distinction between object segregation and individuation is often blurred. However, the relationship between object individuation and object identification is one of more active interest. Object individuation is presumably necessary for object identification, but how the capacity for object identification influences the ability to do object individuation seems to be a more complex question. Infant studies provide a unique opportunity for studying the relationship between these two processes because we can ask how the development of one process affects that of the other.

Questions about when and how infants begin to do object individuation have been a particularly active topic of research in recent years. One question regarding infant object individuation is, of course, at what age infants are capable of individuating objects at all. A further issue is what kinds of information infants at various ages are able to use for object individuation. Other possible research questions include how infants gain access to supporting information that they have previously been unable to access and whether improvement in performance goes through a qualitative shift or gradual, quantitative development.

Much of the research in this area has attempted to connect infants' performance in object individuation tasks with infants' conceptual development. As noted above, the relationship between object individuation and object identification is far from resolved. Kind concepts presumably support object individuation by allowing the infant to use kind differences to determine how many objects are involved. Some research has attempted to make conclusions in the opposite direction, inferring from infants' performance on object individuation tasks what concepts they do and do not have. However, it may sometimes be inappropriate and misguided to make conclusions about conceptual development in this way. This paper reviews the current

literature, discusses the various issues involved in the current debate, and proposes a novel research project to further investigate the relationship between object individuation and conceptual development.

Review of the Literature

Early Views of Infants' Understanding of the Physical World

Historically, there have been several major theories of how, and to what extent, infants understand the physical world around them. In *The Origin of Intelligence in Children*, Jean Piaget proposed his landmark stage theory ascribing the first two years of life to a sensorimotor period in which infants do not have the object concept, that is, the concept of how physical objects behave (Piaget 1952). This theory made precise predictions about infants' capacities to mentally represent and reason about their environment. Piaget proposed that young infants are not aware of an object's existence as a separate, independent entity in the world, apart from the schemes with which the infant interprets the environment. Thus, Piaget predicted that until four months of age, infants are not aware of an object's continuing existence after it is hidden. According to Piaget's theory, the infant's understanding of the physical world develops gradually through interactions with the environment. Not until the last stage of the sensorimotor period, which generally begins around 18 months of age, do infants have a complete object concept, including an understanding of object permanence. Also, only at this time do infants have true mental representations of physical objects (for a more detailed description, see Piaget 1954).

Piaget's theory was strongly empiricist, claiming that infants only gradually, and rather late, develop those capacities underlying a basic understanding of the physical world. Piaget's claims about infant cognition were widely accepted into the 1970s. However, since that time, many studies have demonstrated that infants have access to much more information about the

physical world than Piaget theorized. Indeed, it appears that infants have quite specific expectations about the objects in their environments, even from a very young age. The emerging view is one in which infants' cognitions are more sophisticated than Piaget predicted, and, in some cases, more continuous with that of adults.

Evidence for a More Sophisticated Understanding

A large body of research has now demonstrated that infants have a much richer understanding of the physical world than Piaget predicted. The first researcher to present a substantial challenge to Piagetian theory was T.G.R. Bower. Bower argued that infants are aware of objects as physically enduring separate from themselves but differ from adults in their set of expectations about objects. For example, in Bower and Paterson (1973), the authors theorized that infants under three months old search for an object in one location even after they watch it move to a second location not because they lack an understanding of objects as objective, continually existent entities, but rather because their object concept does not differentiate place and movement. The specific details of Bower's account have not been particularly successful in explaining infant behavior, but his assumption that infants have a greater understanding of the physical world than Piaget predicted has been well supported. More recent research has demonstrated object permanence in infants younger than Piaget predicted. Baillargeon, Spelke, and Wasserman (1985) demonstrated that five-month-old infants are aware of object permanence. Several years later, Baillargeon and Devos (1991) found that even 3.5 month old infants display an understanding that objects continue to exist after being hidden. These studies reveal a much greater sophistication in the infant than Piaget and his followers would have predicted.

This view of the infant has been corroborated as infants' understanding of the physical world is becoming better understood. Research on naïve physics has successfully demonstrated that infants have specific, very early-emerging expectations about how physical objects will behave and interact with each other. Spelke (1990) reviews the principles with which infants appear to perceive objects in complex displays. Infants appear to understand that objects are unified wholes that move in continuous paths and maintain size and shape through motion. They also understand that objects generally do not act on each other from a distance. This characterization of infants' understanding is confirmed in the literature cited by Spelke. However, one research question that is not so well resolved is when and how infants begin to perform object individuation, the process of tracking individual objects through time and space. Currently, there are roughly two schools of thought on infants' ability to do object individuation.

Research on Object Individuation: *The Current Debate*

Object individuation is an area in which there is a clear divide between two theories. Much of the recent debate has focused on the ages at which infants are able to use various types of information in order to succeed in object individuation. This is a particularly important topic because it bears directly on theories of infant conceptual development. The three types of information that infants might use in object individuation are spatiotemporal information, featural information, and kind information. Spatiotemporal information is information about the location and motion of an object. If we see two objects in two separate locations, we infer from this unambiguous spatiotemporal information that there are two distinct objects involved. Featural, or property, information consists of the perceptual features of objects. If we see a bright yellow tennis ball and a smooth, green bowling ball, we may infer the presence of two objects based on the presence of both "yellow-fuzziness" and "green-smoothness." Kind information is

accessed through the classification of an object into a specific category. In the case of the tennis ball and bowling ball, we might infer the presence of two objects based on the presence of an exemplar of "tennis balls" and an exemplar of "bowling balls." These two categories are mutually exclusive, so if there is an exemplar of each, there must be two objects involved.

It is difficult to distinguish empirically whether a subject is using featural or kind information for object individuation. If a subject infers the presence of two objects in the case of the tennis ball and bowling ball, one cannot determine whether the subject used featural information or kind information. As long as there is a kind difference, there will be featural differences, so featural information will always be available to the subject whenever kind information is made available. Indeed, one major critique of many concept acquisition studies has been that the subjects may be using lower-level featural differences to distinguish members of separate categories, rather than forming a concept and then categorizing on that basis. Due to the difficulty in distinguishing featural and kind information, it is useful to refer to featural/kind information for the case in which two objects differ in kind.

The inability of infants to use featural/kind information in object individuation tasks has sometimes been taken as evidence that the infants do not have kind concepts. Much of the present debate in the object individuation literature has focused on whether this is a valid conclusion. This is a significant matter because the evidence from object individuation has been used to claim that infants do not have any kind concepts at all until fairly late in development. If such an argument proved accurate, much of current thought on conceptual development would need to change, and previous results suggesting that younger infants do have kind concepts would need to be reevaluated.

One side of the debate, represented here by Xu and Carey, has argued that 10-month-old infants do not have kind concepts. Xu and Carey base this claim on their finding that 10-month-olds do not use featural/kind information for object individuation (Xu and Carey 1996). Xu and Carey (1996) presented evidence that both 10 and 12 month olds can use spatiotemporal information for an object individuation task, but that only the 12 month olds can successfully use featural/kind information in the absence of unambiguous spatiotemporal cues. Experiment 2 in Xu and Carey (1996) involved a single screen and two objects of different kinds (see Figure 1 in Appendix for diagram of experimental set-up). Every infant watched four introductory trials, which were meant to familiarize the infant with the display. After the introductory trials, infants either saw the property/kind condition, the spatiotemporal condition, or the baseline condition. In the property/kind condition, one object appeared to the left from behind the screen, moved toward the left, reversed directions, and returned behind the screen. Then a second object with different features and belonging to a different kind emerged from the right side of the screen, moved to the right, and then reversed direction and returned behind the screen. This sequence was repeated so that each object emerged four times. Finally, the screen was removed, revealing either two objects (expected outcome) or one object (unexpected outcome). The spatiotemporal condition used the same procedure, except that before the trials the experimenter showed the infant the two objects side by side, thus providing spatiotemporal cues that they were two different objects. A baseline condition was used to test whether infants had a pre-existing looking-time preference for either one or two objects.

Xu and Carey found that 10 month olds expected to see two objects at the end of the test trial in the spatiotemporal condition but not in the property/kind condition. They argue that these results demonstrate that 10 month old infants do not have the kind concepts for the objects used

in the task. If the 10 month olds did have the concepts for these objects, they would use the kind information to individuate the objects and consequently succeed in the property/kind condition. They have titled this hypothesis the emerging kind representations hypothesis because it posits an emergence of all kind concepts between the ages of 10 and 12 months (Xu, Carey, and Quint 2004). Xu has also argued that perhaps the learning of count nouns plays a critical role in this difference between 10 and 12 month olds. Xu proposes that the acquisition of these nouns may precede and contribute to the acquisition of the related kind concepts by allowing the labeling of various objects, and that this labeling enhances performance on the object individuation task (Xu 1999, Xu 2002). Thus, Xu and Carey have argued for a major shift between the ages of 10 and 12 months old, one that allows the emergence of the first kind concepts and the acquisition of the first count nouns.

There are three reasons, two theoretical and one empirical, to be skeptical about this claim. The first theoretical problem is the following: if the 10-month-olds are not able to use featural information for such tasks as object individuation, how do they successfully form concepts later in development? A concept is a mental representation of a category of entities. The infant must be able to recognize the featural regularities among exemplars in a category in order to form a mental representation of that class of items. The second theoretical problem is related to language acquisition. Under Xu and Carey's framework, infants acquire words for categories before, or at the same time as, they acquire the concepts for those same categories. It is unclear how infants could acquire words for which they do not already possess the concepts (for discussion, see Wilcox and Baillargeon 1998 and Murphy 2004, p. 308-309).

The third reason not to accept Xu and Carey's argument that infants do not have kind concepts until 12 months is that it is inconsistent with a large body of empirical research on

conceptual development. A series of habituation/dishabituation studies have demonstrated that infants as young as three months old are able to learn new kind concepts, in the sense that they are able to distinguish between exemplars from two different kind categories. These studies generally involve a habituation/dishabituation design in which the infant habituates across exemplars of a given category and then (if successful in the task) dishabituates to an exemplar of a second category. This dishabituation on the critical trial demonstrates that the infant has formed a concept for the first set of exemplars and perceives the test item as novel since it does not fit the concept (see Figure 2 in Appendix). Using this design, Bomba and Siqueland (1983) demonstrated that three and four-month-old infants are able to learn artificial categories of random dot patterns. Several studies have also demonstrated infants' varying abilities to learn natural categories. Quinn, Eimas, and Rosenkratz (1993) demonstrated that three-month-olds can distinguish cats from birds, dogs from birds, cats from dogs, and also dogs from cats when the two sets of exemplars were matched for variability. Eimas and Quinn (1994) showed that by six or seven months, infants can even distinguish a cat from a tiger or a female lion. These studies directly contradict Xu and Carey's claim that young infants do not have kind concepts.

The other side of the debate has emphasized the three problems described above and has provided an alternative explanation for the Xu and Carey (1996) findings. Wilcox, Baillargeon, and others have argued that infants younger than 12 months old are able to use featural information to do object individuation. They propose that the failure of 10-month-olds to succeed in the Xu and Carey (1996) property/kind condition is an artifact of the complexity of the task. Wilcox and Baillargeon (1998) found that 7.5 month old infants can use featural information to succeed in object individuation if given a simpler task with a smaller information processing load. Wilcox and Baillargeon adapted Xu and Carey's property/kind condition in two different

ways for two separate tasks. One of the experiments reduced the processing required by not requiring infants to compare an occlusion event and a non-occlusion event. 7.5 month olds succeeded in this task. Another experiment reduced the load by simplifying the objects' trajectories. In this experiment, either a ball or a box moved from the left side of the display to go behind the screen. A ball then appeared from the right side of the screen and moved to the right side of the display. Next, the screen fell, revealing nothing (unexpected in the box-ball case, expected in the ball-ball case). This task required infants to track the objects across fewer reversals of trajectory, which the investigators hypothesized would make the task easier in terms of a smaller cognitive load. Indeed, 9.5 month olds succeeded in this simplified version of Xu and Carey's task.

Thus, Wilcox and Baillargeon (1998) presents evidence that 7.5 and 9.5 month old infants can succeed in object individuation when only featural/kind information is available, given a simple enough task. This suggests that the 10 month olds' failure in the Xu and Carey (1996) property/kind condition was an artifact of the complexity of the task and should not be taken as evidence that infants younger than 12 months can only use spatiotemporal information for object individuation. The Wilcox and Baillargeon (1998) results do not directly support the conclusion that infants do have the relevant kind concepts, since it is unclear whether infants were using featural or kind information to succeed in their tasks. However, at the very least, 7.5 and 9.5 month olds do have access to featural information.

Research Proposal

It is clear that more research is required to untangle the various issues in this debate. One topic to further investigate is whether 10-month-old infants might have the relevant kind

concepts and yet still fail Xu and Carey's property/kind condition (Xu and Carey 1996). The purpose of the following study is to answer this question.

Hypothesis

I hypothesize that 10-month-old infants' failure in the property/kind condition of the complex object individuation task used by Xu and Carey (1996) is not indicative of an absence of the relevant kind concepts. I predict that infants who are demonstrated to have those concepts will still fail the task. This would suggest that Xu and Carey (1996)'s results were an artifact of the large information processing load of the task, as Baillargeon and others have argued.

Method

Subjects. The subject population is 10-month-old infants. Since I predict a fairly large effect, the final sample size in each condition need not be larger than 12. Parents of infants would be located from public birth records. Infants would be given small token gifts for participation. Finally, data would be excluded on a case-by-case basis if the infant is deemed unable to attend properly to the visual display for the length of time required.

Materials. In the first portion, the stimuli consist of color images of exemplars from four basic-level animal categories: cats, dogs, birds, and horses. The sets of exemplars for each category are matched in terms of intra-set variability. Half of subjects habituate to exemplars of either cat or dog, and then see the other on the test trial, and the other half of subjects will habituate to exemplars of either bird or horse, and see the other one on the test trial. These pairs (cat-dog, bird-horse) are chosen because previous research has demonstrated that infants of 10 months either already possess, or are able to learn, these concepts. Quinn, et al. (1993) found that

3 month olds can distinguish cats from dogs, and also dogs from cats when the sets of exemplars are equated for variability. Roberts (1988) presented evidence that 9 month olds can distinguish birds from horses. Though that study did not verify whether infants can distinguish horses from birds, I will predict that 10 month old infants can do so. It can reasonably be predicted that 10-month-olds will succeed in the first task, given these stimuli.

For the second portion of the experiment, the stimuli consist of two pairs of physical objects. The first pair is a small toy cat and a small toy dog. The second pair is a small toy bird and a small toy horse. Toys are chosen that will support kind identification as much as possible. Thus, the toys are chosen to appear similar to the exemplars used in the first task. They should also have prominent, accurately shaped faces because there is evidence that faces are especially important in the learning of animal categories (Quinn and Eimas 1996; Spencer, Quinn, Johnson, and Karmiloff-Smith 1997). The number of legs and other major features (such as presence of wings on the bird) should also be as visually obvious as possible without being too different from the exemplars used in the first task.

Procedure. Every subject participates in both tasks. The first task is a paired preference habituation/dishabituation task similar to that used in much of the infant research on conceptual development cited above (Bomba and Siqueland 1983, Quinn et al. 1993). The purpose of this task is to determine that every subject has the relevant concepts before they continue to the second portion of the experiment. Every subject will habituate to a series of images of exemplars from one category and then see an exemplar from a second category on the test trial. This task is chosen because it is generally considered to be a reliable, valid means to investigate infant concept acquisition, and it has been used in much of the infant conceptual development literature to date.

The second part is a replication of the property/kind condition of the task used in Xu and Carey (1996). Xu and Carey's task is replicated exactly except for the use of different stimuli. Each infant sees an expected outcome (two objects) and an unexpected outcome (one object), with the order of outcomes counterbalanced across subjects. There is also a baseline condition in order to gauge infants' baseline preferences for displays with either one or two objects. The choice to use the Xu and Carey task is a principled one, for this study investigates a specific hypothesis about the correct interpretation of infants' performance on that specific task. The stimuli are changed in an attempt to make property/kind information even more salient and accessible to the infants. The stimuli used in Xu and Carey (1996) were a duck and a ball, and a truck and an elephant. In order for infants to use kind information for object individuation, they must first have the relevant kind concepts. While 10-month-old infants may have the concepts for duck, ball, truck, and elephant, there is a lack of empirical evidence suggesting that one can safely assume this. Thus, in this study, stimuli are chosen for which it has been demonstrated empirically that infants younger than 10 months (in some cases a good deal younger) have, or are able to learn, the relevant concepts.

Predictions

I predict that a majority of infants will succeed in the first task, but that only a small minority, if any, will succeed in the second task. Furthermore, I expect that a significant percentage of the infants who succeed in the first task will fail in the second task.

Interpretations of Possible Results

If infants tend to succeed in the categorization task but fail the object individuation task, this will suggest that the failure in the second task is not due to a lack of the relevant kind concepts. There are two alternative explanations for why infants with the relevant concepts

would still fail object individuation. First, perhaps the object individuation task used here is simply too complex for infants to solve, no matter how much supporting information is available. The processing required to track the objects through their multiple reversals of trajectory may be too advanced for 10-month-old infants. The results of Wilcox and Baillargeon (1998) support this interpretation. Second, it is possible that infants are unable to access their kind concepts during the object individuation task. This may be due to a heavy cognitive load, but it may also be caused by some other quality of the object individuation process.

If infants tend to succeed in both the first and the second task, there are several possible interpretations. First, it is possible that the stimuli used in this study were easier for infants to track than the stimuli used in Xu and Carey (1996). They may be simpler, or 10-month-old infants may be more likely to be familiar with the stimuli chosen here than those used by Xu and Carey. Second, it is possible that the first task affected performance on the second task. There are at least two ways this may have occurred. It is possible that participating in the first task made the objects in the second task more salient than they would have been otherwise, and that this increased salience somehow improved performance on object individuation. Perhaps the first task caused infants to attend more to featural/kind differences than they normally would. On the other hand, the first task may have enhanced these infants' conceptual knowledge, thus improving their ability to use featural/kind information in the subsequent object individuation task.

Two Possible Problems with this Design

There are two main sources of problems with this experimental design. The first is the use of the habituation/dishabituation categorization task. The issue is that success in the first task may not require infants to form a concept. It may not be necessary for an infant to form a

conceptual representation in order to dishabituate to a non-member item. If an infant sees a series of images of different cats, and then dishabituates to an image of a dog, it is possible that the infant simply dishabituated to the shorter tail of the dog, or some other low-level perceptual difference. This is a serious concern for the experiment proposed here. Infants' success on the first task may not mean that they have the relevant concepts. If this is the case, we cannot conclude from the infants' subsequent failure on the second task that performance on the second task is not a good indicator of infants' conceptual capacities. One way to avoid this problem is to use categories that are as perceptually similar to each other as possible. Another way is to choose exemplar sets with high intra-set variability (for instance, in the position, color, and other attributes of the animal) to decrease the chance that any one perceptual feature is common of all exemplars in one set.

The second problem is the assumption that whatever concepts infants seem to have during the first task will necessarily also be present during the second task. It is possible that infants might learn the concept in the first task, but then either forget or distort it before the object individuation task begins. The first scenario, that the infants might learn and then forget the concept within minutes, seems unlikely. However, it is plausible that infants' representations might somehow become distorted or damaged. Consolidation of the infant's memory for the conceptual information might not take place between the first and second task due to the minimal amount of training time or due to the distraction of the novel laboratory environment. This problem may be far-fetched, but it is worth considering, since the assumption at stake is essential for the logic of the design.

Conclusion

In conclusion, object individuation is an important topic in infant research. As discussed above, work on object individuation has significant implications for theories of conceptual development. Further research is necessary in order to better resolve the current debate. I hypothesize that Xu and Carey's characterization of infants' object individuation and conceptual development is not correct. It seems theoretically implausible, and it is inconsistent with the present literature on infant concepts. However, the Xu and Carey (1996) results are still interesting because they suggest that infants might have access to featural/kind information in some situations but not in others. Further studies should help to explain this discrepancy.

References

Baillargeon, R. & Devos, J. (1991). Object permanence in young infants: Further evidence. *Child Development, 62* (6), 1227-1246.

Baillargeon, R., Spelke E.S., & Wasserman, S. (1985). Object permanence in 5-month-old infants. *Cognition, 20* (3), *191-208.*

Bomba, P. C. & Siqueland, E. R. (1983). The nature and structure of infant form categories. *Journal of Experimental Child Psychology, 35,* 294-328.

Bower, T.G.R. & Paterson, J.G. (1973). Separation of place, movement, and object in world of infant. *Journal of Experimental Child Psychology, 15* (1), 161-168.

Eimas, P.D. & Quinn, P.C. (1994). Studies on the formation of perceptually based basic-level categories in young infants. *Child Development*, 65 (3): 903-917.

Murphy, G. (2004). *The Big Book of Concepts*. Cambridge, Massachusetts: The MIT Press.

Piaget, J. (1952). *The Origins of Intelligence in the Child*. New York: International Universities Press, Inc.

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

Quinn, P. C., Eimas, P. D., & Rosenkratz, S. L. (1993). Evidence for representations of perceptually similar natural categories by 3-month-old and 4-month-old infants. *Perception, 22,* 463-475.

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.

Roberts, K. (1998). Retrieval of a basic-level category in prelinguistic infants. *Developmental Psychology, 24*, 21-27.

Spelke, E.S. (1990). Principles of object perception. *Cognitive Science, 14* (1), 29-56.

Spencer, J., Quinn, P. C., Johnson, M. H., & Karmiloff-Smith, A. (1997). Heads you win, tails you lose: Evidence for young infants categorizing mammals by head and facial attributes. *Early Development and Parenting, 6,* 113-126.

Xu, F. (1999). Object individuation and object identity in infancy: The role of spatiotemporal information, object property information, and language. *Acta Psychologica, 102* (2-3), 113-136.

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

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

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

Xu, F., Cote, M. & Baker, A. (2005). Labeling guides object individuation in 12-month-old infants. *Psychological Science, 16,* 372-377.

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

Appendix

Figure 1. Task used in Xu and Carey (1996), Experiment 2 (A-E repeated four times)

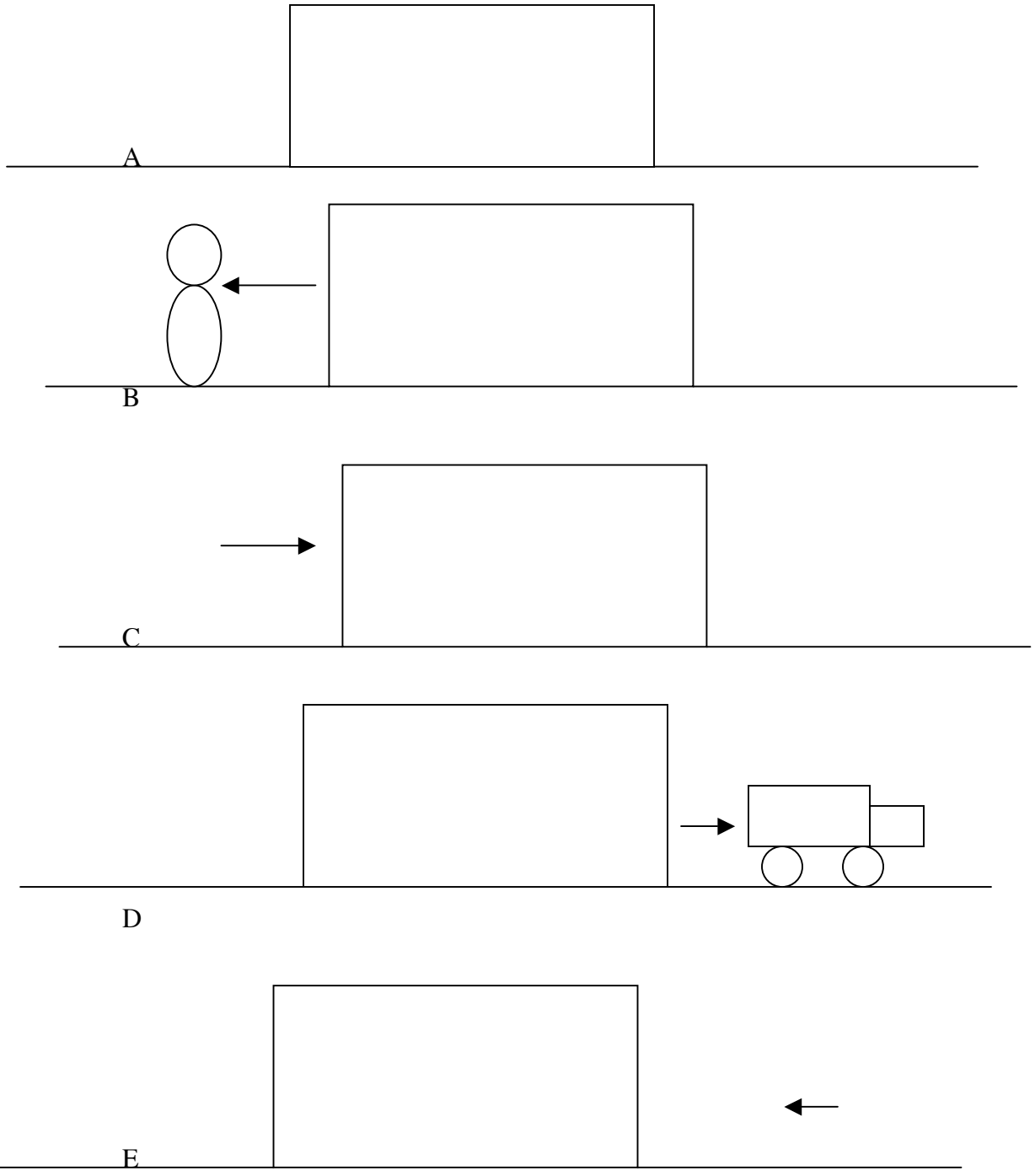

Figure 2. Paired preference habituation/dishabituation task used in Quinn et al. (1993)

Left Side of Display	Right Side of Display
Cat 1	Cat 1
Cat 2	Cat 2
Cat 3	Cat 3
Cat 4	Cat 4
Cat 5	Dog

This is an example design for a study of whether infants can learn the concept for “cat,” as distinct from that of “dog.” There are five trials in total, with the last trial being the critical one.