INFANTS' PROCESSING OF ACTION FOR GIST

by

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Interpreting human object-directed action requires infants to gloss over surface differences in the motion stream between separate action exemplars and extract the meaning—or *gist*—of the action. The experiments reported in this dissertation investigated infants' processing of action for gist. During the habituation phase of each experiment, infants saw an actor manipulate an object. At test, infants were shown two perceptually distinct actions in which the actor used a novel hand configuration to contact—but not manipulate—the object. One test trial depicted an action consistent with the gist of the habituation action, while the other test trial depicted a gist-inconsistent action. In question was whether infants would make a generative inference of what the actor was likely to do with the object in test trials, gloss over surface-level differences between the habituation and test actions, and categorize together actions that were similar in gist. It was predicted that infants would demonstrate gist-level processing by looking longer at gist-inconsistent than gist-consistent test trials. In Experiment 1, 5-

to 7- and 10- to 12-month-olds' gist-level processing of pushing versus pulling actions was investigated. Experiments 2a and 2b attempted to replicate Experiment 1 using a modified methodology with a group of 6- to 7- and 11- to 12-month-olds, respectively. Experiment 3 investigated whether 10- to 12-month-olds, when observing events involving an actor pushing an object toward a recipient, construe the action at a level of gist that captures the dyadic nature of the interaction or simply the spatial location to which an object is moved. Experiment 4 investigated whether 10- to 12-month-olds process the gist of opening and closing actions. Across the set of experiments, 10- to 12-month-old infants routinely displayed clear-cut evidence of gist-level processing—i.e., at test, they looked longer at trials depicting a gist-inconsistent action than a gist-consistent action, despite these actions being equally perceptually dissimilar from actions in habituation. Data from 5- to 7-month-olds were suggestive of gist-level processing for some actions. These findings point to infants' ability to interpret action at an abstract level in the face of the rampant perceptual variability inherent in human action.

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I dedicate this to my mother.

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CHAPTER 1

INTRODUCTION

Overview

The ability to make sense of the behavior of others is a remarkable achievement in human development. Imagine having a bird's-eye view of the kitchen of a busy restaurant. A kitchen apprentice juliennes an onion and fillets a salmon. The pastry chef prepares dough by tossing it in the air, rolling it out on the counter with a rolling pin, and using her hands to smooth the edges. The sous-chef parboils green beans while pan searing a steak before placing it in the oven. After the last dinner order of the night leaves the kitchen, the executive chef opens up the refrigerator door, pulls out a cold bottle of Guinness, and twists off the cap in order to drink to a night well done.

Despite the ongoing and often frenetic movement, an observer would have little difficulty interpreting this scene, an impressive accomplishment that involves a host of processing mechanisms. When observing behavior, adults segment and extract individual action units within the ongoing stream of motion (Baldwin, Andersson, Saffran, & Meyer, 2007; Newtson, 1973; Zacks, 2004) and make inferences about the actors' goals, intentions, beliefs, and other mental states (Holbrook, 2007; Malle, 2004; Meltzoff, 1995). Individual action units are also organized hierarchically (Hard, Tversky, & Lang, 2006; Jackendoff, 2007; Zacks, Tversky, & Iyer, 2001; Zacks & Tversky, 2001) such that a general goal—e.g., to prepare a dough—is broken down into sub-goals such as mixing the ingredients and kneading the dough .

Within the past decade, a growing literature has begun to elucidate the development of these abilities in infancy. Baldwin and colleagues (Baldwin, Baird, Saylor, & Clark, 2001), for instance, found that when viewing a kitchen clean-up scene, 10- and 11-month-old infants parsed the ongoing stream of motion into individual units. Importantly, those units were located at natural junctures in the action which corresponded to breakpoints between separate intentional acts. Not only are infants capable of segmenting actions, but, by 12-months-of-age, infants who see two actions occur in a causal sequence interpret the first action as related to the eventual goal achieved by the second action (Woodward & Sommerville, 2000), an ability which may represent a first step in hierarchical representation of action. These studies are part of a large body of research supporting the contention that several critical developments in infants' ability to interpret observed behavior occur within the first year of life.

There is, however, an additional skill that has been the topic of less research, but which is critical to interpreting human action that; namely, the ability to recognize that two or more perceptually dissimilar behaviors can all have the same goal or meaning. Consider again the kitchen scene described above. The sous-chef engages in two very different actions—briefly placing green beans in boiling water and searing a steak in a frying pan—which are similar in their attempt to partially cook a food item in preparation for additional cooking procedures. Likewise, the executive chef uses two very different kinds of movements—a yank of the arm directed at the refrigerator door and a twist of the wrist directed at the bottle cap—to accomplish the same functional act of opening a container.

The above scenario highlights a tension between attending to local surface details of the motion stream on the one hand, and forming more abstract representations of the action, such as the nature of the actor's goals and intentions, on the other hand. The observer must actively attend to the surface form of peoples' motions to grasp the "gist" of what they are attempting to accomplish, even though some of those details are eventually ignored or forgotten. Consider again an actor manipulating a bottle cap. A slight change in the directionality of twisting—clockwise versus counterclockwise—entirely reshapes the interpretation of ongoing action, changing it from *opening* to *closing*. The observer must therefore attend to local perceptual features of the motion display while simultaneously prioritizing the gist-level analysis over the perceptual analysis when forming representations of the meaning of the observed actions.

An additional component of processing local perceptual features is predicting future action, such as the probable trajectory of an action. As an actor moves through space, highly relevant local details of the actions are often occluded, leaving the observer without information about the nature of the intended act. If the executive chef turned her back to the observer just as she grasped the bottle cap, the observer would be unable to see the critical act of opening the bottle. In such cases, the ability to predict future action is the difference between understanding the event as opening the bottle and being puzzled about why the chef would want to grasp and hold a bottle cap. Furthermore, the observer must then be able to extract the gist of this event not by focusing on the observed motion stream, but instead focusing on the *inferred* act. The importance of action inference for gist-level processing is also seen when using top-down information to analyze a sequence of actions. The ability to see the common gist between the sous-chef's parboiling and pan searing arises from domain knowledge about cooking that allows the observer to recognize the these actions as preparatory, and thus to predict that other cooking methods are likely to follow. Without this abstract representation of the gist of these two actions, a critical similarity between them is lost.

While some research has investigated the formation of abstract action representations in infancy, the bulk of this research has focused on infants' understanding of the goal-directedness inherent in grasping an object (Phillips & Wellman, 2005; Sommerville, Woodward, & Needham, 2005; Todd & Smith, 2008; Woodward, 1998; , 1999; Woodward & Sommerville, 2000), in looking at an object (Moore & Povinelli, 2007; Woodward, 2003), or in pointing at an object (Woodward & Guajardo, 2002). The ability to recognize that grasps, points, and eye-gaze are directed at a particular goal object and not simply at any object is a critical first step in social cognition. Nonetheless, it is an early step on the path to more mature action processing skills (Woodward, Sommerville, & Guajardo, 2001). Making sense of the behavior of others involves more than understanding that people direct grasps at goal objects—it involves interpreting what people actually *do* with objects once they have grasped them. Returning again to the kitchen scene described earlier, it is clear that any meaningful analyses of the action must involve the ability to interpret how people manipulate objects like bottles, knives, and balls of dough. It is possible that an infant is perfectly capable of understanding that the chef is directing her attention to that particular bottle without having the slightest understanding of the meaning of the action that she subsequently performs on the bottle.

Very little is currently known about the development of mechanisms enabling infants to simultaneously interpret the gist of object-directed action while glossing over vast tracts of motion change between exemplars of those actions. The experiments reported in this dissertation investigated whether infants display signs of early sophistication at this human propensity to process action for gist, with specific attention to infants' understanding of the gist of actions involving object manipulation.

As this question has not been the explicit topic of previous research, an explanation of processing for gist is necessary before reviewing the existing literature on infant social cognition. The theoretical foundation of this dissertation was informed by what is known regarding gist-related processing in other domains, such as language. The following sections contain a brief overview of some findings in the language processing literature and a proposal regarding key components in processing action for gist. After discussing the nature of processing for gist, I will return to the literature on infant social cognition, with particular attention to findings that are germane to the topics raised in this dissertation.

Processing for Gist

When exposed to language, either written or spoken, there are at least two kinds of information that can be retained: the surface form—e.g., the words used and the order in which they were presented—and the meaning of the passage. An early and well-documented finding in the literature on text memory was that verbatim memory is not as robust as memory for the meaning, or "idea," of a written passage (English, Welborn, & Killian, 1934; Henderson, 1903; Welborn & English, 1937). The strength of this effect is striking. Participants in one study (English et al., 1934) read passages over 1,500 words in length and had their memory for the material tested at intervals between four and fourteen weeks. Participants were asked two types of true-false questions at test: the first asked whether a given target sentence was a verbatim reproduction of a sentence in the original text, and the second asked whether summary sentences captured ideas in the original. While memory for the verbatim items dropped precipitously, participants' memory for the ideas in the original text showed little-to-no decline, even after fourteen weeks.

Fillenbaum (1966) further investigated processing for the idea or content of a sentence, which he called the *gist*, by testing whether participants' errors in recognition would be more likely to preserve the meaning or surface form of a passage. Participants listened to an audio recording of a list of sentences such as "*the postman is not alive*." In test, they were given a written item—e.g., "*the postman is (a) alive (b) not alive (c) dead (d) not dead*"—and asked to check the option that created the sentence they heard in the familiarization phase. Fillenbaum examined whether participants' errors would be more likely to change the meaning of the sentence but retain some of the surface form (e.g., option *(a) alive* in the above example), or if they would be more likely to make errors that preserved the gist of the sentence but not the surface form (e.g., option *(c) dead* in the above example). As predicted by a gist-processing hypothesis, when participants made errors in recognition they were more likely to preserve the gist of the sentence than preserve some of the surface form. More recent research using a priming methodology (McKoon & Ratcliff, 1980; Ratcliff & McKoon, 1978) found similar effects; namely, that memory for a paragraph of written text is based on the propositions expressed rather than the temporal order in which the sentences were presented within the paragraph. In short, processing for gist entails homing in on the meaning of the input and disregarding surface details that are not critical in representing the gist.

In adopting the term *gist* to describe action processing, first suggested by Baldwin (2005), I propose that observers privilege an interpretation of the meaning of an action—what that action was *for* and the result it produced in the world—rather than surface details that do not influence the functional affordance of that action. This process involves the three following components:[1] (A) The observer identifies the functional affordance, or *gist*, of the action. In this nomenclature, *functional affordance* is defined as that which the action enables the actor to do in the world, referring specifically to actions that produce a clear result on some object or state of affairs in the world. (B) When able to extract the gist of the action, the observer tends to disregard surface motion details unrelated to the gist, much like participants in language processing studies did not encode gist-irrelevant details of a passage into long term memory. As a result, memory for the event is based largely on the more abstract gist-level representation (Loucks, in progress). However, observers maintain attention to the surface motion details in online processing, thus when they are unable to identify the gist they rely more heavily on bottom-up mechanisms an attempt to encode the action in some form (Cohen & Cashon,

[1] No claim is made here regarding the temporal or causal order of these components in on-line processing.

2006; Cohen, Chaput, & Cashon, 2002; see also Gleissner, Meltzoff, & Bekkering, 2000, for a similar proposal regarding older children's action representation system). (C) The observer categorizes action based on the gist, grouping together actions that may be dissimilar in motion details but are similar in gist. This is the case for both observed and inferred actions. The ability to form gist-based action categories is analogous to how even young infants are capable of forming abstract categories of *dog* and *cat*, each of which comprises multiple perceptually distinct exemplars (Quinn, Eimas, & Rosenkrantz, 1993; French, Mareschal, Mermillod, & Quinn, 2004).

The current proposal does not argue that observers are incapable of processing surface detail, or even that they do so infrequently. Research detailing adults' ability to capitalize on statistical regularities in a sequence of action (Baldwin et al., 2007) convincingly demonstrates that adults can attend to and remember surface details of action, and preliminary data from our laboratory (Baldwin et al., in preparation) suggests that infants are capable of doing the same. Rather, the claim is that when observers can readily interpret the gist of an action, in essence re-interpreting the event at a level more abstract than the perceptual, they preferentially base their interpretation on the extracted gist rather than surface details.

In freeing observers from the necessity of encoding all of the minutiae of the surface features inherent in human action, gist-level processing promotes processing efficiency while nevertheless enabling the viewer to reconstruct lower-level perceptual features from memory if those details need to be recalled in the future (Gleissner et al., 2000). For instance, when encoding the chef's actions on the bottle as *opening*, one does not need to explicitly encode into memory the directionality of her movement; knowledge of how bottle caps work, along with the gist-level representation, would allow the observer to accurately infer that she moved her wrist in a counter-clockwise direction. In situations where the gist is not obvious, such as is the case in Baldwin and colleagues' research on observers' attention to statistical regularities in the motion stream (Baldwin et al., 2007; Baldwin et al., in preparation), or in the case of observing a novel action, observers still have access to processing strategies that favor surface-level motion details (Cohen & Cashon, 2006). Gist-level processing, therefore, operates in tandem with bottom-up mechanisms, except that when gist-level representations are available, observers tend to prefer the gist-level representation when categorizing action and possibly even when encoding it in memory (see also Baldwin, 2005; Loucks, in progress; Karmiloff-Smith's [1992] representational redescription hypothesis; and Povinelli's [2001] behavioral abstraction hypothesis, for related proposals).

The key goal of the research contained in this dissertation is to investigate infants' interpretation of actions—and in particular those actions involving object-manipulation—at a level more abstract than the perceptual. Given the large amount of continually changing perceptual information inherent in ongoing, evanescent human action, it is critical that infants are able to attend to the important features and disregard the unimportant features of the motion display. The ability to categorize actions based on gist is a watershed development that allows infants to make connections between distinct action units and to construct hierarchical representations that are based on an actor's goals and intentions. As noted above, previous research has found similar processes involved when encoding the meaning of spoken or written language. A benefit of construing action analysis as "processing for gist" is that it encompasses several interrelated components that are involved in navigating between perceptual and abstract interpretations of human action (Cohen & Cashon, 2006; Cohen et al., 2002). Rather than simply highlighting the observer's skill in arriving at a single interpretation (e.g., the *goal* of her action was to open the bottle), framing action analysis vis-à-vis gist-based representations speaks to how observers move between several levels of analysis when interpreting action, and thus has the potential to capture more of the complexity of the action processing system.

Although the question of whether or not infants process multi-part action sequences for gist has not previously been the direct focus of research, several lines of research have provided relevant data on some of the constituent components described above. The following section contains an exploration of the literature on infant social cognition, as well as a discussion as to why these findings do not answer the questions posed in this dissertation.

Social Cognition in Infancy

Glossing over Changes to Surface Motion Details

Seminal work by Woodward (1998), has investigated infants' ability to recognize that manual grasps are directed at specific goal objects. The focus of this research and subsequent studies on the topic (Guajardo & Woodward, 2004; Phillips & Wellman, 2005; Sommerville et al., 2005; Woodward, 1999; Woodward & Sommerville, 2000) was to ascertain whether infants gloss over at least some motion changes—e.g., to the path of motion—and instead attend to deeper, more meaningful aspects of action, such as the goal object toward which a grasp is directed.

In Woodward's (1998) research on infants' understanding of goal-directed grasps, infants saw two small objects on either side of a stage at the start of habituation trials. An arm then reached into the stage, grasped one of the two items, and held the position while infants' looking time to the event was recorded. After habituating to repeated presentations of this grasp, infants saw a trial in which the locations of the two toys had been switched. The objects remained in the new, switched position for both types of test trial. In *new goal/old path* test trials, the actor reached to the same spatial location to which she had reached in the habituation phase, but now did so in order to grasp the toy she had not previously grasped. In *old goal/new path* test trials, the actor reached out to the side of the stage to which she did not reach in the habituation phase and grasped the same toy that she grasped in the habituation phase. By 6 months of age, infants looked reliably longer at new goal/old path trials than at old goal/new path trials. These findings suggest that, indeed, infants glossed over changes to the path of the reach, privileged a construal of the grasping action as being directed at a goal object, and were more surprised when the actor switched goals than when she switched the location of her reach (but see Bíró & Leslie, 2007; and Király, Jovanovic, Prinz, Aschersleben, & Gergely, 2003, for alternative explanations of these results).

Infants' propensity to gloss over details in the path of a movement has also been documented in research by Gergely and colleagues (Gergely, Nádasdy, Csibra, & Bíró, 1995). After being familiarized to a computer-generated shape move around a barrier in order to reach a goal location, infants saw test trials in which the barrier was no longer present and the shape again went to the goal location. By 12-months-of-age, infants looked longer when the shape took the same path as was taken in the familiarization session than when the shape took a new, straight-line path to the goal locations. According to Gergely and colleagues, this pattern suggests that infants expected the shape to behave in a rational manner in test trials; the old convoluted path was irrational given the absence of the barrier and therefore piqued infants' attention. As with research by Woodward and colleagues on infants' understanding of manual grasps, this research suggests that infants interpret motion events in a way that is deeper and more abstract than a surface-level analysis of the motion parameters such as the path taken.

Although one might be concerned about the ecological validity of research using animated shapes as agents instead of human actors, additional research on infants' interpretation of action as rational has found corroborative evidence using a variety of stimuli, such as a human actor approaching another person (Sodian, Schoeppner, & Metz, 2004) or a goal location (Kamewari, Kato, Kanda, Ishiguro, & Hiraki, 2005), a humanoid robot moving to a goal object (Kamewari et al., 2005), an adult pressing a button, causing it to illuminate (Gergely, Bekkering, & Király, 2002), and an actor reaching for a goal object (Phillips & Wellman, 2005). In each case, infants demonstrated an ability to make an assumption about *how* an action is performed; namely, that self-propelled motion toward a goal-state is rational if it follows a straight line from point A to point B, deviating from that path only to avoid obstacles. These findings furthermore suggest that when multiple construals of an action are possible—e.g., infants can focus on the path or the rationality of the action—infants prefer to focus on the more abstract of the two representations.

While informative, the research described above does not fully capture the gist-processing skill of interest. For one thing, infants in these studies were tested on actions that were actually quite similar, in surface motion terms, to those viewed during habituation. Although the location of the grasp changed, great care was taken to ensure that the hand configuration used to grasp the objects, the speed at which the actor moved, and other motion parameters were held constant between habituation and test trials. Outside of the laboratory, however, people grasp objects at a range of speeds and with a variety of hand configurations. Thus the findings provide little sense of the power of infants' gist-processing skill to gloss over the rampant degree of perceptual variability commonly encountered in human action.

Secondly, these studies are informative about only a limited form of action where an adult reaches out and grasps an object or engages in self-propelled movement toward a goal state. In everyday action, approaching and/or grasping an object is usually a means to accomplish a different end. Although it is clearly necessary for infants to understand grasps as directed at goal objects and to understand that such actions are typically performed in a rational manner, the utility of this understanding arguably lies in its role in enabling infants to interpret the entire action sequence, of which approaching and grasping the object are just two components. It is possible, for instance, to see a person engaging in an action that one does not understand but to nonetheless understand that they are performing that action in a rational, goal-directed manner. When a baseball pitcher reaches down to the dirt behind the mound in order to briefly grasp a small white bag, it is clear that by reaching in a straight line to grasp the bag the pitcher is performing the grasping action rationally (Phillips & Wellman, 2005). Nonetheless, the observer may have little understanding of the action in a deeper sense, such as

the pitcher's use of the powdered rosin contained in the bag to make his or her hands drier and stickier, enabling a better grip on the ball.

Finally, it is not clear from any of the aforementioned studies whether infants' processing is generative, in terms of driving their expectations for actors' subsequent action. One especially valuable aspect of gist-level processing lies in its power to generate inferences regarding future action. I now turn to the evidence on infants' ability to predict future action based on previously viewed action.

Generating Inferences Regarding Future Action

To some extent, the entire literature on the ontogenesis of social cognition speaks to infants' ability to generate inferences regarding future action. In infant looking-time studies, infants' visual preference for test actions is driven by expectations of what an agent is likely to do, and increased looking reflects surprise at a disconnect between the observed and expected behaviors. The bulk of this research has focused on infants' understanding of self-propelled motion to a goal location (Csibra, 2008; Gergely et al., 1995) and grasps (Todd & Smith, 2008; Woodward, 1998). It is not clear from much of this work, however, whether infants are able to generate an inference about what an actor is likely to do with an object once they have contacted it. In Gergely and colleagues' research, for example, we are left not knowing what infants predict for future action upon viewing an actor engage in a rational versus irrational action. Although infants in one study (Csibra, Bíró, Koós, & Gergely, 2003) demonstrated an ability to infer an unseen goal-completion event—infants were habituated to one digitized circle approaching another circle as they exited the computer screen and infants inferred the eventual contact event—it is still unclear if infants would be capable of inferring what would be likely to happen post-contact.

Suggestive evidence of a generative system comes from research by Phillips, Wellman, and Spelke (2002). In the habituation phase, 12- and 14-month-old infants saw an adult emoting positively to one of two stuffed animals. Infants were tested on two types of test trials, each of which comprised two components. The initial component of both test trial types depicted an adult displaying positive affect toward one of the stuffed animals. A curtain was then drawn, occluding the actor, and when it was removed the actor was shown holding a stuffed animal. In the first test trial type, the actor emoted positively toward and retrieved the stuffed animal that was not regarded in habituation trials. In the second test trial type, the actor emoted positively toward the same stuffed animal as in the habituation phase, but was subsequently shown holding the new stuffed animal, toward which she had not displayed any regard. Fourteen-month-old infants—but not 12-month-olds—looked longer at this latter type of test trial, suggesting that they are capable of inferring that if a person emotes positively toward an object, he or she will likely act to obtain it. These findings point to a generative system in that, after seeing one behavior (i.e., the positive emoting), infants infer that the actor will engage in another, previously unseen behavior (i.e., retrieving).

Recent research by Kuhlmeier, Wynn, and Bloom (2003) also speaks to the question of whether infants' skill at inferring future actions is truly generative. The focus of this research was whether infants could engage in social evaluation of a pair of interacting agents; specifically, whether infants recognize the difference between helping and hindering. More germane to the current issue, Kuhlmeier and colleagues investigated whether infants use those classifications to guide their inferences regarding those agents' behavior in novel contexts. During the habituation phase, infants saw a computer-generated circle attempt to climb a hill. After appearing to falter, infants saw, in alternating order, trials in which another animated shape (e.g., a square) came down to help the circle by pushing it up the hill, and trials in which a third animated-shape (e.g., a triangle) hindered the circle by pushing it back down the hill. In test, infants saw a screen with only the three shapes. On alternating trials, the circle approached either the hinderer or the helper. Drawing on previous research suggesting that infants attribute either positive or negative valence to agentive action (Premack & Premack, 1997), Kuhlmeier and colleagues hypothesized that 12-month-old infants would evaluate the likeability of the helper and hinderer shapes and thus expect that if the circle were given the choice to approach either of the two other shapes, it would prefer to approach the helper. Consistent with this hypothesis, infants looked longer when the circle approached the helper, suggesting that infants were able to make a judgment about the likeability of each shape and generated an inference as to which of the shapes the circle was more likely to approach.[2] Follow-up research by Hamlin, Wynn, and Bloom (2007) found similar results with a sample of 10-month-olds.

The research on social evaluation comes closer than previous research to addressing the question of infants' processing for gist. Infants' looking in both the research by Phillips et al. and Kuhlmeier et al. was to events in a very different context than seen in habituation, demonstrating that infants can use their evaluation of previous actions to generate predictions of how agents are likely to behave in new contexts. These results make it plausible that infants can make generative inferences regarding future actions, although the two studies did not reach the same conclusion about whether this ability is present in 12-month-old infants.

Once again, however, these studies do not completely capture the gist-processing skill of interest. First, shapes—even agentive ones—are not capable of the wide range of actions of which humans are capable. Even casting aside potentially critical questions of ecological validity in research that uses computer-generated shapes as agents, an observer of the actions of shapes will never have to gloss over the wide range of surface motion information in order to extract the gist that he or she would have to gloss over in order to extract the gist of human action. Infants might be capable of glossing over perceptual variability between the actions of shapes between different contexts but fail when they try to interpret even the simplest human action.

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[2] Kuhlmeier and colleagues argue that these trials present a "more coherent continuation of the habituation movies" (p. 407), causing the infants to look longer at those trials, therefore supporting the hypothesis. Regardless of questions concerning the most appropriate interpretation of infants' social evaluative skills from this pattern, they demonstrate that infants had an expectation of how the circle would behave on test trials.

Second, the question of infants' understanding of object manipulation was not a focus of this research. While research by Phillips and colleagues demonstrates that 14-month-olds are capable of generative inferences regarding future action, these experiments, like Woodward's, cannot assess infants' predictions of what an actor is likely to do with an object once it is grasped. Returning again to the kitchen example used in the beginning of the introduction, the inferential skills tapped by the research by Phillips et al. and Kuhlmeier et al. are not necessarily the same skills as those that would be required to infer what the executive chef was about to do with the bottle when she turned her back to the observer. The research by Phillips et al. and Kuhlmeier et al. instead point to infants' ability to infer one action unit from another action unit, not to infer the completion of an interrupted action unit involving object manipulation. The question therefore remains: are infants capable of going beyond the obvious surface-level features to extract the gist of everyday human action involving objects?

Understanding Object Manipulation

Two additional lines of research provide some limited evidence of infants' understanding of object manipulation. Song, Baillargeon, and Fisher (2005) investigated whether 13.5-month-old infants attribute behavioral dispositions to actors. In the familiarization phase of the experiment, infants saw three successive trials in which the actor grasped a toy (a different toy was used in each trial) and slid it back-and-forth between herself and the infant. Over the course of these trials, the authors argued that infants attributed a behavioral disposition to the actor—e.g., *this person slides objects.* At test, the actor sat in front of two toy trucks, one in a long box that would enable the actor to slide the truck as in familiarization trials, and the other in a short box that left no room for the truck to slide. Infants looked longer when the actor grasped (but did not move) the truck in the short box, indicating surprise that a person who slides objects would grasp a truck that cannot slide. This finding suggests that by 13.5-months, infants recognize the relationship between grasping and manipulating objects, and they believe that people are likely to possess a disposition to manipulate an object in a given manner.

Additional support for the hypothesis that 12-month-old infants understand something of object manipulation comes from an experiment by Woodward and Sommerville (2000). In this study, infants were habituated to an actor opening the lid of a transparent container and grasping the toy inside. Before the test phase, the boxes remained in their locations but the toys inside the two boxes were switched. On alternating test trials, the actor grasped—but did not open—the lids of the two boxes. Infants looked longer at trials where the actor grasped the lid of the same box containing a new toy than on trials where the actor grasped the lid of a new box containing the same toy. This finding convincingly demonstrates that infants interpreted the point of the lid-grasp as directed at the toy inside rather than at the box itself. Furthermore, these findings suggest that infants understand something about object manipulation (e.g., lids are opened to enable access to the contents of the container) and demonstrate that infants are capable of generating inferences of future action based on limited information (e.g., when the actor grasps the lid, she will open it in order to grasp the toy inside).

As with the research on infants' ability to generate inferences of future actions, the experiments by Song et al. and Woodward and Sommerville both investigated skills related to processing for gist. Infants in both lines of research were able to generate inferences about future action and used these inferences to drive their looking in test trials. Importantly, both sets of results provide evidence that infants understand something about the purpose of actions involving object manipulation.

Several questions remain, however. It is not clear that infants in Song et al.'s experiment interpreted a disposition on the part of the actor. Increased looking to the short box events could have been driven by attention to the object's affordances; according to this explanation, the results could indicate that infants were surprised that, after seeing sliding events, the non-slideable object was grasped, leading infants to infer that they would not see sliding on that trial. The looking patterns in test, therefore, could have had little to do with an understanding of human action.

In addition to questions regarding whether these data shed light on infants' understanding of human action rather than object affordances, it is the case that the motion parameters varied very little between trials in both of these studies. The actor in both Song et al.'s research and in the research by Woodward and Sommerville used the same hand configuration in each habituation and test trial; therefore, it is not possible to assess if infants were processing gist at the expense of surface detail, which infants would do if they prioritized a gist-related construal (Cohen & Cashon, 2006; Fillenbaum, 1966; Welborn & English, 1937). Furthermore, in Woodward and Sommerville's research, the final goal of the action sequences was to grasp an object, leaving unanswered the questions posed in this dissertation regarding infants' understanding of what people do with goal objects after they have grasped them.

Summarizing Research Germane to Processing for Gist

The literature reviewed above has provided important information regarding (1) infants' ability to gloss over perceptual details of the path of grasps (Phillips & Wellman, 2005; Woodward, 1998) and self-propelled motion toward an endstate (Csibra et al., 2003; Gergely et al., 1995; Kamawari et al., 2005) in order to ascertain the goal of the action; (2) infants' ability to generate expectations regarding how agentive shapes will behave toward others in novel contexts (Hamlin et al., 2007; Kuhlmeier et al., 2003; Phillips et al., 2002); and (3) infants' ability to make sense of object manipulation (Sommerville & Woodward, 2005a; Song et al., 2005; Woodward & Sommerville, 2000). Together, each of these studies provide suggestive evidence that infants are capable of at least some of the components involved in processing action for gist.

Although no research to date has investigated processing for gist in infants 12-months or younger, classic work by Meltzoff (1995) provides relevant data for older infants on two of the gist-processing components. In that experiment, 18-month-old infants saw a failed attempt to achieve a goal—e.g., an actor trying to pull apart a dumbbell but having his hands slip off the ends, leaving the two halves intact. When allowed to manipulate the objects themselves, infants imitated the target action—i.e., pulling the dumbbell apart—at greater-than-chance levels, despite never having seen the object manipulated successfully. These findings are highly relevant to the question of interest in that they speak to infants' ability to generate inferences regarding future action and also infants' understanding of object manipulation. Nonetheless, two issues remain: (1) it is not clear from this work that infants, when observing the actions of others, recognize that the surface motion details can vary widely, but do so in a manner that does not alter the gist; and (2) the use of imitation methodologies, which require a high degree of task compliance and motor skills, may underestimate younger infants' understanding.

Despite these impressive advances in the field of infant social cognition, it is still not clear if infants gloss over substantial variation to the surface details of a motion stream to extract the gist of the action, or if they categorize actions based on the inferred gist rather than on the observed surface details. The experiments described below attempted to provide data bearing on each of these issues.

Rationale for the Current Experiments

This dissertation examined whether infants 12-months-of-age and younger process action for gist. In the context of social cognition, processing for gist is defined as interpreting human actions involving object manipulation in a manner that (A) focuses on the functional affordance of the observed action—i.e., what that action allows the actor to do in the world; (B) glosses over surface details inherent in the motion stream that are unrelated to the functional affordance of the action; and (C) prioritizes the gist-level representation such that perceptually dissimilar actions may be seen as exemplars of the same action category, even when such gist-level representations are based on inferred actions.

The current experiments focused on 5- to 7-month-old and 10- to 12-month-old infants. Several lines of research point to a "revolution" in social cognitive processing in the period between 9-12 months (Tomasello, 1999). According to this account, infants see other people as "like me" (Meltzoff & Gopnik, 1993; Meltzoff, 2007), using their understanding of their own action to interpret the actions of other people. As Piaget (1952) noted, at around 8 months infants begin to understand that a single goal can be achieved via a variety of behavioral means. Tomasello argues that 9-month-old infants use their newfound understanding of their own behavioral capabilities to revamp their interpretation of others' actions (see also Sommerville & Woodward, 2005b; Sommerville et al., 2005). The two age groups in the current experiments were selected in order to include infants on either side of this important developmental period. I predicted that older infants would be capable of gist-level processing, whereas younger infants would focus on surface-level details when processing action. Specifically, I predicted that younger infants would show increased attention to all test actions that depicted a perceptually dissimilar action as seen in habituation, whereas older infants would selectively show increased attention only to test events that were inconsistent in gist with the habituation action, regardless of surface-level motion details.

The predictions outlined above are concordant with the observations of Piaget (1952) in that infants younger than 8 months do not yet use a variety of means to achieve a single goal; absent such awareness of their own causal efficacy, they would be limited in their ability to recognize that an actor can engage in several perceptually dissimilar acts that are similar at a more abstract level, such as the goal (Meltzoff & Gopnik, 1993;

Tomasello, 1999). On this account, the development of gist-level processing could be thus driven, in part, by changes in infants' self-action awareness; if infants are to categorize actions in a way that glosses over surface-level detail, they must recognize that they can achieve their own goals via actions that vary in one or more motion parameters. Of course, developments in social cognition could also be influenced by gradual changes in domain-general information processing efficiency (Cohen & Cashon, 2006; Halford, 1993) or the maturation of domain-specific action processing skills (Gergely & Csibra, 2003). Even under these alternative accounts, however, one may predict that infants older than 9-months would perform differently than younger infants. Given the gist-processing skill of interest, 5- to 7-months is an appropriate age to compare to older infants because (a) the current experiments tested infants' understanding of action sequences involving pushing or pulling an object, and infants of this age are thought to lack relevant means-ends understanding of such actions (Piaget, 1952; Sommerville, Hildebrand, & Crane, in press; Sommerville & Woodward, 2005a), while at the same time (b) 5- to 7-month-old infants have been shown to possess basic understanding of the goal-directed nature of grasping actions (Woodward, 1998; 1999). Therefore, a failure to display evidence of gist extraction would not be due to a complete lack of ability to process human action of this kind, but instead would be more likely to reflect differences in gist-level processing per se.

Experiment 1 investigated infants' understanding of the gist of two post-grasping actions—pushing and pulling—when instances of those actions differed considerably on the surface. Push and pull were selected as actions within which to explore the question because pioneering research by Cohen and colleagues (Casasola & Cohen, 2000; Cohen, Bradley, & Casasola, 1995) suggests that, at least by 14-months-of-age, infants can discriminate pushing and pulling events performed by non-human agents. Due to the importance of object manipulation in infants' own action experience (Rochat, 2001; Rochat & Striano, 1998; Sommerville & Woodward, 2005b), it was hypothesized that by 10- to 12-months-of-age, infants would be able to interpret pushing and pulling events performed by human actors.

Experiments 2a and 2b attempted to replicate the effects from the 10- to 12-month-old and 5- to 7-month-old infants, respectively, found in Experiment 1. Slight modifications to the methodology used in Experiment 1 were introduced in Experiments 2a and 2b, with the purpose of increasing infants' attention throughout the procedure.

Experiment 3 investigated gist-level processing of a different action distinction: opening and closing. To the extent that gist-level processing is a powerful and robust skill at 10-12 months, infants should display this skill with a variety of action categories. Opening and closing actions were selected for Experiment 4 because data from research by Woodward and Sommerville (2000) suggest 12-month-old infants understand the functional act of opening a container to get a toy. Experiment 4 built on and extended these results by investigating infants' understanding of closing, in addition to whether they could gloss over substantial variability in the motion parameters and extract the gist of these actions.

Experiment 4 was motivated by two questions. The first question was whether infants can categorize actions on the basis of a shared gist even when several motion parameters vary between two action exemplars. In Experiments 1 through 3, habituation and test actions differed primarily in the hand configuration used to contact the object and in the absence of object motion in the test actions. In Experiment 4, habituation and test actions additionally varied in several other motion parameters, such as the number of hands used to contact the object and whether the actors engaged in direct eye contact. The second question was whether, given two potential gist-related construals of an action, infants would prefer to categorize perceptually dissimilar action exemplars on the basis of the more abstract of the two gist levels.

Additionally, Experiment 4 provided data relevant to an interpretational question regarding the nature of the gist infants may have extracted in the first three experiments. Infants in Experiments 1, 2a, and 2b could have interpreted the actions shown in the habituation phase as either *pushing* and *pulling*, or as *giving* or *taking*. The methodology used in those studies does not allow these two possible interpretations to be differentiated. A new methodology was developed for Experiment 4 that was based on the "new path vs. new goal" manipulation used by Woodward (1998; 1999). This methodology allowed a preliminary investigation as to whether infants encode the dyadic nature of object transfer events in their gist-level representations of the action.

In each of the experiments described above, infants were shown an event depicting an actor manipulating some object during the habituation phase. At test, they were shown two actions that were perceptually dissimilar in several motion parameters and ended before the critical object manipulation event. Therefore, infants needed to infer the actor's likely subsequent action, extract the gist of the test event based on the inferred action, and gloss over the surface-level dissimilarities between the actions seen in habituation and test in order to construe them as similar in gist.

CHAPTER II

EXPERIMENT 1

Overview

Experiment 1 investigated 5- to 7-month-old and 10- to 12-month-old infants' understanding of the gist of pushing and pulling actions using test stimuli that were novel relative to the actions infants viewed during habituation. In question was whether infants are capable of glossing over changes to the motion parameters involved in the manipulation of objects in order to focus on the functional affordance, or gist, of the action.

Infants were habituated to one of two actions. In one action, a woman reached out, grasped a glass on a table, and pushed it to another woman sitting on the opposite side of a table. In the other action, the woman pulled the glass to herself after grasping it. At test, all infants saw two actions. In the *inferred-push* test video, the woman reached out and made contact with the rim of the glass as if to propel the glass forward—i.e., where the gist is to *push*—but did not actually move the glass. In the *inferred-pull* test video, she made contact with the rim as if to propel the glass back toward herself—i.e., where the gist is to *pull*—but, again, did not move the glass. The actor's hand configuration in each test video was noticeably distinct from the ambiguous hand configuration in habituation.

Prior research by Cohen and colleagues (Casasola & Cohen, 2000; Cohen et al., 1995) documented that by 14 months, infants understand the causal relations in animated pushing and pulling events involving self-propelled inanimate objects such as cars and trucks. The current experiment tested younger infants because of the possibility that pushing and pulling events performed by a human actor may be understood earlier than similar events enacted by objects due to infants' own experience with manipulating objects (Rochat & Striano, 1998; Sommerville & Woodward, 2005b; Sommerville et al., 2005). Furthermore, verbs for moving objects (e.g., *push*) appear early in children's productive vocabularies (Tomasello, 1992), suggesting that pushing and pulling events are of considerable interest to infants.

If infants are able to categorize actions based on gist, then those who were habituated to the pulling event should, at test, show greater interest in the inferred-push actions than the inferred-pull actions. Conversely, infants habituated to the pushing event should show greater interest in the inferred-pull actions than the inferred-push actions. This pattern would convincingly attest to gist-related processing because the test videos were carefully designed such that surface motion differences were equivalent between the two types of test videos relative to the habituation videos. Thus, infants' interest in the gist-inconsistent test videos could not be due to surface differences, but would instead reflect their sensitivity to the inferred functional commonality between the action viewed during habituation and the inferred function of the action depicted in the test videos.

I hypothesized that 10- to 12-month-olds—who have displayed an understanding of a handful of complex action sequences in previous research (e.g., Sommerville &

Woodward, 2005b; Woodward & Sommerville, 2000)—would demonstrate gist-level processing by looking longer at gist-inconsistent test trials than at gist-consistent test trials. In contrast, I predicted that 5- to 7-month-olds—who, in their own action, do not generally use a variety of behavioral means to achieve a goal (Piaget, 1952)—would be limited in their ability to categorize perceptually dissimilar actions by a shared gist (Tomasello, 1999) and thus would not process the actions for gist. Rather, I expected that 5- to 7-month-olds would show elevated attention to both test trial types due to their perceptual novelty.

Method

Participants

Sixteen 5- to 7-month-olds ($M = 6$ months, 23 days; range: 5 months 4 days to 7 months 22 days; 8 girls, 8 boys) and sixteen 10- to 12-month-olds ($M = 11$ months, 5 days; range: 10 months 0 days, 12 months 15 days; 8 girls, 8 boys) participated in the study. Twelve additional infants participated, but were excluded from analyses due to parental over-involvement ($n = 2$), coder error ($n = 2$), data with extreme outliers, defined as looking times more than two standard deviations from the mean ($n = 2$)[3] or fussiness and inattention, defined as infants for whom more than three trials had to be re-run due to insufficient looking time—i.e., less than two seconds of looking per trial ($n = 6$).

[3] One infant had two such outliers, one on each test trial type. The second infant had one such outlier in the direction predicted by the hypothesis. The omissions, therefore, did not favor the hypothesis.

Materials

Infants were habituated to one of two digitized action sequences (see Figure 1). Each action sequence began with two women seated across from each other at a table covered with black cloth, looking at each other and smiling. On the table between them was a translucent glass containing brightly colored breakfast cereal. In the first component of the action sequence, lasting 1.93 seconds, one of the women reached out and grasped the glass. The *grasp* video was specifically created to be ambiguous, in that it could be followed by either a pushing action or a pulling action, and predicted neither action. This grasp video was then spliced to, and merged with, the additional motion sequences depicting *push* versus *pull* to create two habituation videos. The same video clip of the gist-ambiguous grasp was used in each video to minimize the possibility that subtle clues in the actor's body language would telegraph the direction of the eventual motion of the glass.

The habituation stimulus presented to infants in the *observed-push* condition began with the grasp video just described, followed by the actor moving the glass toward the other woman. In contrast, infants who were habituated in the *observed-pull* condition saw the grasp action followed by the actor pulling the glass toward herself. The push and pull motions were identical in length (2.37 seconds) and were followed by a three-second still-frame presentation of the last frame of the video. To create a smooth transition from the grasp action to the actor's movement of the glass, merging was performed with iMovie software (Apple, 2005) using a 12-frame overlap transition.

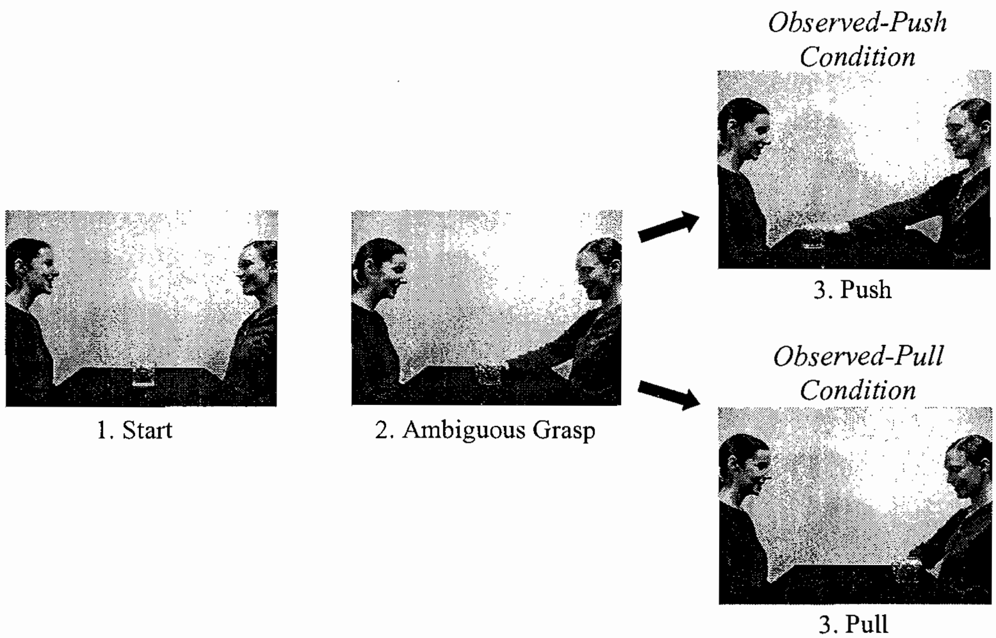

Figure 1: Illustrative still frame images from the videos used in the habituation phase of Experiment 1.

Test videos were of two types: In the *inferred-push* test video, the same actor who manipulated the glass during habituation reached out and contacted the near side of the rim of the glass with her angled palm without moving the glass (see Figure 2). Her hand configuration would enable her to push, but not pull, the glass. In the *inferred-pull* test video, the actor reached out and contacted the opposite side of the glass with her angled palm, which would enable her to pull, but not push, the glass. Again, in neither test video did the actor actually move the glass. The duration of the motion in each test video, 1.93 seconds, equaled the duration of the ambiguous grasp in habituation. Both test trial videos concluded with a one-second still-frame of the actor's hand on the glass.

Procedure

Infants sat on a parent's lap approximately 70 cm away from the 24 x 33 cm video screen. During habituation trials, infants' looking time was recorded throughout the entire action sequence. Both observed-push and observed-pull habituation videos included up to five loops of the action sequence (total duration 40.54 seconds): that is, the sequence of a grasp followed by either a push or a pull was followed by a one-second blank screen, at which point the identical action sequence was displayed again. A trial continued until infants either looked away from the screen for at least two consecutive seconds or all five loops of the video were presented, whichever came first. If infants failed to look at the screen for at least two seconds, the trial was repeated. The habituation phase ended when either the average looking to the three last trials was less than 50% of the average looking time to the first three trials, or when ten trials had been completed. Infants' looking time was coded online by an observer using custom software (Pinto, 2003) that automatically calculated habituation criteria and advanced to test trials when appropriate.

Although infants participated in just one habituation condition (either push or pull), all infants saw both types of test actions presented in alternating order. Infants saw three test trial pairs, with each pair containing one of each type of test action. As in habituation, after the action sequence was complete, a blank screen appeared for one second, followed by up to seven additional looping presentations of the action sequence (total duration 31.48 seconds) within a given test trial. A test trial continued until the infant looked away for two consecutive seconds after accumulating at least two seconds of looking time on that trial. The order of presentation of the two test trials was counterbalanced such that half of the infants in each habituation condition had a inferred-push test trial first, and the other half had an inferred-pull test trial first.

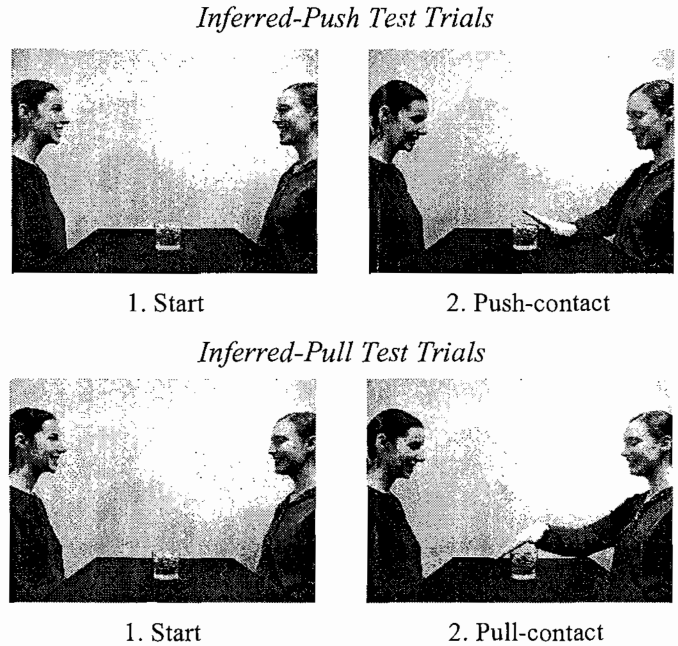

Figure 2: Illustrative still frame images from the videos used in the test phase of Experiment 1.

Results

In this and all experiments reported in this dissertation, looking times were subjected to a log transformation to reduce positive skewness, which is typical of looking time data. For ease of interpretation, all descriptive statistics reported throughout this dissertation are untransformed values.

Habituation Phase Analyses

Infants in the 10- to 12-month age group viewed, on average, 7.6 habituation trials ($SD = 2.0$) and accumulated a total of 68.24 seconds ($SD = 21.85$) of looking over the course of the habituation phase. There were no differences between infants in the two habituation conditions with respect to average looking times during the first three habituation trials, average looking time to the last three habituation trials, the total amount of looking time during the entire habituation phase, or in the number of trials viewed during the habituation phase (all *F*s < 1.8, all *p*s > .20). A Fisher's exact test examined whether infants in the two habituation conditions differed in the frequency with which they met the habituation criterion before moving to test trials; this analysis revealed no differences between infants in the observed-pull condition (4 met criterion, 4 did not) and infants in the observed-push condition (6 met criterion, 2 did not), $p = .61$.

Infants in the 5- to 7-month age group viewed, on average, 8.7 habituation trials ($SD = 1.8$) and accumulated a total of 49.18 seconds ($SD = 19.96$) of looking over the course of the habituation phase. There were no differences between infants in the two habituation conditions with respect to average looking times during the first three habituation trials, average looking time to the last three habituation trials, the total amount of looking time during the entire habituation phase, or in the number of trials viewed during the habituation phase (all *F*s < 1.3, *ns*). Fisher's exact test was used to examine whether infants in the two habituation conditions differed in the frequency with which they met the habituation criterion before moving to test trials; this analysis revealed no differences between infants in the observed-pull condition (5 met criterion, 3 did not) and infants in the observed-push condition (1 met criterion, 7 did not), $p = .12$.

Test Phase Analyses

The central question was whether infants, regardless of habituation condition, looked longer at gist-inconsistent than gist-consistent test trials. Repeated measures ANOVAs with habituation condition (observed-push versus observed-pull) as the between-subjects factor and test gist-type (gist-consistent versus gist-inconsistent) and test trial pair (first and second) as within-subjects factors were performed separately on the two age groups. Only the first two trial pairs were included in the analysis because of general disinterest during, and missing data on, the third trial pair. It was predicted that, within the older sample only, infants would look significantly longer at gist-inconsistent than gist-consistent test trials, resulting in a significant main effect of test gist-type.

Ten- to 12-Month-Olds. Preliminary ANOVAs on infants' looking times toward test stimuli revealed that sex, order of presentation of test stimuli, and infants' tendency to meet the habituation criterion yielded neither significant main effects on test performance nor interacted with other factors; therefore, subsequent analyses collapsed across these factors.

A repeated measures ANOVA with habituation condition (observed-push versus observed-pull) as the between-subjects factor and test gist-type (gist-consistent versus gist-inconsistent) and test trial pair[4] (first and second) as within-subjects factors was

[4] Although the test trial pair factor was not part of the a priori model, preliminary analyses found that it had a significant effect on the results; therefore, it was included in the final model.

performed on the data. The predicted main effect of gist type was not significant, $F(1, 14) = 1.90, p = .19$.

There was an unexpected interaction, however, between test gist-type and test trial pair, $F(1, 14) = 8.35, p < .05$. A follow-up 2 (habituation condition) x 2 (test gist-type) repeated measures ANOVA tested for the predicted effect on the first trial pair only. Here, the predicted main effect of test gist-type was significant, $F(1, 14) = 5.78, p < .05, d' = .75$[5] (see Figure 3), demonstrating that infants preferred to look at the first presentation of test events depicting an action inconsistent in gist ($M = 11.30$, $SD = 8.24$) with the action seen during habituation relative to test actions consistent in gist with the action seen in habituation ($M = 5.88$, $SD = 3.32$).[6] Non-parametric analyses confirmed that infants looked longer at the first presentation of gist-inconsistent test trials than the first presentation of gist-consistent test trials, Wilcoxon signed-ranks $Z = 2.02, p < .05$.

Planned directional simple effects analyses tested for the predicted effect within each habituation condition. Infants in the observed-push condition showed marginally significant longer looking to gist-inconsistent test trials (inferred-pull average $M = 11.63$, $SD = 8.21$) than to gist-consistent test trials (inferred-push average $M = 5.94$, $SD = 2.85$), $F(1, 14) = 2.52, p < .07, d' = .60$ (see Figure 4). Infants in the observed-pull condition looked significantly longer to gist-inconsistent test trials (inferred-push average $M =$

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[5] As Cohen's d overestimates δ when sample sizes are small, d'—which adjusts d to correct this bias (Hedges & Olkin, 1985; Hunter & Schmidt, 1990)—is reported throughout this dissertation.

[6] One might be concerned that the predicted pattern of findings was obtained only for the first pair of test trials. Fortunately, the design precautions we undertook meant that data from the first test trial were carefully controlled for order of presentation, ruling out the possibility that infants simply looked longest to the first test trial regardless of gist type. Moreover, it is not unusual in habituation studies for the prediction to be confirmed only on the first test trial (e.g., Bíró & Leslie, 2007; Gergely et al., 1995; Saxe, Tzelnic, & Carey, 2007), in part because test trials attenuate the very effects under investigation (Hunter & Ames, 1988).

10.97, SD = 8.82) than to gist-consistent test trials (inferred-pull average M = 5.82, SD = 3.93), $F(1, 14) = 3.27, p < .05, d' = .73$. The simple effects analyses are striking given that a) only eight infants participated in each habituation condition, and b) the pattern of looking times during test trials was similar between the two conditions despite the fact that different actions were gist-consistent or gist-inconsistent between the conditions.

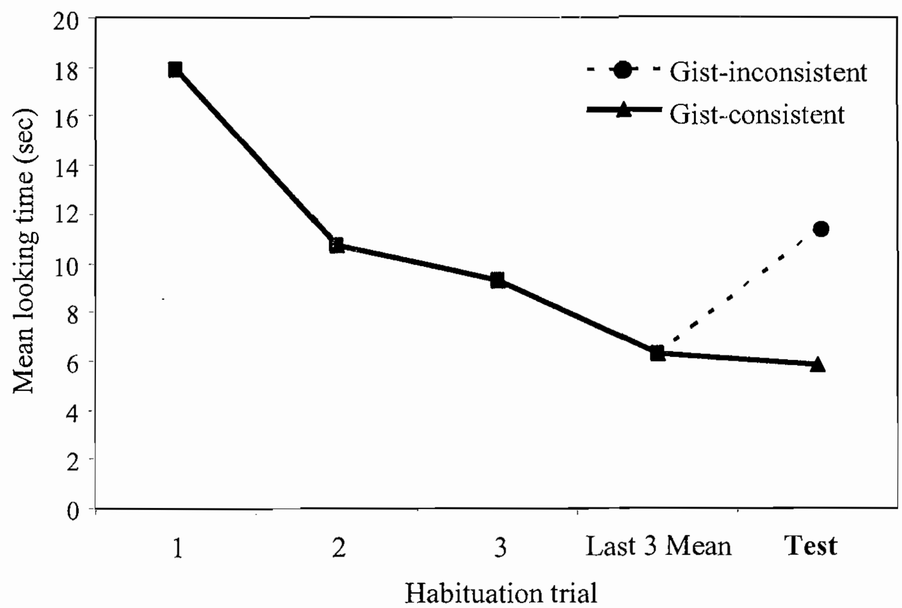

Figure 3: Ten- to 12-month old infants' mean looking times (in seconds), collapsed across habituation condition, to the first three habituation trials, the mean of the last three habituation trials, and the first presentation of each test trial type in Experiment 1.

Five- to 7-Month-Olds. Preliminary analyses found no effects of sex, infants' tendency to meet the habituation criterion, or the order of presentation of test stimuli; these factors were removed from the analysis. In contrast to the older sample, there were no effects of test trial pair, so responses were collapsed across the first two trial pairs.

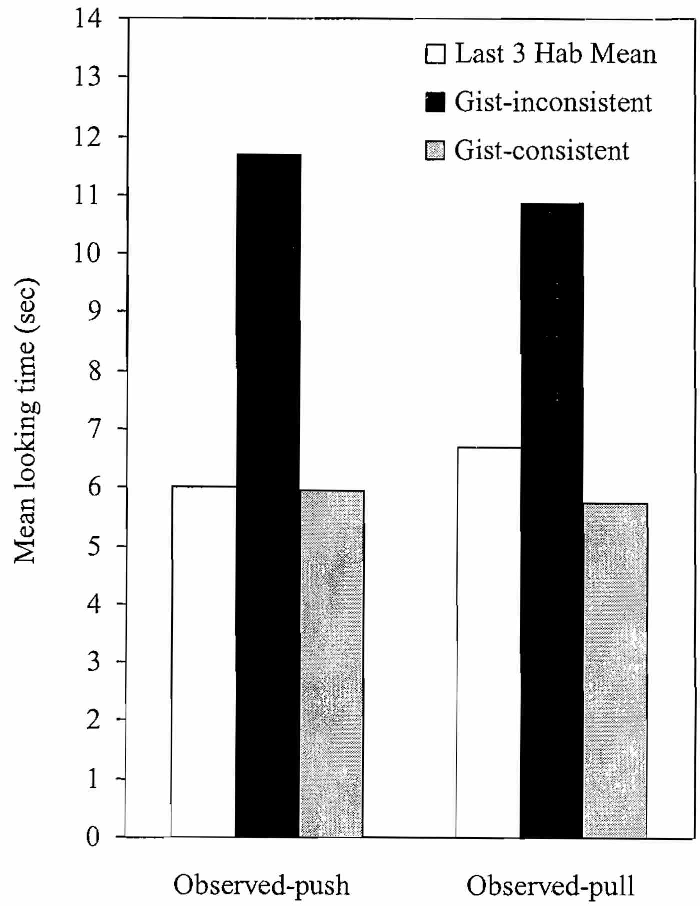

Figure 4: Ten- to 12-month-olds infants' mean looking times (in seconds), by habituation condition, to the mean of the last three habituation trials and the first presentation of each test video in Experiment 1.

As predicted, the main effect of test gist-type was not significant with the younger age group; 5- to 7-month-old infants did not look reliably longer at either gist-inconsistent ($M = 6.58$, $SD = 4.28$) or gist-consistent test trials ($M = 5.14$, $SD = 3.56$), $F(1, 14) = 2.06, p = .17, d' = .35$ (see Figure 5).

However, there appeared to be an unexpected effect of condition (see Figure 6). When planned directional simple effects analyses were used to test infants' looking times to the two test gist-types, a trend emerged such that infants in the two conditions performed differently. Infants in the observed-push condition looked significantly longer at gist-inconsistent test actions (inferred-pull $M = 6.71$, $SD = 4.06$) than at gist-consistent test actions (inferred-push $M = 3.83$, $SD = 1.73$), $F(1, 14) = 3.40$, $p < .05$, $d' = .81$. This difference was also significant using a Wilcoxon signed-ranks test, $Z = 1.96$, $p = .05$. The same comparison did not approach significance for infants in the observed-pull condition ($F < 0.1$, *ns*). These findings suggest that infants as young as 5- to 7-months-old have a nascent understanding of the gist of pushing actions.[7] Possible interpretations and implications of these findings are discussed below.

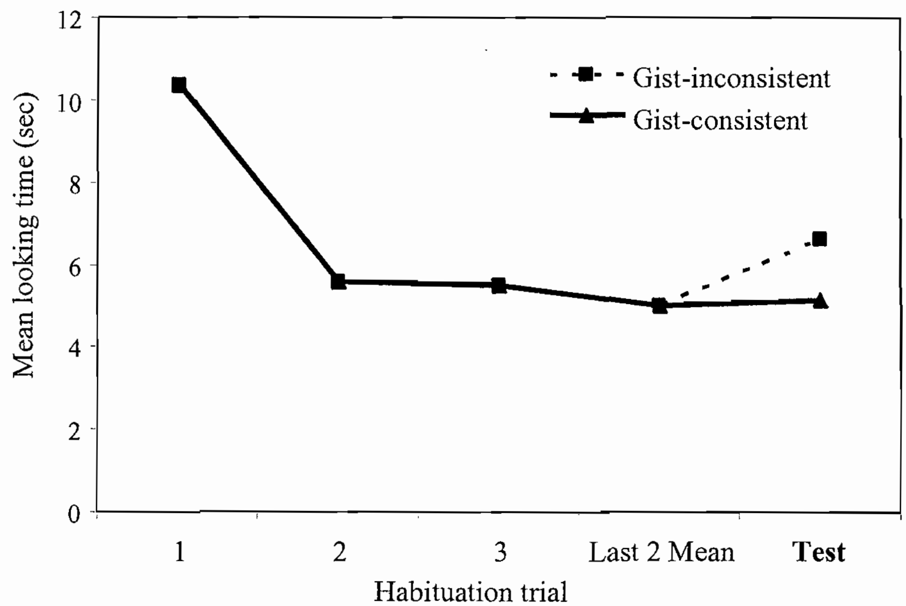

Figure 5: Five- to 7-month old infants' mean looking times (in seconds), collapsed across habituation condition, to the first three habituation trials, the mean of the last three habituation trials, and each test trial type in Experiment 1.

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[7] Due to findings that infants' understanding of the goal-directed nature of grasping actions strengthens in the period between 5-6 months (Woodward, 1998), infants' performance within the younger group were inspected to see if there were changes in performance between 5-7 months. These analyses revealed no significant differences. Similar analyses performed on each sample throughout the dissertation likewise yielded no significant age-related differences within a single age range.

Looking Time Recovery Analyses

Another route to examining the central question within this data set involved testing whether infants' looking time to each test trial type was elevated relative to the average of the last three habituation trials. If infants processed action for gist at the expense of superficial motion parameters, they should recover looking time to test actions inconsistent in gist with the habituation action, but should not recover looking time to test actions consistent in gist. This pattern would be noteworthy in that the action depicted in each test trial type was equally dissimilar to habituation events.

As predicted, 10- to 12-month olds' looking time to the first gist-inconsistent test trial ($M = 11.30$, $SD = 8.24$) was significantly longer than their average looking time to the last three habituation trials ($M = 6.31$, $SD = 2.88$), directional paired-samples $t(15) = 2.82$, $p < .05$, $d' = .85$. In contrast, there was a nonsignificant trend toward decreased looking time to the first gist-consistent test trial ($M = 5.88$, $SD = 3.32$), $t < 1$, *ns*.

Similar tests were performed on the data from 5- to 7-month-olds, with the exception that the average looking across both trial pairs was used as there was no significant effect of trial pair in the looking time of these infants. Overall, younger infants showed significant recovery of looking time from the average of the last three habituation trials ($M = 4.98$, $SD = 3.13$) to gist-inconsistent test trials ($M = 6.58$, $SD = 4.28$), directional paired-samples $t(15) = 1.77$, $p < .05$, $d' = .49$. Looking time to gist-consistent test trials ($M = 5.14$, $SD = 3.56$) was not significantly different from the last three habituation trials, $t < 1$, *ns*. Despite the condition differences found with the simple effects analyses reported above, when Looking Time Recovery Analyses were performed separately within each habituation condition no significant patterns emerged (*t*s < 1.7, *p*s > .15).

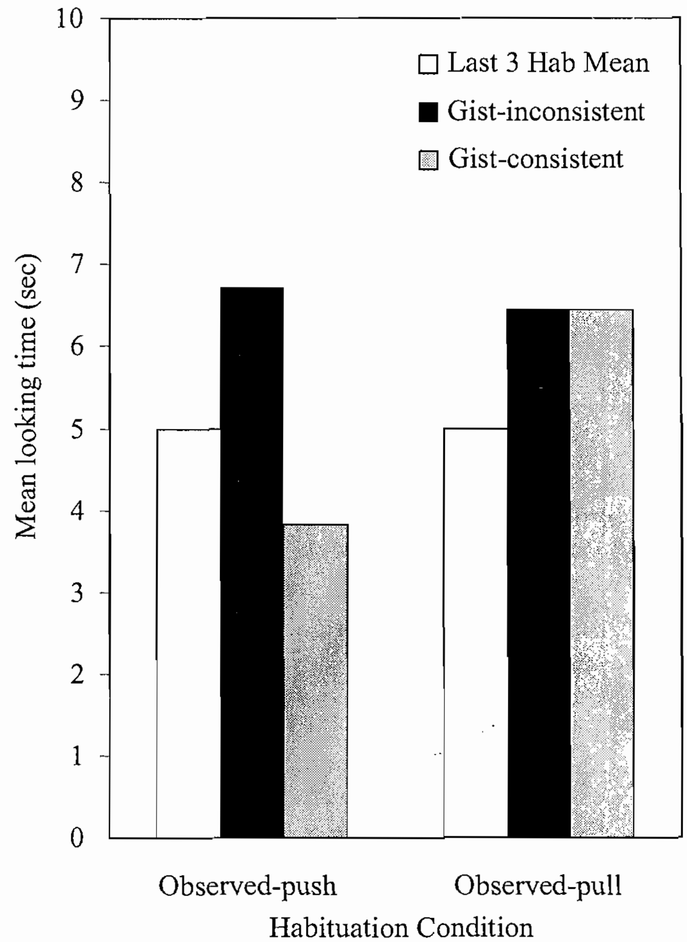

Figure 6: Five- to 7-month-olds infants' mean looking times (in seconds), by habituation condition), to the mean of the last three habituation trials and each test trial type in Experiment 1.

Thus, both groups of infants displayed recovery specifically to test videos novel in gist relative to the habituation video they viewed, despite the fact that equivalent perceptual novelty was present to both gist-novel and gist-familiar test videos.

Discussion

Experiment 1 investigated whether 5- to 7- and 10- to 12-month-old infants could readily gloss over changes in the perceptual motion details of a pushing or pulling action and recognize a perceptually dissimilar action as being either consistent or inconsistent with the familiar action. After seeing an actor grasp and then push a glass to another person, both 5- to 7- and 10- to 12-month-olds looked longer at test videos in which the actor reached out and touched the opposite side of the glass as if to pull it than at test videos depicting the woman making contact with the glass as if to push it. Ten- to 12-month-old infants—but not 5- to 7-month-olds—who were shown the actor grasping and then pulling the glass toward herself in the habituation phase showed the opposite pattern of looking time at the test events. Looking preferences across both conditions for 10- to 12-month-olds, and in the observed-push condition for 5- to 7-month-olds, suggest that infants did not regard perceptual changes consistent with the same inferred action—an action familiar in gist—as indicative of a novel action category. In contrast, an equivalent degree of perceptual change indicative of a novel inferred action—an action inconsistent in gist—struck infants as noteworthy. In order for infants to be skilled interpreters of human action, they need to be able to extract the gist of what people do with objects after they grasp them. Findings from the current study suggest that infants understand pushing and pulling actions earlier than previously documented (Casasola & Cohen, 2000; Cohen et al., 1995) and can categorize hand-to-glass touches as potentiating either a push or a pull, and therefore augment the literature on infants' social cognition in providing some of the first evidence regarding infants' understanding of object manipulation.

Methodologically, the current study is immune to certain criticisms of existing looking-time findings regarding infants' action understanding (e.g., Sirois & Jackson, 2007). The concern is that infants may have preferred one stimulus in test (e.g., "new goal" versus "new path" trials in Woodward's procedure) based merely on some salience-enhancing perceptual aspect of the stimulus. In the present research, infants preferred opposite test stimuli across the two habituation conditions, hence ruling out a simple perceptual salience account.

An additional benefit of methodology used in the current experiment is the level of control over the videos. Each habituation video used the same grasp clip that was spliced with pushing or pulling motions that were each identical in length. Furthermore, the latency between the onset of hand motion and the initial contact of the glass was identical between the grasp clip used in the habituation stimuli and both of the test stimuli. The level of methodological control used in the videos here is similar to the level of control often only achieved by the use of animated stimuli. The current experiment thus makes a significant contribution to the literature by promoting ecological validity and generalizability to real-world human action while maintaining the benefits of rigorous experimental control over the action stimuli shown to infants.

While the current results provide the strongest evidence to date that 10- to 12-month-old infants are able to form abstract, gist-level categories of human action that supercede variability in surface motion parameters, it is not clear how best to interpret younger infants' performance. Younger infants in the observed-push condition showed a similar pattern as older infants, whereas younger infants in the observed-pull condition recovered interest (although not significantly so) to both types of test trials. As a group, the younger infants also selectively recovered looking time to only gist-inconsistent test trials. Perhaps, then, the period between 7-10 months marks important developments in infants' ability to gloss over surface properties of actions to discern their deeper functional significance.

One possible explanation for the locus of this developmental change lies in the efficiency of infants' perceptual analysis of action. Infants in the observed-pull condition saw an initial motion trajectory as the actor moved her hand away from the body in order to grasp the glass, and then a subsequent trajectory reversal as she moved the glass toward her body, whereas infants in the observed-push condition saw a unidirectional motion trajectory away from the body. In order to extract the gist of *pulling* from the observed-pull stimulus, infants would have needed to identify the outward trajectory as simply preparing to engage in the second motion component of pulling. Extracting the gist of the observed-pull action, then, required an efficient perceptual analysis in which infants ignore the first trajectory and focus on the second. Infants who saw the observed-push stimulus were not faced with such a dilemma, perhaps contributing to their ability to extract the gist of the action.

The current findings clearly indicate that infants are capable of a degree of abstraction beyond the level of registering simple motion patterns; however, both lean and rich interpretations are possible for the nature of the gist-level representation.

According to a lean interpretation, infants saw object motion, predicted the motion trajectory based on details of the actor's hand position in the test videos, and then looked longer when the anticipated motion did not correspond with the observed motion in test. This *directional push* or *pull* representation is still at the level of gist because when infants saw the contact test videos, they did not simply process the observed hand contact, but took an unseen action component (i.e., inferred object motion) as an important characteristic by which to analyze the action. A richer reading of these data would hold that infants formed a *dyadic interaction* representation, which encodes the recipient of the object. On this reading, infants' representations of the actions could have been as *give* or *take*, rather than *push* or *pull*. Experiment 3, reported below, investigated whether 10- to 12-month-old infants are capable of construing object transfer events as dyadic interactions, or whether they are limited to the leaner directional push construal.

Although the methodology used in the current study cannot disambiguate the precise level of abstraction at which infants construed the push and pull stimuli used in the current experiment, these findings nevertheless provide the strongest evidence to date that 10- to 12-month-old infants are able to form abstract-level categories of human action that supercede featural details. Data from 5- to 7-month-old infants further suggest that this skill begins to develop in the first half of the first year of life, and also that perceptual analyses of motion parameters influences gist extraction.

These data extend the seminal work of Woodward (1998; 1999) and Gergely and colleagues (Gergely et al., 1995) in showing that infants are capable of glossing over even higher degrees of perceptual variability in order to interpret and categorize human action. Human action in everyday life varies based on context, objects involved, position of the body in relation to manipulated objects, and the like. Faced with this variability, it is striking that infants as young as 5- to 7-months can, Bruner's (1957) words, "go beyond the information given" to register inferred functional commonalities, even when this requires looking past gist-irrelevant surface characteristics of the motion stream.

CHAPTER III

EXPERIMENT 2A

Overview

The results obtained in Experiment 1 suggest that by 10- to 12-months, infants construe the gist of pushing and pulling actions at a level more abstract than the purely perceptual. Infants have action categories of pushing and pulling that comprise multiple possible exemplars in which featural information regarding the hand/object interaction is allowed to vary. Additionally, those findings demonstrate that infants are capable of generating inferences of likely future action based on surface features like hand position, and then to categorize the action based on this generative inference rather than simply on observed motion parameters.

Previous research investigating infants' processing of pushing and pulling events performed by nonhuman agents found that 14-month-olds, but not 10-month-olds, understand such events (Casasola & Cohen, 2000; Cohen et al., 1995). Given the contrast in age, combined with the novelty of the methodology employed in Experiment 1 and the presence of the effect on the first test trial only, replication is essential in order to be confident of the robustness of the effect.

Experiment 2a was a replication of Experiment 1 with a sample of 11- to 12-month-old infants. The stimuli and procedure were slightly modified to increase infants' attention throughout the study. Experiment 2b, reported in the next chapter, was a replication of Experiment 1 with a sample of 6- to 7-month-old infants.

Method

Participants

Sixteen 11- to 12-month-olds (*M* = 12 months, 6 days; range: 11 months 13 days to 13 months 0 days; 8 girls, 8 boys) participated in the study. Nine additional infants participated but were excluded from analyses due to parental over-involvement (*n* = 2), interruptions during the test trial (*n* = 1; the infant's hair got caught in the parent's sweater), or fussiness and inattention (*n* = 6), with the latter defined as infants for whom more than three trials (habituation or test) had to be re-run due to insufficient looking time.

Materials

The current experiment used the same stimuli as Experiment 1, except for the following three modifications, all of which were designed to increase infants' attention throughout the procedure. (1) During the entire procedure, mellow classical music played in the background. Research on intersensory facilitation (Paden, 1974; Self, 1974) has found that auditory stimuli, such as music or the sound of the mother's voice, can increase visual attention to presented stimuli. (2) A half-second black screen was used to separate action sequences in both habituation and test trials. In Experiment 1, one-second black screens were used. However, infants may have become bored after a full second of black screen and looked away due to this boredom, resulting in low overall looking throughout the study. (3) A three-second pause was inserted at the end of test trials, rather than the one-second pause used in Experiment 1. The test sequences used in Experiment 1 were three seconds long with a one-second pause at the end. It is possible that infants in Experiment 1 found the rapid repetitions of the action sequence to be aversive, leading them to look less to trials as the test phase progressed. The longer pause was used in an attempt to make the test stimuli more pleasant and to give infants more time in which to extract the gist of the action.

Procedure

The procedure used in Experiment 2a was identical to Experiment 1, with one exception: given the presence of the predicted interaction on the first test trial only in Experiment 1, infants in the current experiment viewed two presentations of each test trial type, rather than three.

Results

As in Experiment 1, the question of interest was whether infants in the observed-push condition looked longer to inferred-pull test videos than to inferred-push videos, and whether infants in the observed-pull condition showed the opposite pattern.

Habituation Phase Analyses

Infants viewed, on average, 7.9 habituation trials (*SD* = 2.0) and accumulated a total of 75.45 seconds (*SD* = 29.69) of looking over the course of the habituation phase.

There were no differences between infants in the two habituation conditions with respect to average looking times during the first three habituation trials, average looking time to the last three habituation trials, the total amount of looking time during the entire habituation phase, or in the number of trials viewed during the habituation phase (all Fs < 1, *ns*). Fisher's exact test was used to examine whether infants in the two habituation conditions differed in the frequency with which they met the habituation criterion before moving to test trials; this analysis revealed no differences between infants in the observed-push condition (4 met criterion, 4 did not) and infants in the observed-pull condition (5 met criterion, 3 did not), $p = .99$.

Test Phase Analyses

Preliminary ANOVAs on infants' looking times toward test stimuli revealed that none of the following factors had a significant effect on test performance: sex, whether or not infants met the habituation criterion, or whether the gist of the first test trial was consistent or inconsistent with the action seen in the habituation phase. Subsequent analyses collapsed across these factors.

A repeated measures ANOVA with habituation condition (observed-push versus observed-pull) as the between-subjects factor and test gist-type (gist-consistent versus gist-inconsistent) and test trial pair (first and second) as within-subjects factors was performed.[8] Unlike in Experiment 1, there was no main effect of test trial pair, nor did test trial pair interact with other factors (Fs < 1.1, *ns*). This finding suggests that the methodological changes introduced in Experiment 2a were successful in eliciting infants'

[8] Two infants had parental interference during the second test trial pair and were not able to be included in this analysis.

sustained attention throughout the procedure. Therefore, data were averaged across both test trial pairs in the resulting repeated measures ANOVA,[9] which had habituation condition (observed-push versus observed-pull) as the between-subjects factor and test gist-type (gist-consistent versus gist-inconsistent) as the within-subjects factor.

Recall that if infants in the current experiment processed the pushing and pulling actions for gist, it would result in a significant main effect of test gist-type, such that infants would look longer to test trials inconsistent in gist relative to the habituation actions than to test trials consistent in gist.

The main effect for gist-type was marginally significant, $F(1, 14) = 3.75, p < .09$, $d' = .29$ (see Figure 7). This result is qualified, however, by an unexpected interaction between habituation condition and test gist-type, $F(1, 14) = 7.03, p < .05$ (see Figure 8). Planned directional simple effects analyses tested for the effect separately within each habituation condition. Infants in the observed-pull condition looked significantly longer at test videos inconsistent in gist with the habituation action ($M = 11.72$, $SD = 8.07$) than at test videos consistent in gist ($M = 7.37$, $SD = 6.59$), $F(1, 14) = 10.18, p < .005$, $d' = .66$. Non-parametric Wilcoxon signed-rank tests also yielded significant results for this comparison, $Z = 2.10, p < .05$. Infants in the observed-push condition showed no significant differences in looking times at test trials consistent in gist (inferred-push

[9] For the two infants whose data were not available for the second test trial pair, the looking times on the first trial pair were used as their average values. This ANOVA was performed both with and without these two infants in the model; test results did not change when those data were excluded. All results reported below are of tests that included those data.

average $M = 9.27$, $SD = 9.28$) and at test trials inconsistent in gist (inferred-push average $M = 8.70$, $SD = 9.49$), $F < 1$, *ns*.[10]

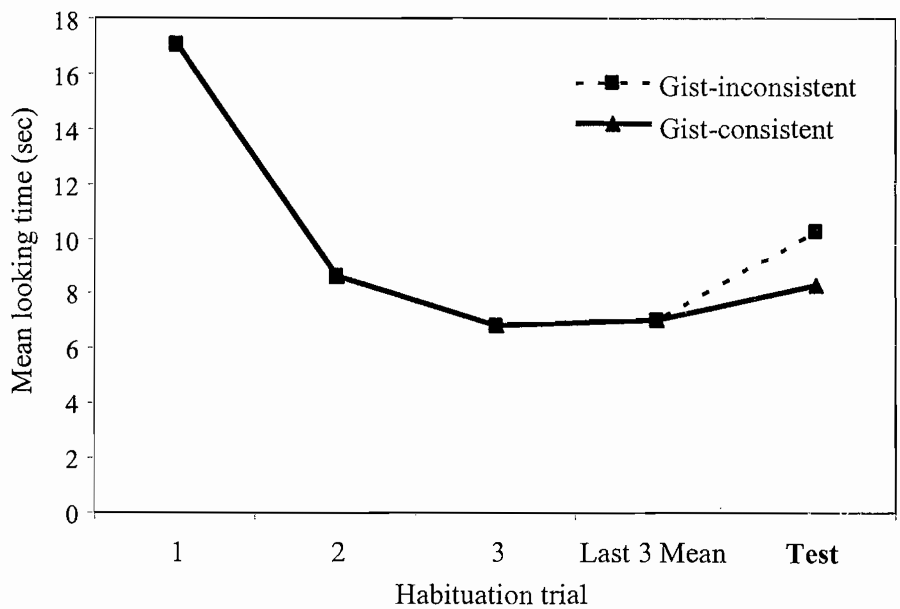

Figure 7: Eleven- to 12-month-olds infants' mean looking times (in seconds), collapsed across habituation condition, to the first three habituation trials, the mean of the last three habituation trials, and each test trial type in Experiment 2a.

Looking Time Recovery Analyses

Directional paired *t*-tests examined whether infants in the two habituation conditions selectively recovered looking time to test trials depicting an action inconsistent in gist with the action seen during the habituation phase. Infants in the observed-push condition looked longer, but not significantly so, at both test trials novel in gist (inferred-pull average $M = 8.70$, $SD = 9.49$) and test trials familiar in gist (inferred-

[10] Due to the effect of test trial pair in Experiment 1, post-hoc analyses were performed on the data from the first test trial pair only. None of the results changed in these analyses.

push average $M = 9.27$, $SD = 9.28$) relative to the average of the last three habituation trials ($M = 6.57$, $SD = 2.10$), both *ts* < 1, *ns*.

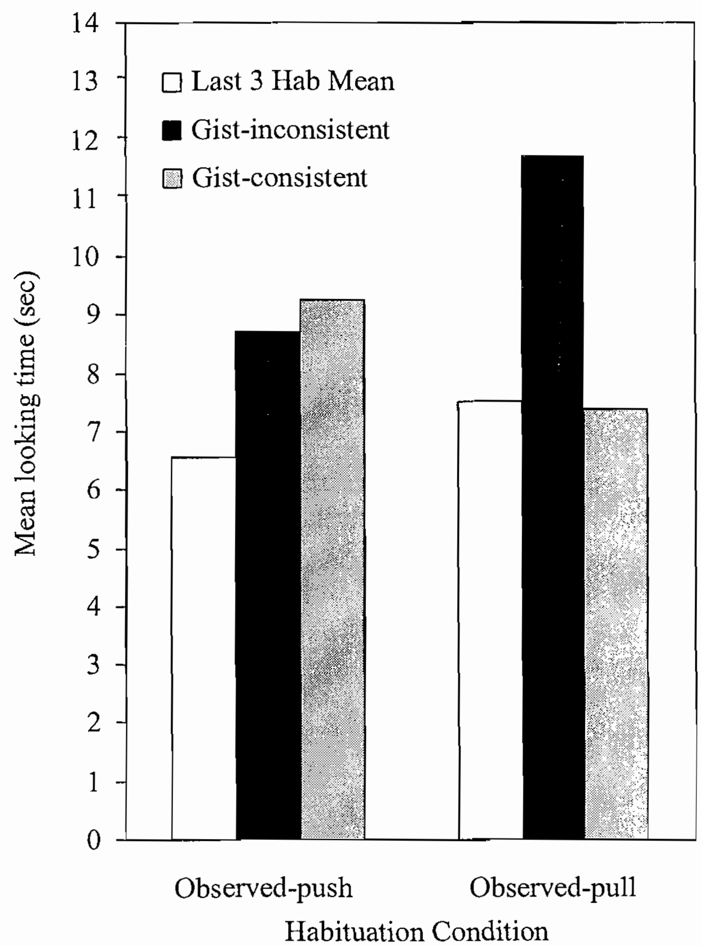

Figure 8: Eleven- to 12-month-olds infants' mean looking times (in seconds), by habituation condition, to the mean of the last three habituation trials and each test trial type in Experiment 2a.

In contrast to infants in the observed-push condition, infants in the observed-pull condition showed significant increases in looking time from the average of the last three habituation trials ($M = 7.51$, $SD = 5.79$) to the average of test trials novel in gist (inferred-push average $M = 11.72$, $SD = 8.07$), $t(7) = 2.02$, $p < .05$, $d' = .57$. However, as predicted, looking time to test trials familiar in gist showed a non-significant decrease (inferred-pull average $M = 7.37$, $SD = 6.59$), $t < 1$, *ns*.

The results of both the ANOVA and the looking time recovery analyses suggest that the data from infants in the observed-pull condition replicated the findings from Experiment 1 and show that 11- and 12-month-old infants process at least some actions for gist. However, Experiment 2a represents a failure to replicate Experiment 1 for infants in the observed-push condition. It appears that infants in this condition did not interpret the inferred-pull test action as more inconsistent in gist to the habituation action than the inferred-push test action.

Discussion

Experiment 2a attempted to replicate the findings from Experiment 1 suggesting that infants process pushing and pulling actions performed by a human actor for gist. The current experiment tested only 11- to 12-month-old infants and modified the method in order to elicit more sustained attention throughout the experiment. On the one hand, the goal of sustaining infants' attention throughout the experimental procedure was met in Experiment 2a. However, contrary to the results of Experiment 1 in which 10- to 12-month-old infants processed both pushing and pulling actions for gist, only infants in the observed-pull condition in the current experiment showed evidence of gist-processing.

Upon closer inspection, the lack of evidence for gist-related processing in infants in the observed-push condition seems to be attributable, in part, to increased attention to inferred-push test trials—infants looked for nearly 3 seconds longer at inferred-push test trials than the last three habituation trials, suggesting that the null results in this condition may be due not only to less looking at test trials inconsistent in gist, but also to increased attention to gist-consistent test trials.

A potential explanation of this finding relates to the use of a three-second still frame pause at the end of test trials, in contrast with the one-second pause used in Experiment 1. The pushing event depicted in the habituation phase involved the actor's arm and the glass making a long, continuous motion trajectory away from the actor's body. Therefore, when the actor made contact with the glass as if to push it but remained motionless for three seconds, infants may have seen this stillness as violating their expectation of what the actor was going to do; namely, push the glass. Perhaps this would not have been a factor in Experiment 1, however, as the actor's remaining motionless for only one second might not have violated infants' expectations to the same degree as when she remained motionless for three-seconds while maintaining a posture suggestive of pushing the glass.

In contrast to the pushing habituation stimulus, the motion in the pulling habituation stimulus was not continuous. When the actor grasped the glass, she interrupted the outward motion trajectory and introduced a discontinuity as she then pulled the glass toward herself. It is possible that infants in the observed-pull condition were not affected by the three-second pause as they were more used to the interruption in the motion stream.

Note that this explanation is similar to the one proposed for the performance of 5- to 7-month-old infants in Experiment 1. Those infants provided evidence of gist-related processing in the observed-push condition only, perhaps due to eased perceptual processing demands for continuous, unidirectional movements relative to actions involving changes in motion direction. In the current experiment, infants in the observed-push condition may have also formed a stronger expectation about the timing of the motion kinematics when the actions were unidirectional and therefore possessed surface motion details that were easier to process. If these hypotheses are correct, they suggest that gist-level processing is tightly bound with bottom-up processing of surface-level detail. Infants' ability to extract the gist from human action relies on an efficient bottom-up analysis of the motion stream; when infants succeed at both, they gloss over surface-level details and focus on the gist, but when they are unsuccessful at either, they rely more on the bottom-up analysis (Cohen & Cashon, 2006). These implications are developed more fully in the General Discussion.

CHAPTER IV

EXPERIMENT 2B

Overview

Results from Experiment 2a did not perfectly replicate those from Experiment 1. Specifically, the data from infants in the observed-pull condition beg the question of whether the methodological changes introduced in Experiment 2a could also alter younger infants' performance in the study. Experiment 2a tested 6- and 7-month-old infants on the same procedure used in Experiment 2a, save one change. Due to the possibility that the three-second pause at the end of test trials caused the push test videos to appear odd after viewing the pushing action in habituation, but did not have the same effect for the pull test videos, a one-second still frame pause was used at the end of test trials.

Method

Participants

Sixteen 6- to 7-month-olds (*M* = 6 months, 29 days; range: 6 months 2 days to 7 months 18 days; 7 girls, 9 boys) participated in the study. Seven additional infants participated, but were excluded from analyses due to parental over-involvement (*n* = 1), data with extreme outliers ($n = 1$),[11] or fussiness and inattention ($n = 5$), which was defined as infants for whom more than three trials (habituation or test) had to be re-run due to insufficient looking time.

Materials and Procedure

The current experiment used the same stimuli as Experiment 2a, except that a one-second still frame pause was used at the end of test trials. The procedure used in the current experiment was identical to Experiment 2a.

Results

Habituation Phase Analyses

Infants viewed, on average, 9.1 habituation trials ($SD = 1.7$) and accumulated a total of 63.54 seconds ($SD = 22.74$) of looking over the course of the habituation phase. There were no differences between infants in the two habituation conditions with respect to average looking times during the first three habituation trials or in the number of trials viewed during the habituation phase (both Fs < 1, *ns*). However, infants in the observed-push condition looked significantly longer over the course of the habituation phase ($M = 78.23$, $SD = 20.74$) than infants in the observed-pull condition ($M = 48.84$, $SD = 13.58$), $F(1, 14) = 11.14, p < .005, d' = 1.45$. Furthermore, infants in the observed-push condition displayed marginally significantly longer looking, on average, to the last three habituation trials ($M = 8.00$, $SD = 4.09$) than infants in the observed-pull condition ($M =$

[11] The outliers were in the direction predicted by the hypothesis; their omission, therefore, did not favor the hypothesis.

4.91, $SD = 2.86$), $F(1, 14) = 3.91, p < .07, d' = .86$ (see Figure 9). Fisher's exact test was used to examine whether infants in the two habituation conditions differed in the frequency with which they met the habituation criterion before moving to test trials; this analysis revealed no differences between infants in the observed-push condition (3 met criterion, 5 did not) and infants in the observed-pull condition (2 met criterion, 6 did not), $p = .99$.

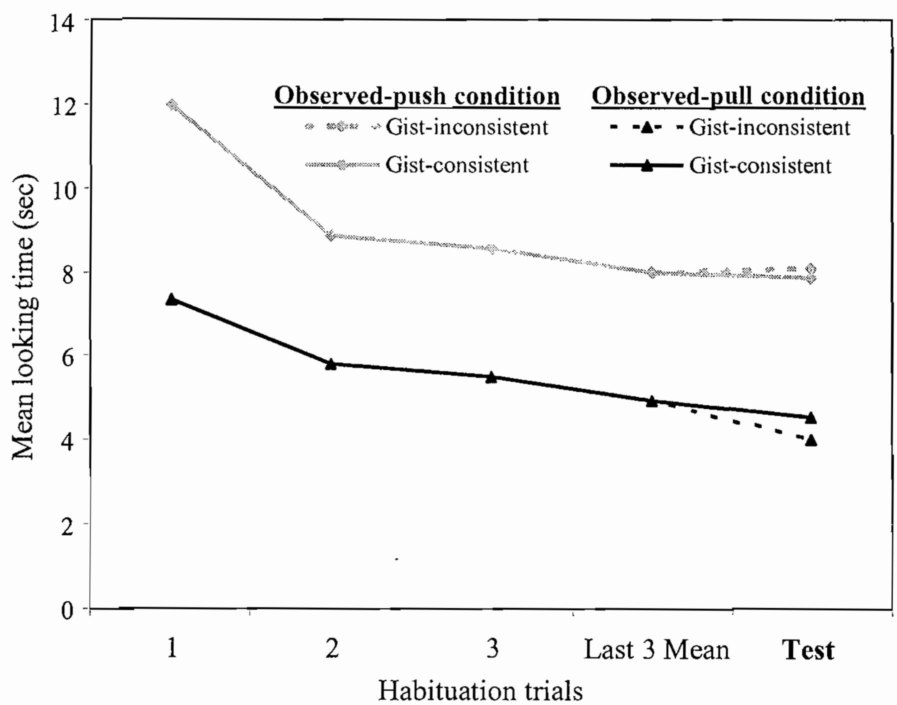

Figure 9: Six- to 7-month-old infants' mean looking times (in seconds), by habituation condition, to the first three habituation trials, the mean of the last three habituation trials, and each test trial type in Experiment 2b. The lines with diamond joints represent the data from infants in the observed-push condition; the lines with triangle joints represent the data from infants in the observed-pull condition.

Test Phase Analyses

Consistent with condition differences in looking time during the habituation phase, infants in the observed-push condition displayed significantly longer looking, on average, to both test trial types ($M = 7.97$, $SD = 3.51$) than infants in the observed-pull condition ($M = 4.27$, $SD = 1.04$), $F(1, 14) = 9.49$, $p < .01$, $d' = 1.33$ (see Figure 9). No other effects were statistically significant.

Discussion

Five- to 7-month-old infants in the current study did not preferentially look at either gist-consistent or gist-inconsistent test trials. Due to the unexpected findings that infants in the observed-push condition looked significantly longer throughout the experiment, it is difficult to draw any conclusions from Experiment 2b. It is possible that the failure to replicate the findings from the observed-push condition Experiment 1 was due, in part, to a ceiling effect. Average looking to the last three habituation trials, gist-inconsistent test trials, and gist-consistent test trials among infants in the observed-push condition in the current experiment were all longer than comparable looking times among infants in both conditions in Experiment 1 and the observed-pull condition in the current experiment. In other words, according to every metric, infants in the observed-push condition, as a group, looked longer than any other group of 5- to 7-month-old infants in Experiments 1 or 2b. Perhaps those infants simply looked to fatigue during test trials.

In contrast, infants in the observed-pull condition showed minimal attention during test trials, indicating a possible floor effect. Regardless of test trial type, those infants watched only a single presentation of the test action during a single test trial, whereas infants in the observed-pull condition in Experiment 1 showed increased looking to both test trial types relative to the last three habituation trials.

The methodological differences between the current experiment and Experiment 1 were introduced in order to increase infants' attention throughout the study. The findings from the current experiment show that to the extent these changes were successful in increasing attention, they did so only in the observed-push condition. It is difficult to provide an account for this pattern other than random variation as the stimuli were nearly identical to those used in Experiment 1.

It is also possible that the findings from 5- to 7-month-olds in Experiment 1 were spurious and that infants at this age are not yet capable of processing for gist, as was hypothesized before Experiment 1. Future studies on this topic should attempt to develop stimuli that garner infants' interest and contain surface motion details that promote their processing of the relevant structure. Research has shown that infants look longer at live events than at videotaped presentations of the same event (Pierroutsakos & Diener, 2007); the use of live actors who engage in actions that promote efficient perceptual analysis may be useful for future investigations into young infants' processing for gist.

CHAPTER V

EXPERIMENT 3

Overview

The previous experiments demonstrate that infants form action categories based on the gist of an action. These studies, however, share a shortcoming with much of the existing literature in that they focus on a single action comparison, in this case actions involving sliding an object to oneself or another person. If infants generally process action by forming gist-based categories, then they should use this strategy when interpreting other actions, as well. Experiment 3 tested the hypothesis that 10- to 12-month-old infants would be sensitive to the gist of an additional action comparison: opening or closing a door.

Despite the suggestive evidence from Experiment 1 that 5- to 7-month-olds can process some actions for gist, the current experiment tested only 10- to 12-month-old infants. This change was made because infants who participated in Experiment 3 also participated in Experiment 4 during the same visit to the laboratory. As no studies to my knowledge have investigated infants' social-cognitive skills on two different tasks in the same experimental session, Experiments 3 and 4 were paired in order fill this gap and test for individual differences in social cognition.[12] This design feature, however, left younger infants ill-suited for the task for two reasons First, younger infants in Experiment 1 had lower looking times throughout the experiment than older infants, casting doubt on whether 5- to 7-month-olds would be likely to complete both experiments. Second, the stimuli used in Experiment 4 were considerably more complex in that they contained several action components, including eye contact between the actors and joint attention on an object, and prior research suggests that it is not until the end of the first year of life that infants develop the ability to interpret a means-ends action sequences (Sommerville & Woodward, 2005a; Woodward & Sommerville, 2000). Therefore, the sample was restricted to 10- to 12-month-olds.

Method

Participants

Sixteen 10- to 12-month-olds (M = 11 months, 6 days; range: 10 months 18 days to 12 months 15 days; 8 girls, 8 boys) participated in the study. Nine additional infants participated, but were excluded from analyses due to technical problems (n = 1), parental interference (n = 2), or were unable to finish the study due to fussiness and inattention (n = 6).

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[12] Unfortunately, only twelve infants completed both experiments. This resulted in cross-experiment analyses that lacked statistical power and which did not reveal any relationship between performance in Experiments 3 and 4.

All infants who participated in Experiment 3 also participated in Experiment 4. Infants were randomly assigned to participate in either Experiment 3 first (n = 8) or Experiment 4 first (n = 8). Twelve infants completed both studies.

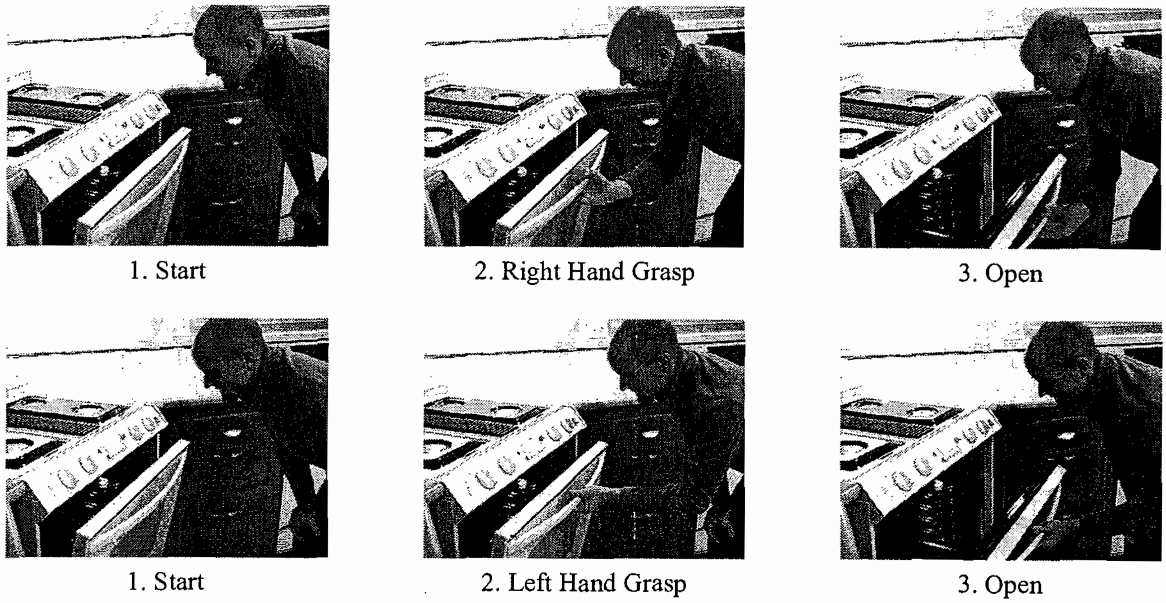
Materials

Infants were habituated to one of two action sequences involving either opening or closing an oven door. In the beginning of both habituation videos, a smiling male wearing a blue long sleeved shirt was seen standing in a bent position near an oven, the door of which was ajar. The habituation video used in the *observed-open* condition, depicted the actor grasping an oven handle with an underhand grip and pulling the door open (see Figure 10A). The video used in the *observed-close* condition depicted the same actor using an underhand grip when grasping and closing the door (see Figure 10B). On alternating habituation trials the actor used his right or left hand to open or close the door, resulting in four total habituation videos. Which hand was used to manipulate the door on the first test trial was counterbalanced across infants.[13]

The time-course of all four habituation videos was identical. In all videos the actor grasped the handle 2.5 seconds into the video. The actor then pulled the door handle to open the door, stopped at the 4.3-second mark of the video and held the position for three seconds. After the 7.3-second event was completed, a half-second black screen appeared and the event was repeated.

[13] Infants saw the action performed with both hands because, in test, the actor used his right hand on inferred-open trials and his left hand on inferred-close trials. By alternating use of right- and left-hand habituation trials infants were not able to develop an expectation regarding which hand the actor favored, thus any preferences at test could not be driven by increased attention to test trial types depicting the actor using a new hand to contact the door.

(A) *Observed-Open Condition*



(B) *Observed-Close Condition*

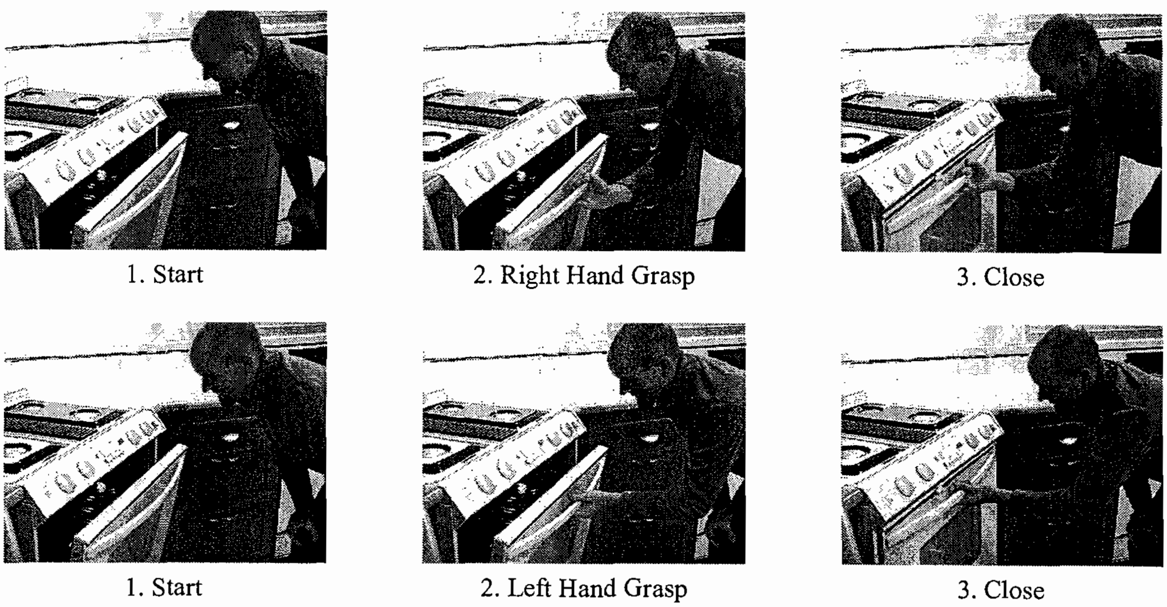


Figure 10: Illustrative still frame images from the videos used in the habituation phase of Experiment 3. Images from the observed-open condition are in the top two rows and images from the observed-closed condition are in the bottom two rows. In each condition, on alternating trials the actor used his right hand (top row in each section) or left hand (bottom row in each section) to open or close the door.

At test, infants saw *inferred-open* and *inferred-close* trials, each presented twice and in alternating order, counterbalanced across infants. Both test trials started with the actor in the same position as in the beginning of habituation trials. In inferred-open test trials, the actor put the palm of his right hand on the inside of the door, allowing him to potentially open, but not close, the door (see Figure 11). In inferred-close trials, the actor put the palm of his left hand on the outside face of the door handle, allowing him to potentially close, but not open, the door.

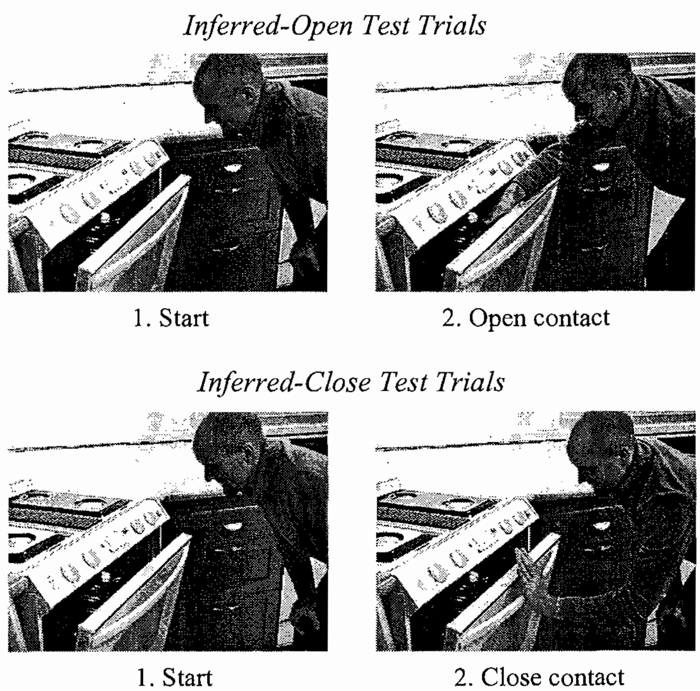


Figure 11: Illustrative still frame images from the videos used in the test phase of Experiment 3.

Each test video had the same time-course; the actor made contact with the door at the 2.5-second mark and held the position for 1.5 seconds until the 4-second video ended. After a half-second black screen, the video was repeated.

Procedure

Habituation. Infants sat on a parent's lap approximately 70 cm away from the 24 x 33 cm video screen. During habituation trials, infants' looking time was recorded throughout the entire action sequence. On each trial, the video continued to play until either five presentations of the video had been completed (total duration 38.5 seconds) or the infant looked away for two consecutive seconds, whichever came first. If infants did not accumulate at least three seconds of viewing on any habituation trial, the trial was repeated. (A three-second criterion was selected because the actor did not begin to move the object until three seconds into the video). The habituation criterion was set as the first three-trial sequence over which infants accumulated 30 seconds or more of looking time (i.e., where the average looking time per trial was at least ten seconds). The habituation phase ended when either eight trials had been completed or the average looking to the two[14] most recent trials was less than 50% of the habituation criterion, whichever came first. Infants' looking time was coded online by an observer using custom software (Loucks & Vukcevich, in preparation) that automatically calculated habituation criteria and advanced to test trials when appropriate.

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[14] The change from the standard three-trial average used to check whether infants met the habituation criterion in Experiments 1, 2a, and 2b to the two-trial average used in Experiments 3 and 4 was made in order to facilitate infants' reaching the criterion and advancing to test trials in a timely manner. Several of the infants omitted from the analysis due to fussiness in the previous experiments accrued several re-run trials due to insufficient looking at the end of the habituation phase, a possible sign that infants were bored with the habituation action despite not having met the habituation criterion. Even infants included in the sample seemed to have difficulty reaching the habituation criterion, in part because their average looking to the first three trials was short (e.g., $M = 9.88$ seconds in Experiment 1). This made it difficult for infants to have three consecutive trials the average of which was both over two seconds (the minimum looking time needed for a valid trial) as well as below 4.94 seconds (50% of the average of the first three). By using a two-trial average—rather than three—to check for habituation, and requiring that the habituation criterion not be set until the average of three trials exceeded ten seconds, it was hoped that more infants would reach criterion and move to test trials when bored with the habituation stimulus.

Test. All infants saw two presentations each of inferred-open and inferred-close test actions in alternating order. On each test trial, the video continued to play until either the infant looked away for two consecutive seconds after accumulating at least two seconds of looking time, or until the video was presented a total of seven times (total duration 33.7 seconds). (A two-second criterion was used for test trials because the actor's hand configuration foreshadowed opening or closing within two seconds of the start of the video). If infants did not accumulate at least two seconds of looking on any test trial, that trial was repeated. The order of presentation of the two test trial types was counterbalanced such that half of the infants in each habituation condition had a new recipient/old location trial first, and the other half had the old recipient/new location trial first.

Results

Habituation Phase Analyses

Infants viewed, on average, 7.8 habituation trials (*SD* = .4) and accumulated a total of 69.61 seconds (*SD* = 25.24) of looking over the course of the habituation phase. There were no differences between infants in the two habituation conditions with respect to average looking times during the first three habituation trials, average looking time to the last three habituation trials, the total amount of looking time during the entire habituation phase, or in the number of trials viewed during the habituation phase (all Fs $<$ 1.8, *ns*). A Fisher's exact test was used to examine whether infants in the two habituation conditions differed in the frequency with which they met the habituation criterion before moving to test trials; this analysis revealed no significant differences between the frequency with which infants in the observed-open condition reached criterion (1 met criterion, 7 did not) and the frequency with which infants in the observed-close condition reached criterion (3 met criterion, 5 did not), $p = .60$.

Test Phase Analyses

The question of interest in Experiment 3 was whether infants, regardless of habituation condition, looked longer at gist-inconsistent than gist-consistent test trials. It was predicted that infants would display significantly longer looking to gist-inconsistent test trials than gist-consistent test trials, resulting in a significant main effect of test gist-type.

Preliminary ANOVAs on infants' looking times toward test stimuli revealed that sex, order of presentation of test stimuli, and infants' tendency to meet the habituation criterion yielded neither significant main effects nor interacted with other factors; therefore, subsequent analyses collapsed across these factors.

A repeated measures ANOVA with habituation condition (observed-open versus observed-close) as the between-subjects factor and test gist-type (gist-consistent versus gist-inconsistent) and test trial pair (first or second) as the within-subjects factors was performed on the data. There was a significant effect of test trial pair, $F(1, 14) = 6.25$, $p < .05$, such that infants' attention generally decreased across the test phase. However, the interaction between trial pair and gist-type was not significant ($F < 1$, *ns*), and none of the analyses reported below changed depending on whether the model included the average of both habituation trials or the first test trial pair only. Therefore, subsequent analyses collapsed across trial pair.

After removing test trial pair from the analysis, a repeated measures ANOVA with habituation condition (observed-push versus observed-pull) as the between-subjects factor and test gist-type (gist-consistent versus gist-inconsistent) as the within-subjects factor was performed on the data. The predicted main effect of gist type was significant, $F(1, 14) = 17.41, p < .001, d' = 1.14$ (see Figure 12). Infants looked significantly longer at gist-inconsistent test trials ($M = 11.03$, $SD = 5.82$) than at gist-consistent test trials ($M = 5.60$, $SD = 3.05$). Non-parametric analyses corroborated the results of the ANOVA; infants looked significantly longer at gist-inconsistent trials than at gist-consistent trials (Wilcoxon signed ranks $Z = 2.39, p < .05$). There was no main effect of habituation condition or interaction between habituation condition and test gist-type in the ANOVA, indicating that infants in the two habituation conditions did not differ significantly in their looking patterns in test.

Planned directional simple effects analyses tested for the predicted effect within each habituation condition. Infants in the observed-open condition showed significantly longer looking to gist-inconsistent test trials (inferred-close $M = 10.83$, $SD = 5.21$) than to gist-consistent test trials (inferred-open $M = 5.00$, $SD = 3.12$), $F(1, 14) = 12.56, p < .005$, $d' = 1.28$ (see Figure 13). Infants in the observed-close condition also looked significantly longer to gist-inconsistent test trials (inferred-open $M = 11.22$, $SD = 6.74$) than to gist-consistent test trials (inferred-close $M = 6.20$, $SD = 3.07$), $F(1, 14) = 5.56, p < .05$, $d' = .80$. Together, these analyses show that infants' looking to test trials was driven primarily by whether or not the inferred action was consistent with the gist of the action seen during habituation, rather than the actual behavior (i.e., open versus close).

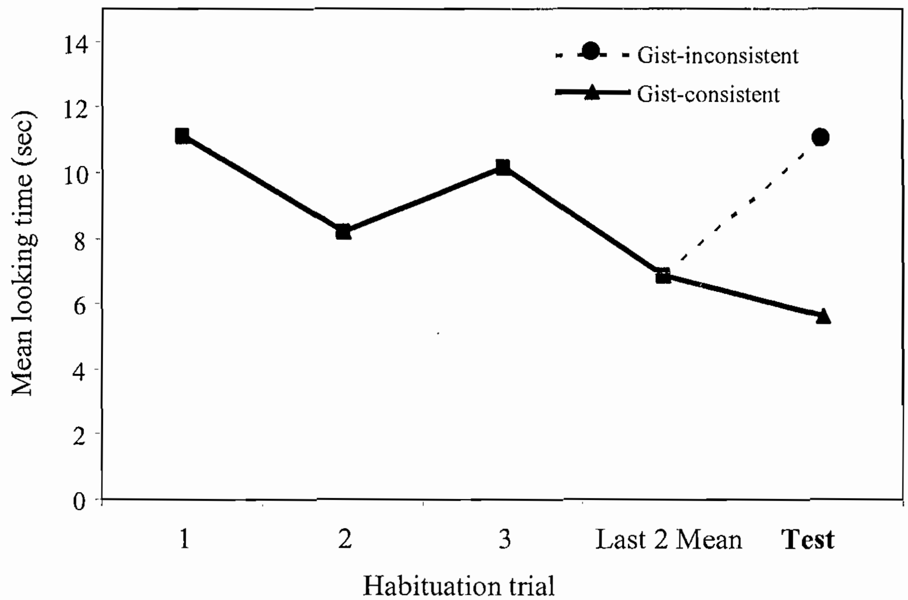


Figure 12: Ten- to 12-month-old infants' mean looking times (in seconds), collapsed across habituation condition, to the first three habituation trials, the mean of the last two habituation trials, and each test trial type in Experiment 3.

Looking Time Recovery Analyses

Directional paired *t*-tests examined whether infants selectively recovered looking time to gist-inconsistent test trials relative to the last viewed two habituation trials. As predicted, infants looked significantly longer at gist-inconsistent test trials ($M = 11.03$, $SD = 5.82$) compared to the average of the last two viewed habituation trials ($M = 7.10$, $SD = 2.40$), $t(15) = 2.27$, $p < .05$, $d' = .71$. In contrast, there was a significant decrease in looking to gist-consistent test trials ($M = 5.60$, $SD = 3.05$), $t(15) = -1.83$, $p < .05$, $d' = .69$.

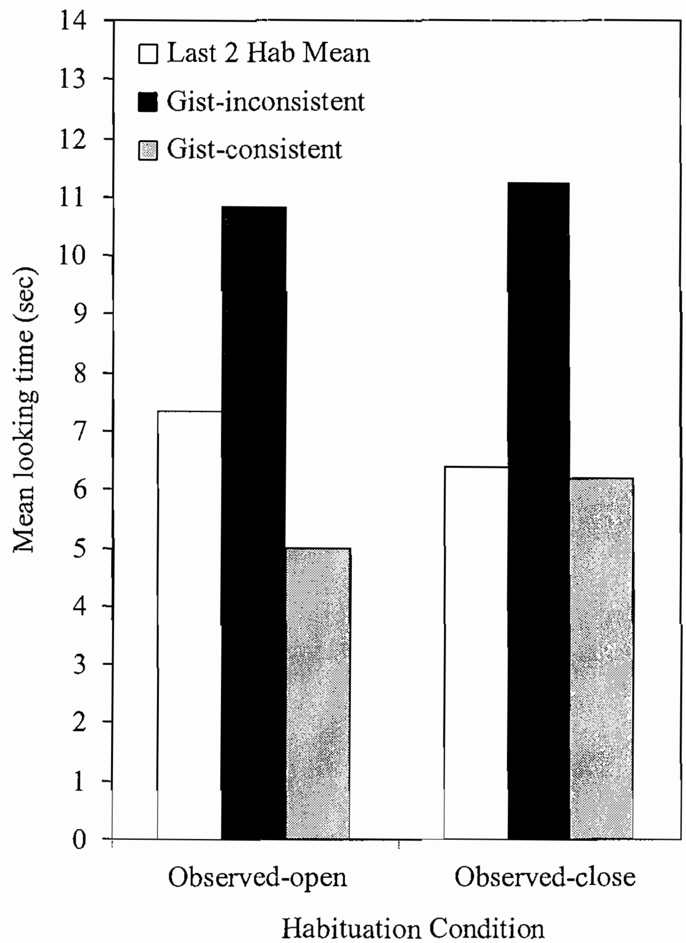


Figure 13: Ten- to 12-month-old infants' mean looking times (in seconds), by habituation condition, to the mean of the last two habituation trials and each test trial type in Experiment 3.

Discussion

Experiment 3 investigated whether 10- to 12-month-old infants used gist-related processing when observing an actor opening or closing a door. Infants who observed an actor open an oven door in the habituation phase looked longer at test trials in which the actor contacted the door in such a way that would enable him to close—but not open—the door than at trials in which he contacted the door as if to open it. The opposite pattern was obtained among infants in the observed-close condition; at test, they preferred to look at test trials in which the actor appeared likely to open the door than in trials in which he appeared likely to close it. As in previous experiments, these findings attest to infants' ability to gloss over substantial perceptual variability between action exemplars in order to categorize the actions based on a shared gist.

On a methodological note, the length of still-frame pauses at the end of test actions (1.5 seconds) were closer in duration to those used in Experiment 1 (1 second) than Experiment 2a (3 seconds). As the methodology used throughout this dissertation is novel, the experiments reported throughout had to empirically verify which pause latencies were optimal for the experimental design. The findings from the current experiment, as well as from Experiment 1, suggest that pause lengths between 1 and 1.5 seconds allow infants enough time to extract the gist of the action without disrupting their predictions regarding the actor's movements.

The stimuli used in the current experiment contribute to the ecological validity of the current package of studies, as well as to the extant literature on infant social cognition. In the previous experiments in this dissertation, and in the majority of research on infant social cognition, the action exemplars depicted in the stimuli were performed in visually-sparse contexts. When experiments employ stimuli that depict human action, the adult actor is often seated at a table containing one or two distinct objects, and in front of a curtain or a bare wall. Simplifying the visual environment is obviously critical for maintaining experimental control and ensuring that infants are attending to the appropriate aspects of the stimulus. However, successful action analysis in the real world has to contend with a large amount of visual clutter in order to identify the gist of the action. Therefore, experiments that use stimuli in contexts containing potentially distracting visual stimuli, such as the current experiment and the seminal research by Baldwin et al. (2001), are important in extrapolating laboratory findings to real-world action processing contexts.

A potential limitation of the current experiment relates to whether the actions shown to infants were qualitatively distinct from the actions in Experiments 1, 2a, and 2b. The *opening* actions in both the habituation and test phases of the current experiment depicted an actor pulling a door, whereas the *closing* actions depicted the actor pushing the door. As such, one might question whether the findings of Experiment 3 provide any insight into infants' gist-related processing beyond that provided by the previous experiments, which depicted an actor pushing and pulling a small object.

Against this critique, however, there are at least two arguments. First, research by Woodward and Sommerville (2000) suggests that 11- to 12-month-old infants are sensitive to the functional affordances enabled by opening a container, lending plausibility to the argument that infants in the current experiment were sensitive to the functional affordance—i.e., the gist—of the opening and closing actions performed on the door. Second, the pushing and pulling actions depicted in the current experiment are distinct, in several surface motion parameters, from the pushing and pulling actions depicted in the previous experiments. For instance, in Experiments 1, 2a, and 2b, the actor was shown using her right hand to slide a small object on the horizontal plane between two people. In contrast, the actor in Experiment 3 alternated between using his right and left hand to move an object part (the door of an oven) around a fulcrum in the absence of another person. Categorizing the video depicting *pushing* from the previous experiments together with the video depicting *pushing* from the current experiment together would require sophisticated gist-level processing mechanism in its own right. Therefore, regardless of whether infants interpreted the actions as *push* and *pull* or *open* and *close*, the current experiment provides additional supporting evidence that infants can interpret a range of action exemplars for gist.

Findings from the current experiment extend the findings from the previous experiments in this dissertation in demonstrating the robustness of infants' ability to process action for gist. Specifically, these findings show that infants' gist-related processing skills are not limited to sliding an object on a table. This suggests that by at least 10- to 12-months of age, gist-related processing skills are part of infants' more general action-processing strategies.

CHAPTER VI

EXPERIMENT 4

Overview

Two questions motivated Experiment 4. The first question was whether infants categorize actions on the basis of a shared gist when action exemplars differ on several motion parameters. Experiments 1, 2a, and 3 provided evidence that 10- to 12-month-old infants who observe an action involving object manipulation can gloss over changes in hand configuration and whether the object is moved and categorize those actions at the more abstract gist level. However, the action exemplars shown to infants in the habituation and test phases of those experiments were highly similar in several other parameters, such as the direction of eye gaze, the number of hands used, and the position of the actors and objects at the beginning of the action. Each of these motion parameters may vary between action exemplars infants observe outside of the laboratory. If the gist-processing skills infants demonstrated in previous experiments do, in fact, operate when infants process everyday action, they must be able to contend with even greater perceptual variability between action exemplars than was established in the previous experiments. Experiment 4 investigated whether infants are capable of categorizing actions by a shared gist when action exemplars depicting object transfer differ on several motion parameters, including hand configuration, whether or not the actor moves the object, the number of hands used to contact the object, the spatial location of the actors, whether or not the actors establish eye contact, and whether the recipient of the object in a giving action interacts with the object.

The second question that motivated the current research was whether the results from previous experiments point to infants' preference to categorize actions at the more abstract gist level relative to a purely perceptual level, or whether those results might also indicate that infants prefer to categorize actions at more abstract levels of gist relative to less abstract levels of gist (cf. Cohen et al., 2002). Experiment 4 was designed such that there were [at least] two potential gist-level interpretations of the action; in question was the level at which infants would prefer to categorize the actions. The two potential gist-level construals will be clearer after a brief description of the methodology.

The current experiment married the gist-processing methodology used throughout this dissertation with the object-switch methodology used by Woodward (1998) to investigate infants' understanding of goal-directed grasps. Infants in the habituation phase of the current experiment were shown an actor seated at a table with two other people seated on either side of the actor. The actor grasped and moved an object to one of these people, released the object, after which the recipient grasped it. At test, the two people switched locations and infants saw two test trial types. In the first test trial type, the actor contacted the object as if to push it to the opposite side of the table than she had pushed it during habituation, but toward the same person. In the second test trial type, the actor contacted the object as if to push it to the same spatial location as in habituation, but toward a new person.

If infants interpreted the gist of the habituation videos as the actor moving an object to a specific spatial location—i.e., the right or left side of the table—they should have expected the actor to move the object to the same location in test trials. This would result in longer looking at test trials depicting the actor preparing to push the object to the new location. Note that this *directional push* interpretation is still a gist-related construal of the action and would suggest that infants are capable of glossing over even more variability in motion parameters—e.g., changes in eye gaze, the number of hands used, and the location of the actors—than demonstrated in previous experiments.

If, however, infants encoded the identity of the recipient in the object transfer event, then they should show the opposite pattern, looking longer to test trials in which the actor contacted the object as if to move it to the same location as in habituation, but to the new recipient who was seated there. This construal of the action represents a more abstract level of interpretation, as infants would need to not only understand the gist of moving an object to a particular spatial location, but also would need to recognize that the identity of the agents in the dyadic interaction is a critical feature of the gist of the action. Based on prior research demonstrating that 10- to 12-month-old infants are capable of interpreting at least some interactions between multiple agents (Hamlin et al., 2007; Kuhlmeier et al., 2003; Sodian et al., 2004), I hypothesized that infants would be capable of the more abstract level of processing, encoding the identity of the recipient in their representation of the action. I thus predicted that infants would look longer at new recipient/old location test trials than at old recipient/new location test trials.

Method

Participants

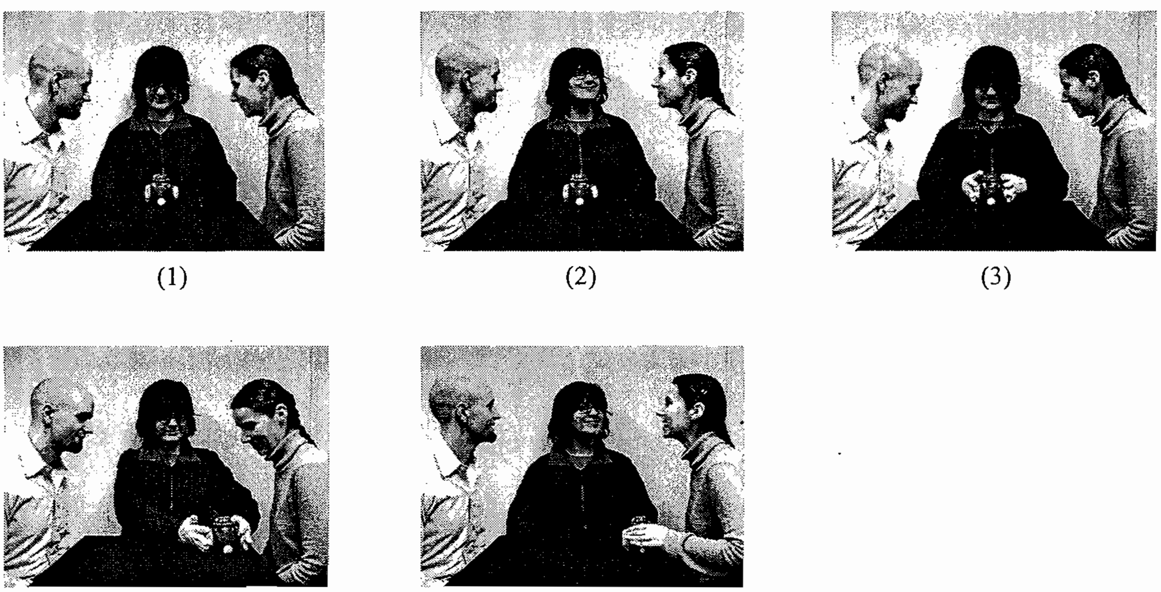
Sixteen 10- to 12-month-old infants (*M* = 11 months, 12 days; range: 10 months 18 days to 12 months 18 days; 8 girls, 8 boys) participated in the study. Nine additional infants participated, but were excluded from analyses due to technical problems (*n* = 1), ambient noises that distracted the infant during test (*n* = 1), or inability to finish the study due to fussiness and inattention (*n* = 7).

All infants who participated in Experiment 4 also participated in Experiment 3. Infants were randomly assigned to participate in either Experiment 3 first (*n* = 8) or Experiment 4 first (*n* = 8). Twelve infants completed both studies.

Materials

During the habituation phase infants viewed a digitized action sequence that depicted a female actor giving an object to one of two people who were sitting on opposite sides of a table (see Figure 14). The recipient (male or female) and the location of the recipient (right or left side of the actor) were counterbalanced, resulting in four habituation videos. The actor wore a brown long sleeved jacket, as well as yellow gloves intended to draw infants' attention to the motion of the actor's hands. The other two participants were a male wearing a long sleeved blue shirt and a female wearing a long sleeved green shirt.

The action sequence began with all three people looking at the object and smiling. The *actor* and the *recipient* then looked at each other while the *observer* looked at the actor. (Throughout the video clip, the observer's eye-gaze always mirrored the direction of the recipient's eye-gaze). All three participants then looked at the object, after which the actor grasped the object with two hands and moved it in front of the recipient. The actor then withdrew her hands and the recipient grasped the object with his or her hand that was closest to the video camera. After grasping the object, the recipient and the actor looked at each other and smiled broadly while the observer also looked at the actor and smiled widely. This pose was held for two seconds until the end of the trial. The entire action sequence lasted 11.7 seconds (same for all four versions of the habituation videos).



(1) (2) (3)

(4) (5)

Figure 14: Illustrative still-frame images from one of the videos used in the habituation phase of Experiment 4. The sequence was the same for the other conditions formed by varying whether the male or female received the toy and the side of the table on which the recipient sat.

After the end of the habituation phase, but before the beginning of test trials, infants saw an *orient* trial in which the recipient and onlooker had switched locations (see Figure 15). The orient trial was a still-frame image of the three people looking at the object and smiling. The orient trial allowed infants to observe the new locations of the actors, increasing the probability that looking time to test trials would be driven by interpretations of the actions, rather than the perceptual novelty of the location switch. The onlooker and recipient remained in the new, switched locations throughout each of the test trials.

Orient trial — *New recipient/Old location* test trial — *Old recipient/New location* test trial

Figure 15: Illustrative still frame images from one of the videos used in the test phase of Experiment 4. After an orient trial, infants saw test trials that began with the actors seated at the table as in orient trials, followed by the actor moving her hand and making contact with the object; the still frames shown for the test trials are of the position of final contact.

All infants saw two test trial types. Test actions began with all three participants in the same pose as in the orient trial: looking at the object and smiling. In *old recipient/new location* trials, the actor reached out her hand and contacted the object with her palm as if to push it to the old recipient who was now sitting on the opposite side of the table (see Figure 15). Her hand was angled in such a way that she could only push it toward one of the two other participants. In *new recipient/old location* trials, she engaged in the same action, except that her angled palm was placed on the object in a manner that would enable her to push the object to the same spatial location but toward a new recipient (the observer from the habituation phase).

There were four test actions in all, although an individual infant only saw the two versions of the video that depicted the recipient and onlooker on the opposite sides of the table relative to where they sat during the habituation video. In each of the four videos, it took the actor roughly 2.6 seconds to contact the object and she held the pose for roughly 1.4 seconds until the video clip ended. Each action sequence lasted 4 seconds.

Procedure

Habituation. Infants sat on a parent's lap approximately 70 cm away from the 24 x 33 cm video screen. During habituation trials, infants' looking time was recorded throughout the entire action sequence. Each action sequence was followed by a half-second presentation of a black screen, whereupon the sequence was repeated. On each trial, the video continued to play until infants either looked away from the screen for at least two consecutive seconds or four loops of the video were presented, whichever came first. If infants did not accumulate at least four seconds of viewing on any habituation trial, the trial was repeated. (A four-second criterion was selected because the actor did not begin to move the object until four seconds into the video). The habituation criterion was set as the first three-trial sequence over which infants accumulated 30 seconds or more of looking time (i.e., where the average looking time per trial was at least ten seconds). The habituation phase ended when either eight trials had been completed or the average looking to the two most recent trials was less than 50% of the habituation criterion, whichever came first. Infants' looking time was coded online by an observer using custom software (Loucks & Vukcevich, in preparation) that automatically calculated habituation criteria and advanced to test trials when appropriate.

Test. Although infants participated in just one of the four habituation conditions made by counterbalancing the recipient (male or female) and his or her location (right or left side of the table). all infants saw new recipient/old location and old recipient/new location test actions in alternating order.

The test phase was preceded by an *orient* trial. After the orient trial, infants saw two trial pairs, with each pair containing one of each type of test action. As in habituation, each action sequence in a given test trial was followed by a half-second black screen and repeated. A test trial ended when the infant looked away for two consecutive seconds after accumulating at least two seconds of looking time, or until six presentations of the action sequence had been completed, whichever came first. (A two-second criterion was used for test trials because the actor's hand configuration clarified the direction of intended object movement within two seconds of the start of the video). If infants did not accumulate at least two seconds of looking on any test trial, that trial was repeated. The order of presentation of the two test trial types was counterbalanced such that half of the infants in each habituation condition had a new recipient/old location trial first and the other half had the old recipient/new location trial first.

Results

Habituation Phase Analyses

Infants viewed, on average, 7.5 habituation trials (*SD* = .8) and accumulated a total of 169.47 seconds (*SD* = 67.04) of looking over the course of the habituation phase. One-way ANOVAs were performed to look for condition differences in average looking times to the average of the first three habituation trials, average looking time to the last three habituation trials, the total amount of looking time during the entire habituation phase between the various habituation conditions, and the number of trials viewed during the habituation phase. Infants who saw the actor give the object to the recipient on her left in habituation did not differ significantly in any of these tests from infants who saw the actor give the object to the recipient on her right (all *F*s < 2.9, all *p*s $> .11$). Infants who, in habituation, saw the actor give the object to the female recipient viewed marginally significantly more habituation trials ($M = 7.88$, $SD = .35$) than infants who saw the actor give the object to the male recipient ($M = 7.13$, $SD = .99$), $F(1, 14) = 4.07$, $p < .07$, $d' = .25$. (To preview, the sex of the recipient did not predict any patterns during the test phase). There were no significant differences between the two habituation trial types with respect to any of the habituation looking time measures (all *F*s < 2.9, all *p*s $>$ .11).

Additional one-way ANOVAs examined whether infants who met the habituation criterion differed from infants who did not meet the habituation criterion with respect to overall looking time during habituation, average looking to the first three habituation trials, and average looking to the last two viewed habituation trials. Habituators had significantly longer looking times over the first three habituation trials (*M* = 37.70 seconds, *SD* = 5.99) than non-habituators (*M* = 15.55 seconds, *SD* = 8.35), $F(1, 14) = 26.82, p < .001, d' = 2.27$ (see Figure 16). In addition, habituators displayed marginally significant longer overall looking during the habituation phase (*M* = 203.47 seconds, *SD* = 50.52) than non-habituators (*M* = 143.03 seconds, *SD* = 68.67), $F(1, 14) = 4.15, p < .07, d' = .90$. This finding is startling given that habituators viewed fewer habituation trials (*M* = 6.86, *SD*= .90) than non-habituators (who viewed eight habituation trials without meeting the habituation criterion). There were no differences between the two groups of infants with regard to average looking over the last two viewed habituation trials ($F < 1.1$, *ns*).

Two Fisher's exact tests were used to examine whether infants in the four habituation conditions differed in the frequency with which they met the habituation criterion before moving to test trials. The first analysis compared frequencies between infants who saw the actor give the object to the person on her left in the habituation phase (5 met criterion, 3 did not) to infants who saw the actor give the object to the person on her right (2 met criterion, 6 did not). This analysis revealed no significant difference between infants in the two conditions, $p = .31$. A similar analysis compared frequencies between infants who saw the male receive the object in the habituation phase (5 met criterion, 3 did not) and infants who saw the female receive the object (2 met criterion, 6 did not). This analysis revealed no differences between infants in the two conditions, $p = .31$.

Test Phase Analyses

The question of interest in Experiment 3 was whether infants would show increased attention to new recipient/old location test trials relative to old recipient/new location trials. Such a pattern would suggest that infants encoded the gist of the action shown in habituation as involving a social exchange, rather than a directional push of an object to a particular spatial location.

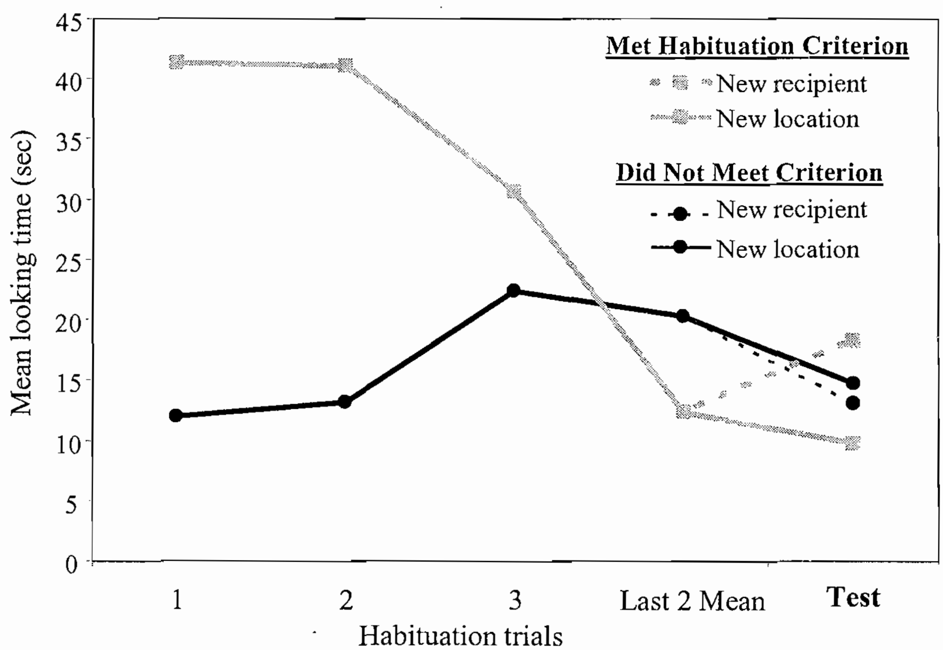


Figure 16: Ten- to 12-month-old infants' mean looking times (in seconds) to the first three habituation trials, the mean of the last two viewed habituation trials, and each test trial type in Experiment 4. The lines with square joints represent the data from infants who met the habituation criterion; the lines with circle joints represent the data from infants who did not meet the habituation criterion.

ANOVAs on infants' looking times toward test stimuli revealed that none of the following factors had a significant effect on test performance: sex, test trial pair, which gist-type of test trial was seen first, whether the male or female received the object in habituation, or whether the object was given to the recipient on the actor's left or right. Subsequent analyses collapsed across these factors.

Preliminary analyses revealed an unexpected result: whether infants reached the habituation criterion had a significant effect on the infants' test performance (but did not interact with any independent variables). Therefore, the data were analyzed using a repeated measures ANOVA with test gist-type (new recipient vs. new location) as the within-subjects factor and whether or not infants met the habituation criterion as the between subject factor (7 met criterion, 9 did not). In this analysis, the predicted main effect of test gist-type was marginally significant, $F(1, 14) = 3.48, p < .09, d' = .40$ (see Figure 17). Infants looked longer at new recipient trials ($M = 15.32$, $SD = 6.68$) than at new location trials ($M = 12.48$, $SD = 5.53$). However, there was a significant interaction between whether infants met the habituation criterion and test gist-type, $F(1, 14) = 8.19$, $p < .05$. As suggested by Figures 16 and 17, habituators appeared to look longer at new recipient trials, whereas non- habituators did not prefer either test trial type.

The significant effect of reaching the habituation criterion suggests that the results from the ANOVA above may be misleading and that a simple effects analysis would be a more appropriate analytic approach. Post-hoc directional simple effects analyses—controlling for multiple comparisons by setting family-wise α at 0.5 with a Bonferroni correction—were therefore used to test for the effect separately within the groups of habituators and the non-habituators. Habituators looked significantly longer on new recipient test trials ($M = 18.22$ seconds, $SD = 7.62$) than on new location test trials ($M = 9.66$ seconds, $SD = 4.29$), $F(1, 14) = 5.17, p < .05, d' = 1.11$. Non- habituators did not look significantly longer at either test trial type (new recipient $M = 13.06$, $SD = 5.50$; new location $M = 14.68$, $SD = 5.58$; $F < 1$, *ns*). A Fisher's exact test confirmed these analyses; habituators were more likely to look longer at new recipient trials (all seven habituators looked longer at new recipient trials), whereas non- habituators were more likely to prefer new path trials ($n = 6$) than new recipient trials ($n = 3$), $p = .01$.

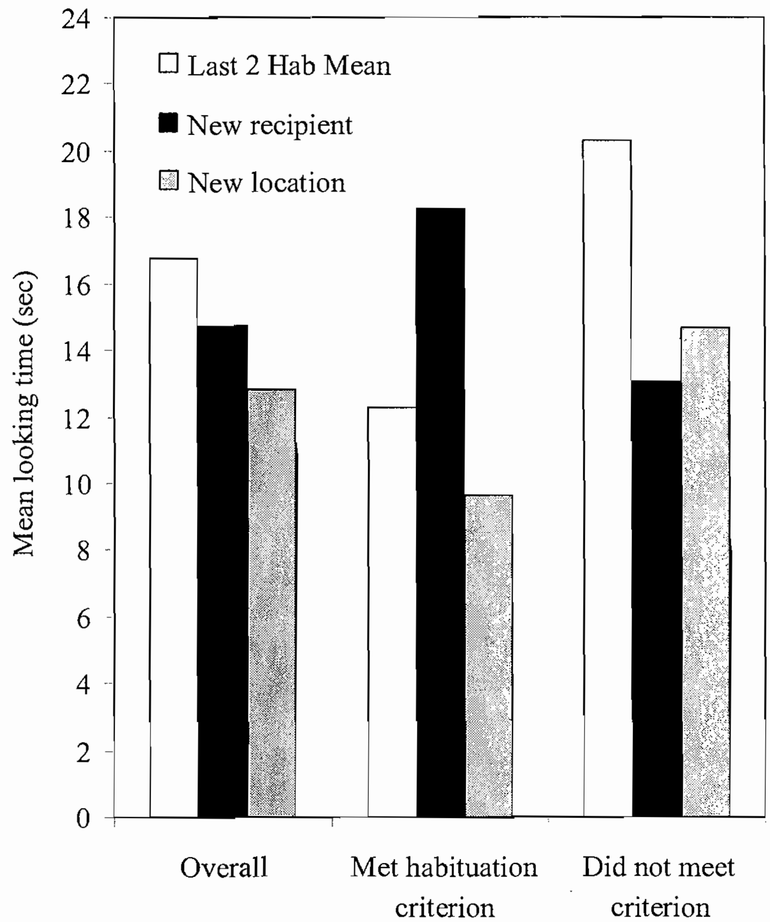


Figure 17: Ten- to 12-month-old infants' mean looking times (in seconds) to the mean of last two viewed habituation trials and each test trial type in Experiment 4. Data are presented separately for the entire sample, infants who met the habituation criterion, and infants who did not meet the habituation criterion.

Looking Time Recovery Analyses

Directional paired *t*-tests examined whether infants selectively recovered looking time to new recipient test trials. These analyses were performed separately on the group that met the habituation criterion and the group that did not. Habituators looked significantly longer at new recipient trials ($M = 18.22$, $SD = 7.62$) compared to the average of the last two viewed habituation trials ($M = 12.30$, $SD = 4.64$), $t(6) = 4.90$, $p < .005$, $d' = .67$. In contrast, there was a significant decrease in looking to new path test trials ($M = 9.65$, $SD = 4.29$), $t(6) = -2.07$, $p < .05$, $d' = .52$. Non-habituators had non-significant decreases to both new recipient test trials ($M = 13.07$, $SD = 5.57$) and new location test trials ($M = 14.68$, $SD = 5.58$), compared to the last two habituation trials ($M = 20.02$, $SD = 13.23$), *t*s < 1.2, *ns*, *d*s < .45.

Discussion

In Experiment 4, infants saw an actor give an object to one of two people; in question was whether infants would construe the gist of the event as a directional push or as a dyadic interaction. Although, overall, infants did not show any systematic tendency to construe the action in either of these ways, there was a stark difference between the looking preferences of infants who reached the habituation criterion and those who did not. Infants who reached the habituation criterion looked longer during the habituation phase and subsequently preferred to look at new recipient test trials than at new location test trials, selectively dishabituating to the former. This pattern suggests that these infants processed the action at the more abstract of the two possible gist levels, as evidenced by their apparent ability to encode the identity of the recipient in the object transfer event, his or her role in the interaction, and keying in on the change to one of the participants in the interaction as representing a change in gist. Infants who did not reach the habituation criterion did not prefer either test trial type.

The observed difference between infants who did and did not reach the habituation criterion is concordant with the observations of theorists who argue that whether infants meet the criterion can result in predicable changes in looking time patterns to test trials (e.g., Cohen, 2004; Hunter & Ames, 1988). As Cohen and Cashon (2006) note, infants who do not habituate are likely to show familiarity preferences at test, and the probability of that happening rises when stimulus complexity increases. The stimuli in the current study were quite complex when compared to other studies of infant social cognition that often show infants animated shapes against a simple background (Gergely et al., 1995; Kuhlmeier et al., 2003) or just the arms of the actor (Woodward, 1998). Very few experiments involving infants 12-months-of-age or younger have shown infants dyadic interactions between two people (e.g., Experiments 1, 2a, and 2b in this dissertation; Sodian et al., 2004), and fewer yet (e.g., Robertson & Suci, 1980) have shown infants events involving three people. Given this complexity, it is not surprising that infants who were more engaged throughout the habituation phase and who eventually reached the habituation criterion showed a strong preference for test actions depicting a change in recipient, whereas infants who were less engaged and failed to habituate did not show any clear patterns at test. The complexity of the actions shown in Experiment 4 relative to Experiments 1, 2a, and 2b may also explain why meeting the habituation criterion was not a factor in the previous experiments, but was a critical factor in the current experiment.

The current findings could shed light on the results from Experiments 1 and 2a. In the habituation phase of those studies, infants saw an actor either push a glass toward another person or pull it toward herself. At test, infants tended to look longer when the actor contacted the object in such a way that would only allow her to move the glass in the opposite direction as seen in habituation. That infants showed this pattern in the face of substantial perceptual variability between the habituation and test actions attests to the their ability to process action for gist. The precise nature of that gist, however, was unclear. Infants could have interpreted the actions in terms of either the direction of motion (i.e., *push* versus *pull*) or the nature of the social interaction (i.e., *give* versus *take*). The current experiment suggests that not only are 10- to 12-month-old infants capable of extracting the gist of a dyadic interaction, but also that, at least when these processing strategies would predict conflicting construals of the test action, 10- to 12-month-old infants prefer to categorize the action on the basis of the more abstract gist (cf., Cohen & Cashon, 2006; Cohen et al., 2002). Based on these findings, one could speculate that to the degree that infants saw the actions in Experiments 1 and 2a as social interactions, they processed the gist of the actions in genuinely dyadic terms—i.e., as *give* versus *take*. Of course, these two gist-level construals are not mutually exclusive; infants could have simultaneously interpreted the gist at multiple levels. However, what the current findings demonstrate is that 10- to 12-month-old infants are capable of representing the more abstract of those two gist-related levels, and privilege that representation when categorizing action exemplars.

If this interpretation is correct, and infants are inclined to process object transfer events in genuinely dyadic terms, then the current findings are the first to my knowledge to demonstrate this skill within the first year of life. Research investigating infants' understanding of dyadic human actions involving one person giving an object to a recipient has often focused on infants in the second year of life (e.g., Golinkoff & Kerr, 1978; Robertson & Suci, 1980; Scherf & Tabb, 2005). Clearly, however, any conclusions regarding infants' construal of the dyadic nature of these interactions must be tentative. It is not clear, for instance, that infants encoded the fact that the recipient was human; it is possible that infants would show the same pattern of results if they saw an actor push the toy to one of two salient objects. The argument that infants' representation of the action was genuinely social would rest on findings that infants only encoded the identity of the recipient if the recipient was a human rather than an inert object or mechanical claw. Nonetheless, the hypothesis that 10- to 12-month-old infants are capable of representing human interaction in dyadic terms is consistent with a growing body of research suggesting that infants of this age experience rapid and profound changes in their social cognitive skills (Csibra et al., 2003; Gergely et al., 1995; Kuhlmeier et al., 2003; Meltzoff, 2007; Moore & Corkum, 1994; Povinelli, 2001; Sommerville et al., in press; Tomasello, 1999; Tomasello, Carpenter, Call, Behne, & Moll, 2005; Tomasello & Haberl, 2003; Woodward, 2003; Woodward & Guajardo, 2002). The current findings therefore provide additional weight to the argument that infants in previous experiments were capable of interpreting the actions at the relatively rich level of gist that incorporates the dyadic nature of the interaction.

The findings from Experiment 4 demonstrate that infants as young as 10- to 12-months-of-age are skilled at glossing over substantial variability in surface detail when processing human action. In order to construe new location test actions as similar in gist to the habituation action, and to construe new recipient test trials as dissimilar in gist, infants had to gloss over changes to the number of hands the actor used to make contact with the object, the absence of any eye-contact in test trials that would help infants establish the likely recipient, the path of arm movement, the nature of the hand configuration at the moment of contact, and the absence of object motion. Although the test phase of studies in infant social cognition are always perceptually distinct, the differences tend to comparatively small (e.g., changes to the path of motion, Bíró & Leslie, 2007; Csibra, 2008; Woodward, 1999) to the differences in the current experiment. Despite the multitude of changes to surface motion details, infants were nonetheless able to infer the likely recipient of the object in test trials, home in on the gist of the dyadic interaction, and compare it with the gist of action observed in habituation trials. Due to the experimental design, infants could have glossed over changes to the person sitting on a given side of the table in order to process the gist of the action as a directional push, or they could have glossed over changes to the spatial location of the object motion in order to process the gist of the action as a dyadic interaction. The current findings indicate that infants used the latter strategy, which points to their cognitive flexibility in recognizing which features of an action display are critical for identifying the gist, and also their tendency to favor more abstract gist-level representations over relatively less abstract gist-level representations.

CHAPTER VII

GENERAL DISCUSSION

Overview

In order to make sense out of evanescent, often frenetic, and perceptually variable displays of human action, infants must be able to efficiently attend to appropriate surface details while glossing over some aspects of the motion stream, all the while attempting to identify the gist of the action. The key goal of the experiments reported here was to examine 5- to 7- and 10- to 12-month-old infants' ability to extract the gist of observed and inferred actions, to gloss over the substantial surface-level perceptual variability between multiple action exemplars, and to categorize actions based on similarities in gist. It was predicted that infants in the older group would demonstrate gist-level processing when observing several types of action. As predicted, across four experiments—with the exception of one condition in Experiment 2a and infants who did not habituate in Experiment 3—10- to 12-month-old infants routinely looked longer at test trials in which the gist of an inferred action was inconsistent with the gist of an action shown in the habituation phase than at test trials in which the inferred gist was consistent with the gist of actions shown in habituation. This effect was observed despite the fact that the actions depicted in both gist-consistent and gist-inconsistent test trials were equally perceptually dissimilar to the actions depicted in the habituation phase. After reviewing the results from each of the experiments in more detail and drawing some conclusions regarding what they indicate about gist-level processing, I will discuss some contributions these findings make to the literature on infants' social cognition, and end by outlining directions for future research.

Summary of Findings

Experiment 1 examined whether 5- to 7- and 10- to 12-month-old infants could process pushing and pulling actions for gist. During the habituation phase, half of the infants in each age group saw an actor grasp a glass and push it to another person, and the other half of infants saw the actor grasp the glass and pull it toward herself. At test, all infants saw trials in which the actor contacted the glass with a perceptually distinct hand configuration that would enable her to push—but not pull—the glass, as well as other trials in which the actor contacted the glass with a perceptually distinct hand configuration that would enable her to pull—but not push—the glass. In neither test video did the actor move the glass. Ten- to 12-month-old infants who saw the actor push the glass in the habituation phase looked longer at the first presentation of test trials in which the actor was poised to pull the glass toward herself, whereas 10- to 12-month-old infants who saw the pull event in habituation looked longer at the first presentation of test trials in which the actor was poised to push the glass away from herself and toward another person. These findings indicate that 10- to 12-month-old infants are able to extract the gist of both observed and inferred actions and, despite perceptual dissimilarities between the various actions, categorize them on the basis of a shared gist.

In contrast, among the 5- to 7-month-old sample, infants who saw the push event in habituation showed similar patterns as the older infants, whereas infants who saw the pull event in habituation did not prefer either test trial type. These findings suggest that gist-level action processing strategies may be online by the sixth month of life.

Experiment 2a attempted to replicate the findings from the older infants in Experiment 1 while introducing three methodological changes—playing background music, decreasing the delay between action presentations within a trial, and instituting a three-second still-frame pause at the end of test trials—all of which were aimed at increasing 11- to 12-month-old infants' visual attention throughout the experiment. Results from infants in the observed-pull condition replicated findings from Experiment 1, but infants in the observed-push condition did not look longer at either test trial type. One possibility for this pattern is that observed-push habituation trials depicted an action with a continuous, unidirectional motion trajectory, leading infants who saw that action during the habituation phase to be surprised by both test trials because they introduced a lengthy pause in the middle of the motion stream.

Experiment 2b attempted to replicate the findings from the younger infants in Experiment 1 using a methodology nearly identical to that used in Experiment 2a. However, due to the possibility that the three-second pause differentially affected perceptual processing between infants in the two habituation conditions, test trials were followed by a one-second still-frame pause as in Experiment 1. Despite this methodological improvement, results from this experiment were inconclusive, as infants in the observed-push condition looked significantly longer throughout the entire experiment than infants in the observed-pull condition. No differences were seen in infants' looking to the two test trial types.

Experiment 3 addressed the question of whether or not processing for gist is a strategy that 10- to 12-month-old infants use when interpreting actions involving other objects and body positions than those involved in the prior studies. Half of the infants in Experiment 3 saw an actor open an oven door in the habituation phase, and half saw the actor close the door. In test, all infants saw the actor make contact with the door in a manner that would enable him to open—but not close—the door, and other trials in which the contact was made in a manner that would enable him to close—but not open—the door. Infants who saw the open event in habituation looked longer at test trials in which the actor was poised to close the door, whereas infants who saw the close event in habituation looked longer at test trials in which the actor was poised to open the door. As in the preceding experiments, infants had to make a genuinely generative inference based on a perceptually novel act, extract the gist of the inferred action, and categorize the gist of the inferred act along with the gist of the observed action observed during the habituation phase. These results suggest that infants process opening and closing actions—at least those performed by pushing or pulling a door—for gist, and they represent a first step in examining whether processing for gist is a general strategy that infants use when interpreting human action.

Experiment 4 examined whether 10- to 12-month-olds can process action for gist when several motion parameters beyond hand configuration and the absence of object motion varied between habituation and test action exemplars. Moreover, Experiment 4 examined whether infants prefer to categorize actions on the basis of a more abstract level of gist relative to a less abstract level of gist. Infants in Experiment 4 saw an actor give an object to one of two people, who were seated on either side of a table. At test, the recipient and an observer were seated on opposite sides of the table as they were seated in habituation trials. On alternating test trials, the actor either contacted the object using a novel hand configuration as if to push it to a new location, but to the same recipient, or contacted the object as if to push it to a new recipient who was on the same side of the table as where the object was moved in habituation trials. Infants who reached the habituation criterion looked longer at test trials in which the actor contacted the object as if to push it to a new recipient. Infants who did not reach the habituation criterion did not show a preference between the two test trial types. The findings from habituators corroborated findings from the previous experiments—that is, that infants can infer future actions, can gloss over substantial differences in perceptual information between action exemplars, and can categorize actions based on shared gist—and extended those findings by demonstrating infants' ability to gloss over changes to several motion parameters and to categorize action at a more abstract level of gist which incorporates the actor, object motion, and the recipient of the object. Furthermore, these findings provide suggestive evidence that at least some infants process action in terms of the specific individuals involved in a dyadic interaction.

The Nature and Development of Processing for Gist

In the introduction to this dissertation, processing for gist was proposed to comprise at least three components: (A) identifying the functional affordance—or *gist*—of the action; (B) glossing over gist-irrelevant surface-level features of the motion stream (except when the gist is not easily identified, in which case the observer once again bases his or her interpretation of the action on surface details); and (C) categorizing both observed and inferred action based on the more abstract gist level rather than on low-level surface features.

Results from four experiments provide support for the hypothesis that by the end of the first year of life, infants process action in concordance with each of these components. In Experiments 1 and 3, 10- to 12-month-old infants' construal of test events was driven by the action they had seen in habituation. Only actions that provided the actor with a functional affordance that was dissimilar to the action seen in habituation elicited increased visual attention, thus supporting (A). Looking time to a single test video appeared to be driven by its gist-level similarity to the actions shown in habituation, despite substantial perceptual variability between the actions, thus supporting (B). That infants showed this preference rather than recovering attention to each perceptually novel test stimulus provides support for (C). These findings were equally true for each of the test events in each of the conditions in Experiments 1 and 4. Similar evidence was provided by infants in the observed-pull condition of Experiment 2a and habituators in Experiment 4. In fact, 10- to 12-month-old infants throughout all four experiments showed the predicted pattern, save two exceptions: infants in the observed-push condition in Experiment 2a and non-habituators in Experiment 4. Speculations as to what each of these exceptions may indicate about the nature and development of gist-related processing are included in the future directions section below.

Tentative support for a richer interpretation of (C) comes from Experiment 4. Infants could have construed the actions at two levels of gist. At the less abstract level, infants may have glossed over changes to the hand configuration and motion trajectory, focusing instead on the spatial location to which the actor moved the object. At the more abstract level, they may have also encoded each partner in the dyadic interaction. When these two gist-related construals of an action were possible, infants who habituated appeared to give encoding preference to the more abstract of the two gist levels for categorizing the actions (cf., Cohen et al., 2002). On this richer interpretation of (C), infants' preference for gist-level representations when categorizing actions would not necessarily be due to a distinction between perceptual and gist-level analyses, *per se*, but rather to the privileged status of more abstract representations over less abstract representations.

Conclusions regarding this richer interpretation of (C), however, are tentative due to a caveat regarding the presence of this effect in only half of the sample of Experiment 4. Unlike in the other experiments, which suggest that infants at the end of the first year typically process action for gist, infants in Experiment 4 were divided into two groups. The first group comprised the [roughly] half of infants who were highly attentive throughout the habituation phase, met the habituation criterion, and universally appeared to encode the dyadic nature of the object transfer event. The second group comprised the other half of infants who were far less attentive in habituation, did not meet the habituation criterion, and showed no preference for either test trial type. This caveat notwithstanding, the differences between infants who did and did not habituate are predictable in light of proposals regarding domain-general information processing mechanisms (Cohen & Cashon, 2006). As a stimulus increases in complexity, as was the case with the actions depicted in Experiment 4, infants are more likely to become overloaded with information, causing them to regress to a lower level of analysis. It is not surprising, therefore, that only the infants who appeared to show heightened attention to the actions were able to move to more abstract levels of analysis. Whether this reflects individual differences in gist-level processing, or whether it simply reflects the amount of attention devoted to habituation trials, remains a question for future research. In the future directions section below, I return to this question regarding the relevance of the current work to research on individual differences in social cognition.

The above discussion begs the ontogenetic question: what are the developmental mechanisms that allow 10- to 12-month-old infants to process action for gist with a sophistication—or at least a consistency—that is lacking in 5- to 7-month-old infants? If the description of gist-related processing offered above is correct, and gist-level processing differs from purely surface-level processing in the level of abstraction needed to form the representation, then it is unlikely that the locus of the developmental change lies in a newfound ability to form abstractions. After all, research on infant categorization has shown that 3-month-olds are capable of forming abstract object categories (French et al., 2004). One possible explanation for this developmental progression is that domain general changes in infants' information processing strategies enable them to process additional dimensions of perceptual input, which then leads to the creation of categories that incorporate more elements. Infants—as well as older children—will be better able to form abstract representations of human behavior as they are increasingly able to hold more information in mind (Halford, 1982) and process that information quickly and efficiently (Carlson, Mandell, & Williams, 2004; Case, 1992), particularly in cases where the event spans greater periods of time (Halford, 1993). These skills would undoubtedly help infants attend to a multitude of action characteristics. They would be better able to monitor whether joint attention has been established between two or more people, encode the identity of the actor, monitor her hand configuration, use that hand configuration to predict the direction of object motion, encode the identity of the recipient and monitor his interaction with the object, all the while monitoring the relationships between these elements and attempting to identify the gist of the action.

This proposal is intended to complement, rather than replace, current theories regarding developmental mechanisms. It could still be the case—and the mounting evidence suggests that it is—that infants' own sensorimotor experience drives changes in their ability to interpret other people's actions via a "like me" mapping system (Meltzoff, 2007; Piaget, 1952; Sommerville et al., 2005; Tomasello, 1999; Tomasello et al., 2005). In other words, domain-general developments need not preclude domain-specific ones. Identifying the role of information processing advances in enabling the creation of more abstract action representations simply provides an explanation for why older infants may be able more efficiently sort through the perceptual input (Halford, 1993) and generate abstract, gist-level representations.

Contributions

The package of results presented in the current experiments adds to the literature on infant social cognition. Building on previous research that has demonstrated infants' robust ability to gloss over some perceptual aspects of a motion display, such as the path of a reach (Woodward, 1998; Phillips & Wellman, 2005) or the path of self-propelled motion toward a goal location (Gergely et al., 1995), the current research suggests that infants can contend with changes to the hand configuration used to contact objects, to the presence of object motion (even when the gist of the action involves moving an object), and to the location toward which an object will be pushed in order to reach a recipient (Experiment 4). Furthermore, by demonstrating that infants process action for gist across three sets of stimuli comprising two action comparisons (object transfer and opening versus closing a door), the results presented in this dissertation make a compelling case for gist-level processing as a skill that infants generally employ when interpreting human action.

Beyond simply demonstrating that infants can gloss over more types of action parameters than previously demonstrated, these experiments also provide evidence that infants can gloss over some surface-level motion details in an entirely different way relative to what has previously been demonstrated. In prior research, care was taken to ensure that perceptual components critical for action identification were held constant between habituation and test. For instance, in research on infants' understanding of grasps (Buresh & Woodward, 2007; Sommerville & Woodward, 2005a; Todd & Smith, 2008; Woodward, 1998), the configuration of the hand while grasping was identical between habituation and test actions. In research on infants' understanding of self-propelled human motion toward a goal state (Kamewari et al., 2005; Phillips & Wellman, 2005; Sodian et al., 2004), the beginning and ending of actions were identical in habituation and test actions; only the path taken was changed. In all of this research, perceptual features that allowed the observer to categorize the action were held constant throughout the study. Grasps were always clearly grasps, and infants' task was to assess which components of clearly-identified grasps were critical and which could be glossed over—e.g., the object grasped versus the location in which the grasping took place.

In contrast, infants in the current research did not have the benefit of consistent surface-level motion details—e.g., hand configuration and object motion—that would allow them to easily recognize that the actions in test were the same as habituation. Pushing events in habituation looked little like the pushing events shown in test. Based on an analysis that utilized surface-level details exclusively, the two test events would be seen as closer to each other than to the habituation action. For instance, both test actions in Experiment 1 depicted contact with the glass using an angled palm, both of which would be seen as equally dissimilar to the habituation event in which the actor grasped the glass using a cupping hand configuration. Thus, a purely surface-level perceptual analysis of habituation and test actions would not be sufficient to group those actions in a single category. Unlike in previous research where the perceptual similarities between habituation and test actions allowed easy categorization—e.g., every grasp was clearly a grasp—infants in the current experiments had to rely on their ability to interpret hand configuration cues as potentiating some motions but not others, infer those actions, form a gist-based representation of the inferred action, and only *then* be able to categorize habituation and test actions together at the gist level. In other words, whereas previous research has pointed to infants' ability to categorize actions and then interpret them, the current research demonstrates that infants can, in a sense, interpret actions and then categorize them.

The current experiments also make gains in promoting ecological validity within the literature on infant social cognition. In the interest of experimental control, many previous experiments have used computer generated shapes that appear agentive (Heider & Simmel, 1944) in order to construct the action stimuli shown to infants (Gergely et al., 1995; Kuhlmeier, Wynn, & Bloom, 2003). When human action has been shown, great lengths have been taken to simplify the display (but see Baldwin et al., 2001, for a notable exception). Often, only the actor's arm is visible (Woodward, 1998). When the actor is shown, it is often from the waist-up, seated in front of a blank wall (Phillips & Wellman, 2005; Sommerville & Woodward, 2005a). In most of this research that has used exemplars of human action, infants' looking time was measured to the statically-presented endpoint of an action (e.g., Woodward 1998). Simplified displays of human action, some features of which were also employed in some of the experiments reported here, are often necessary to ensure that infants' attention is drawn toward the relevant information.

Despite the necessity of experimental control, the simplified nature of the stimuli used in these studies raises questions about whether infants are capable of using the processing skills uncovered by laboratory tests when analyzing chaotic, perceptually variable, and evanescent human action in the real world. Therefore, it is critical that some research examines infants' processing with more ecologically valid stimuli. Throughout the current research, steps in this direction were taken. For instance, in all of the experiments reported in this dissertation, infants' looking times were measured to ongoing human action rather than to static displays. If infants are to successfully interpret real-world action, they must be able to interpret ongoing action; an action processing mechanism that could only operate on displays of statically-presented endstates would have a difficult time making sense out of evanescent human action.

The complexity of the events was also increased by presenting infants with actions carried out in environments containing visual clutter (Experiment 3), interactions between two people (Experiments 1, 2a, 2b), or a dyadic interaction between two of three people (Experiment 4). Considering the complexity of real-world actions, the stimuli used throughout the experiments in this dissertation increase the ecological validity of the research. This increase in ecological validity did not come at the cost of experimental control, however, as the use of videotaped stimuli allowed several perceptual features to be strictly controlled. Within each experiment, the habituation stimuli used in each condition were always equal in overall length and also in the relative amount of time it took for each action component to be completed; the same was true when comparing test stimuli within an experiment. The balance of ecological validity and experimental control throughout the experiments in this dissertation allows for increased confidence in extrapolating the findings from these laboratory tasks to the action processing strategies infants use in their everyday lives.

Speculations and Future Directions

Several promising avenues for future research grow out of the results reported here. Infants in the current set of experiments displayed an ability to categorize actions at the gist level by the end of the first year. These findings raise interesting questions about the development of a system that comprises multiple gist-related levels, as there clearly are many potential abstract levels on which an observer can categorize an action. Observers can form hierarchies that comprise several levels of goals and sub-goals that are involved in task completion (Hard et al., 2006; Zacks & Swallow, 2007; Zacks & Tversky, 2001; Zacks et al., 2001) and identify some of those action components as more critical to the task than other components (Jackendoff, 2007; Reed, Montgomery, Schwartz, Palmer, & Pittenger, 1992). Observers are also able to make inferences about the actor's goals (Woodward, 1998; Woodward & Sommerville, 2000) and intentions (Carpenter, Akhtar, & Tomasello, 1998; Meltzoff, 1995) and even traits that may have motivated the behavior (Holbrook, 2007; Malle, 2004). Despite the processing skills displayed by infants in the current set of experiments, research has shown that even older children fall short in understanding many of these more abstract concepts, such as the representational mental states of others (Wimmer & Perner, 1983). A fruitful topic for future longitudinal research will be to investigate whether the abstract processing skills documented in the current research are precursors to these later developments in representing action at abstract levels (cf., Woodward et al., 2001).

Although very little longitudinal work has directly examined such questions regarding the continuity of infant social cognition, recent research by Wellman and colleagues (Wellman, Lopez-Duran, LaBounty, & Hamilton, 2008; Wellman, Phillips, Dunphy-Lelii, & LaLonde, 2004) has begun to look at whether infants' social cognitive prowess, as measured by looking-time techniques, predicts theory of mind developments in preschool. Some of the current findings may provide solutions for methodological issues that have proved problematic in these previous studies. For instance, in Wellman and colleagues' (2004) attempt to see if infant looking time measures predicted preschool social cognition, the same 14-month-old infants who participated in Phillips, Wellman, and Spelke's (2002) study were given a battery of theory of mind tests at 4-years-of-age. Unfortunately, there was minimal variation within the looking time data in the Phillips et al. research as the majority of 14-month-old infants behaved similarly well in the looking time task. Wellman et al. (2004) did not find any relationship between children's performance in the test phase of the infant looking time task and the theory of mind tests when the children were preschool age, a null finding that they hypothesized may have been due to the lack of variation in the infant looking time data.

In a more recent study, Wellman and colleagues (2008) used a group of 10- to 12-month-old infants who were not expected to perform as well on the social cognition looking time task based on results from Phillips et al. (2002). The authors predicted that the data from these younger infants would provide greater variability with which to predict future performance on the theory of mind tasks. This manipulation was partially successful, as looking time patterns in the habituation phase were predictive of developments in theory of mind, but interestingly, performance at test was not. Thus, while those data suggest that attention to social displays predicts later social cognitive developments, critical questions regarding the stability of the quality of their action processing skills, and the lack of predictive power from test performance, remain puzzlingly unclear. The findings from Experiment 4 may be useful in addressing this confusion in future research. That habituators and non-habituators in Experiment 3 displayed stark differences throughout the habituation and test phases suggests that the methodology tapped in to substantive processing variation between infants. To my knowledge, no other study in the literature on infant action processing has found such a clear, data-driven method for breaking infants into two groups that differ on displayed social-cognitive skills. Therefore, by using a task such as that employed in Experiment 3, it would be possible to test for individual differences using a between-subjects comparison rather than a correlational one, which might avoid some of the problems due to restricted variability in infant looking-time measures.

Results from the current experiments demonstrate infants' gist-level processing of actions involving object transfer as well as opening and closing a door. That infants have demonstrated this ability across multiple action categories strengthens the argument that gist-level processing is a strategy infants generally use when processing action. Future research should attempt to further delineate actions for which infants demonstrate gist-level processing. For example, would infants show similar skills when observing each step in a means-end sequence (Sommerville & Woodward, 2005a; Woodward & Sommerville, 2000)? Given the wide range of actions infants observe, research identifying which action types infants can process for gist at which ages will provide important evidence on the development of social cognition.

Another possible direction to take this research is to investigate the relation between surface-level processing and gist processing. Two unexpected findings suggest this as a fruitful direction for future research. It is important to note that because each of these findings was unexpected, the interpretation I offer here is just one of many possible post-hoc accounts. Nonetheless, these findings may open up interesting lines of research in that they converge on the conclusion that attention to surface detail is an important component of gist-level processing. After a review of each of these findings, I discuss what those findings may indicate about the role of bottom-up processing mechanisms and how this line of research would enrich the field of infant social cognition.

The first suggestive finding comes from 5- to 7-month-old infants in Experiment 1, who were predicted to show elevated attention to both test trial types, which would be indicative of sensitivity to changes in the surface-level perceptual components of the motion stream. Surprisingly, infants in the observed-push condition instead displayed a pattern indicative of gist-level processing, looking longer at inferred-pull trials than inferred-push trials. Infants in the observed-pull condition showed the predicted pattern of increased attention to both test trial types. A key difference between the actions shown in the habituation phase of these two conditions is in motion continuity: in the push action, the actor's arm movements were continuous—all of the motion moved away from her body—whereas in the pull action, half of the motion moved away from her body as she reached for the glass and half of the motion was toward her body as she retrieved it. Five- to 7-month-old infants in the observed-pull condition may have had a difficult time construing the motion away from the body as the means to the more important end—i.e., pulling—while identifying the second action component involving a motion trajectory toward the body as more important to gist-related processing. Compared with this bidirectional pulling action, infants in the observed-push condition may have had an easier time processing the continuous, unidirectional motion stream depicted in the pushing action. If this explanation of the condition differences in test performance is correct, it would suggest that infants are continually attentive to the available perceptual information, and that when infants cannot sort through the perceptual information in an efficient manner in order to identify the key action components (cf., Reed et al., 1992), they are unable to form gist-level representations.

The unexpected condition differences among 11- to 12-month-old infants in Experiment 2a likewise point to the importance of bottom-up processing when extracting the gist of human action. This explanation also points to the differential perceptual complexity of the actions shown in the habituation phase: the pushing actions were unidirectional and continuous, whereas the pulling actions were bidirectional and discontinuous. Although neither habituation action contained an actual pause in the motion stream, the change in motion direction in the pulling action introduced a discontinuity and may have led infants who saw that action in habituation to expect an interruption to the outward trajectory of the hand, while infants who saw the pushing action would not expect an interruption. In the test trials of Experiment 2a, the actor paused for three seconds after making contact with the object. On a purely surface-level analysis of the action, the presence of a three-second discontinuity in the motion stream would seem novel to infants who had seen the continuous pushing action in the habituation phase. In line with this observation, infants in the observed-push condition did not prefer either test trial type, suggesting that the introduction of a lengthy pause in both test trials struck them as noteworthy. In contrast, among infants in the observed-pull condition, for whom a motion discontinuity was familiar, the lengthy pause did not interfere with their gist-level processing, as evidenced by their longer looking at inferred-push test trials than inferred-pull test trials. This effect may not have been present in Experiment 1 due to the relatively short one-second pause at the end of still frame trials in that experiment.

Together, the findings from 5- to 7-month-old infants in Experiment 1 and the findings from 11- to 12-month-old infants in Experiment 2a suggest infants are continually attentive to surface-level details of the motion stream even as they attempt to form gist-based representations of the action. Put another way, infants seem to exploit surface properties to inform a gist-level analysis. When the available perceptual information is too complex, infants—and adults as well—may not be able to achieve a gist-level analysis, and contradictory perceptual information (e.g., a discontinuity in the motion stream is introduced where it would be unexpected) may actively impede infants' construction of a gist-level interpretation of action.

Increased attention to the important role of bottom-up mechanisms would fill a gap in the extant literature, which has traditionally looked to other factors for ontogenetic accounts of social cognition. Specifically, a lively current debate in the literature centers on whether social cognitive development is driven by action experience and sensorimotor developments (Meltzoff, 2007; Rochat & Striano, 1998; Rochat, 2001; Sommerville et al., in press; Sommerville & Woodward, 2005b; Sommerville et al., 2005; Tomasello, 1999), or whether such advances reflect the maturation of abstract action processing principles (Csibra et al., 2003; Gergely & Csibra, 2003; Johnson, 2003; Király et al., 2003) and domain specific modules (Leslie, Friedman, & German, 2004; Premack & Premack, 1997). While few, if any, of these proposals would deny the importance of perceptual processing, the role of bottom-up processing mechanisms has not been in the forefront of this debate. In much of the previous research, surface-level complexity of the motion stream was treated as a source of noise obscuring researchers' ability to answer other questions. As such, perceptual motion features were controlled either by strictly dictating the pace of human action and the precise movements involved, or by omitting human actors entirely in favor of simple, easily controlled computerized shapes. Of course, given that the question of interest in this research was related to infants' understanding of goals or principles that underlie human action, such rigorous experimental control of perceptual complexity has been necessary.

However, when one takes a broader view of infant social cognition and asks how infants make sense out of everyday human action, one must ask how infants take the available information, fraught with perceptual noise though it may be, and process it for gist. Three findings from this dissertation all point to the importance of bottom-up processing in forming gist-level representations of action: (1) 5- to 7-month-old infants in Experiment 1 demonstrated gist-level processing for pushing actions only, (2) there were condition differences in test performance among the 11- to 12-month-old infants in Experiment 2a, and (3) when complex stimuli were presented to 11- to 12-month-old infants in Experiment 3, habituators and non-habituators performed differently. Each of these findings suggests that bottom-up processing of surface-level motion details can influence infants' ability to process action for gist (see also Carlson, Mandell et al., 2004; Carlson, Moses, & Claxton, 2004; and Moses, 2005, for similar proposals regarding the importance of domain-general processes to social cognition). This broad view of infant social cognition and the suggestive results from this dissertation both suggest that a productive direction for future research would be to probe how bottom-up and abstract processing mechanisms operate concurrently and in tandem (Baird & Baldwin, 2001; Baldwin, 2005; Povinelli, 2001; Tomasello, 1999).

Conclusion

Human action in everyday life varies based on the context, the objects involved, the position of the body in relation to the manipulated objects, and the degree to which an observer has visual access to each of these components. Faced with this variability, it is important that infants gloss over changes to surface-level perceptual features inherent in ongoing, evanescent human action in order to identify the meaning—or gist—of the action. The experiments presented in this dissertation demonstrate that by 10- to 12-

months-of-age, and possibly by 5- to 7-months-of-age, infants engage in gist-level processing of a range of human actions. These findings provide some of the first evidence of infants' ability to cope with the rampant perceptual variability inherent in human action and engender several promising directions for future research.

REFERENCES

Apple. (2005). iMovie (Version 5.0.2). Cupertino, CA.

Baird, J. A., & Baldwin, D. A. (2001). Making sense of human behavior: Action parsing and intentional inference. In B. F. Malle, L. J. Moses & D. A. Baldwin (Eds.), *Intentions and intentionality: Foundations of social cognition* (pp. 193-206). Cambridge, MA: MIT Press.

Baldwin, D. A. (2005). Discerning intentions: Characterizing the cognitive system at play. In B. D. Homer & C. S. Tamis-LeMonda (Eds.), *The development of social cognition and communication* (pp. 117-144). Mahwah, NJ: Lawrence Erlbaum Associates

Baldwin, D. A., Andersson, A., Saffran, J., & Meyer, M. (2007). Segmenting dynamic human action via statistical structure. *Cognition, 106*(3), 1382-1407.

Baldwin, D. A., Baird, J. A., Saylor, M. M., & Clark, A. M. (2001). Infants parse dynamic action. *Child Development, 72*(3), 708-718.

Baldwin, D. A., Olofson, E. L., Andersson, A., Craven, A., Loucks, J., Meyer, M. A., & Myhr, K. (in preparation). *Action extraction: Statistical learning promotes infants' discovery of segmental structure in dynamic human action.*

Bíró, S., & Leslie, A. M. (2007). Infants' perception of goal-directed actions: Development through cue-based bootstrapping. *Developmental Science, 10*(3), 379-398.

Bruner, J. S. (1957). Going beyond the information given. In *Contemporary Approaches to Cognition* (pp. 41-69). Cambridge, MA: Harvard University Press.

Buresh, J. S., & Woodward, A. L. (2007). Infants track action goals within and across agents. *Cognition, 104*(2), 287-314.

Carlson, S. M., Mandell, D. J., & Williams, L. (2004). Executive function and theory of mind: Stability and prediction from ages 2 to 3. *Developmental Psychology, 40*(6), 1105-1122.

Carlson, S. M., Moses, L. J., & Claxton, L. J. (2004). Individual differences in executive functioning and theory of mind: An investigation of inhibitory control and planning ability. *Journal of Experimental Child Psychology, 87*(4), 299-319.

Carpenter, M., Akhtar, N., & Tomasello, M. (1998). Fourteen- through 18-month-old infants differentially imitate intentional and accidental actions. *Infant Behavior & Development, 21*, 315-330.

Casasola, M., & Cohen, L. B. (2000). Infants' association of linguistic labels with causal actions. *Developmental Psychology, 36*(2), 155-168.

Case, R. (1992). A neo-Piagetian approach to the issue of cognitive generality and specificity. In R. Case (Ed.), *The mind's staircase: Exploring the conceptual underpinnings of children's thought and knowledge*. Hillsdale, NJ: Lawrence Earlbaum Associates.

Cohen, L. B. (2004). Uses and misuses of habituation and related preference paradigms. *Infant and Child Development, 13*(4), 349-352.

Cohen, L. B., Bradley, K. L., & Casasola, M. (1995). *Infants' ability to discriminate between pushing and pulling*. Poster presented at the meeting of the Society for Research in Child Development, Indianapolis.

Cohen, L. B., & Cashon, C. H. (2006). Infant Cognition. In W. Damon (Editor-in-Chief), R. M. Lerner, D. Kuhn & R. S. Siegler (Eds.), *Handbook of child psychology: Vol. 2. Cognition, perception, and language* (6th ed., pp. 214-251). New York: Wiley.

Cohen, L. B., Chaput, H. H., & Cashon, C. H. (2002). A constructivist model of infant cognition. *Cognitive Development, 17*(3-4), 1323-1343.

Csibra, G. (2008). Goal attribution to inanimate agents by 6.5-month-old infants. *Cognition, 107*(2), 705-717.

Csibra, G., Bíró, S., Koós, O., & Gergely, G. (2003). One-year-old infants use teleological representations of actions productively. *Cognitive Science, 27*(1), 111-133.

English, H., Welborn, E., & Killian, C. (1934). Studies in substance memorization. *Journal of General Psychology, 11*, 233-260.

Fillenbaum, S. (1966). Memory for gist: Some relevant variables. *Language and Speech, 9*, 217-227.

French, R. M., Mareschal, D., Mermillod, M., & Quinn, P. C. (2004). The role of bottom-up processing in perceptual categorization by 3- to 4-month-old infants: Simulations and data. *Journal of Experimental Psychology: General, 133*(3), 382-397.

Gergely, G., Bekkering, H., & Király, I. (2002). Rational imitation in preverbal infants. *Nature 415*, 755.

Gergely, G., & Csibra, G. (2003). Teleological reasoning in infancy: The naive theory of rational action. *Trends in Cognitive Sciences, 7*(7), 287-292.

Gergely, G., Nádasdy, Z., Csibra, G., & Bíró, S. (1995). Taking the intentional stance at 12 months of age. *Cognition, 56*, 165-193.

Gleissner, B., Meltzoff, A., & Bekkering, H. (2000). Children's coding of human action: Cognitive factors influencing imitation in 3-year-olds. *Developmental Science, 3*(4), 405-414.

Golinkoff, R. M., & Kerr, J. L. (1978). Infants' perception of semantically defined action role changes in filmed events. *Merrill-Palmer Quarterly, 24*(1), 53-61.

Guajardo, J. J., & Woodward, A. L. (2004). Is agency skin deep? Surface attributes influence infants' sensitivity to goal-directed action. *Infancy, 6*(3), 361-384.

Halford, G. S. (1982). *The development of thought.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Halford, G. S. (1993). *Children's understanding: The development of mental models.* Hillsdale, NJ: Lawrence Earlbaum Associates.

Hamlin, J. K., Wynn, K., & Bloom, P. (2007). Social evaluation by preverbal infants. *Nature, 450*(7169), 557-559.

Hard, B. M., Tversky, B., & Lang, D. S. (2006). Making sense of abstract events: Building event schemas. *Memory & Cognition, 34*(6), 1221-1235.

Hedges, L. V., & Olkin, I. (1985). *Statistical methods for meta-analysis.* Orlando: Academic Press.

Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *American Journal of Psychology, 57*, 243-259.

Henderson, E. (1903). A study of memory for connected trains of thought. *Psychology Review Monograph 5*(6), 94.

Holbrook, J. (2007). The time course of social perception: Inferences of intentionality, goals, beliefs, and traits from behavior. *Dissertation Abstracts International: Section B: The Sciences and Engineering, 67*(10-B), 6113.

Hunter, J. E., & Schmidt, F. L. (1990). *Methods of meta-analysis: Correcting error and bias in research findings*. Thousand Oaks, CA: Sage Publications.

Hunter, M. A., & Ames, E. W. (1988). A multifactor model of infant preferences for novel and familiar stimuli. In C. Rovee-Collier & L. P. Lipsitt (Eds.), *Advances in infancy research* (Vol. 5, pp. 69-95). Norwood, NJ: Ablex.

Jackendoff, R. (2007). *Language, consciousness, culture: Essays on mental structure.* Cambridge, MA: MIT Press.

Johnson, S. C. (2003). Detecting agents. *Philosophical Transactions of the Royal Society: B-Biological Sciences, 358*(1431), 549-559.

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*(2), 303-320.

Karmiloff-Smith, A. (1992). *Beyond modularity: A developmental perspective on cognitive science.* Cambridge, MA: MIT Press.

Király, I., Jovanovic, B., Prinz, W., Aschersleben, G., & Gergely, G. (2003). The early origins of goal attribution in infancy. *Consciousness and Cognition: An International Journal, 12*(4), 752-769.

Kuhlmeier, V., Wynn, K., & Bloom, P. (2003). Attribution of dispositional states by 12-month-olds. *Psychological Science, 14*(5), 402-408.

Leslie, A. M., Friedman, O., & German, T. P. (2004). Core mechanisms in `theory of mind'. *Trends in Cognitive Sciences, 8*(12), 528-533.

Loucks, J. (in progress). *Familiarity and organization of action memory in adults and young children.* Manuscript in progress.

Loucks, J., & Vukcevich, R. (in preparation). iLook: A MATLAB script for infant looking-time studies. University of Oregon, Eugene, OR.

Malle, B. F. (2004). *How the mind explains behavior: Folk explanations, meaning, and social interaction.* Cambridge, MA: MIT Press.

McKoon, G., & Ratcliff, R. (1980). Priming in item recognition: The organization of propositions in memory for text. *Journal of Verbal Learning & Verbal Behavior, 19*(4), 369-386.

Meltzoff, A., & Gopnik, A. (1993). The role of imitation in understanding persons and developing a theory of mind. In S. Baron-Cohen, H. Tager-Flusberg & D. J. Cohen (Eds.), *Understanding other minds: Perspectives from autism* (pp. 335-366). New York: Oxford University Press.

Meltzoff, A. N. (1995). Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology, 31*(5), 838-850.

Meltzoff, A. N. (2007). 'Like me': a foundation for social cognition. *Developmental Science, 10*(1), 126-134.

Moore, C., & Corkum, V. (1994). Social understanding at the end of the first year of life. *Developmental Review, 14*(4), 349-372.

Moore, C., & Povinelli, D. J. (2007). Differences in how 12- and 24-month-olds interpret the gaze of adults. *Infancy, 11*(3), 215-231.

Moses, L. J. (2005). Executive functioning and children's theories of mind. In B. F. Malle & S. D. Hodges (Eds.), *Other minds: How humans bridge the divide between self and others* (pp. 11-25). New York: Guilford Press.

Newtson, D. (1973). Attribution and the unit of perception of ongoing behavior. *Journal of Personality and Social Psychology, 28*(1), 28-38.

Paden, L. (1974). The effects of variations of auditory stimulation (music) and interspersed stimulus procedures on visual attending behavior in infants. In F. D. Horowitz (Ed.), Visual attention, auditory stimulation, and language discrimination in young infants. *Monographs of the Society for Research in Child Development, 39*(5-6, Serial No. 158), 29-41.

Phillips, A. T., & Wellman, H. M. (2005). Infants' understanding of object-directed action. *Cognition, 98*(2), 137-155.

Phillips, A. T., Wellman, H. M., & Spelke, E. S. (2002). Infants' ability to connect gaze and emotional expression to intentional action. *Cognition, 85*(1), 53-78.

Piaget, J. (1952). *The origins of intelligence in children*. New York: Basic Books.

Pierroutsakos, S. L., & Diener, M. (2007). *Infants' preference for live vs. video presentations*. Poster presented at the meeting of the Society for Research in Child Development, Boston.

Pinto, J. (2003). VideoHAB (Version 0.9d). Stanford, CA.

Povinelli, D. J. (2001). On the possibilities of detecting intentions prior to understanding them. In B. F. Malle, L. J. Moses & D. A. Baldwin (Eds.), *Intentions and intentionality: Foundations of social cognition* (pp. 225-248). Cambridge, MA: 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*(6), 848-856.

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

Ratcliff, R., & McKoon, G. (1978). Priming in item recognition: Evidence for the propositional structure of sentences. *Journal of Verbal Learning & Verbal Behavior, 17*(4), 403-417.

Reed, E. S., Montgomery, M., Schwartz, M., Palmer, C., & Pittenger, J. B. (1992). Visually based descriptions of an everyday action. *Ecological Psychology, 4*(3), 129-152.

Robertson, S. S., & Suci, G. J. (1980). Event perception by children in the early stages of language production. *Child Development, 51*(1), 89-96.

Rochat, P. (2001). *The infant's world.* Cambridge, MA: Harvard University Press.

Rochat, P., & Striano, T. (1998). Primacy of action in early ontogeny. *Human Development, 41*(2), 112-115.

Saxe, R., Tzelnic, T., & Carey, S. (2007). Knowing who dunnit: Infants identify the causal agent in an unseen causal interaction. *Developmental Psychology, 43*(1), 149-158.

Scherf, K. S., & Tabb, T. (2005). *How do infants parse dynamic human action involving multiple intentional agents?* Poster presented at the meeting of the Society for Research in Child Development, Atlanta.

Self, P. A. (1974). Control of infants' visual attending by auditory and interspersed stimulation. In F. D. Horowitz (Ed.), Visual attention, auditory stimulation, and language discrimination in young infants. *Monographs of the Society for Research in Child Development, 39*(5-6, Serial No. 158), 16-28.

Sirois, S., & Jackson, I. (2007). Social cognition in infancy: A critical review of research on higher order abilities. *European Journal of Developmental Psychology, 4*(1), 46 - 64.

Sodian, B., Schoeppner, B., & Metz, U. (2004). Do infants apply the principle of rational action to human agents? *Infant Behavior and Development, 27*(1), 31-41.

Sommerville, J. A., Hildebrand, E. A., & Crane, C. C. (in press). Experience matters: The impact of doing versus watching on infants' subsequent perception of tool use events. *Developmental Psychology*.

Sommerville, J. A., & Woodward, A. L. (2005a). Infants' sensitivity to the causal features of means-end support sequences in action and perception. *Infancy, 8*(2), 119-145.

Sommerville, J. A., & Woodward, A. L. (2005b). Pulling out the intentional structure of action: The relation between action processing and action production in infancy. *Cognition, 95*(1), 1-30.

Sommerville, J. A., Woodward, A. L., & Needham, A. (2005). Action experience alters 3-month-old infants' perception of others' actions. *Cognition, 96*(1), B1-B11.

Song, H., Baillargeon, R., & Fisher, C. (2005). Can infants attribute to an agent a disposition to perform a particular action? *Cognition, 28*(2), B45-B55.

Todd, J., & Smith, P. H. (2008). Twelve-month-olds' understanding of prior actions and final goals. *Infant Behavior and Development, 31*(2), 311-315.

Tomasello, M. (1992). *First verbs: A case study of early grammatical development*. Cambridge: Cambridge University Press.

Tomasello, M. (1999). *The cultural origins of human cognition*. Cambridge, MA: Harvard University Press.

Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing intentions: The origins of cultural cognition. *Behavioral and Brain Sciences, 28*(5), 675-735.

Tomasello, M., & Haberl, K. (2003). Understanding attention: 12- and 18-month-olds know what is new for other persons. *Developmental Psychology, 39*(5), 906-912.

Welborn, E., & English, H. (1937). Logical learning and retention: A general review of experiments with meaningful verbal materials. *Psychological Bulletin, 34*(1), 1-20.

Wellman, H. M., Lopez-Duran, S., LaBounty, J., & Hamilton, B. (2008). Infant attention to intentional action predicts preschool theory of mind. *Developmental Psychology, 44*(2), 618-623.

Wellman, H. M., Phillips, A. T., Dunphy-Lelii, S., & LaLonde, N. (2004). Infant social attention predicts preschool social cognition. *Developmental Science, 7*(3), 283-288.

Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition, 13*(1), 103-128.

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

Woodward, A. L. (1999). Infants' ability to distinguish between purposeful and non-purposeful behaviors. *Infant Behavior & Development, 22*, 145-160.

Woodward, A. L. (2003). Infants' developing understanding of the link between looker and object. *Developmental Science, 6*(3), 297-311.

Woodward, A. L., & Guajardo, J. J. (2002). Infants' understanding of the point gesture as an object-directed action. *Cognitive Development, 17*(1), 1061-1084.

Woodward, A. L., & Sommerville, J. A. (2000). Twelve-month-old infants interpret action in context. *Psychological Science, 11*, 73-77.

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.

Zacks, J. M. (2004). Using movement and intentions to understand simple events. *Cognitive Science: A Multidisciplinary Journal, 28*(6), 979-1008.

Zacks, J. M., & Swallow, K. M. (2007). Event segmentation. *Current Directions in Psychological Science, 16*(2), 80-84.

Zacks, J. M., & Tversky, B. (2001). Event structure in perception and conception. *Psychological Bulletin, 127*(1), 3-21.

Zacks, J. M., Tversky, B., & Iyer, G. (2001). Perceiving, remembering, and communicating structure in events. *Journal of Experimental Psychology: General, 130*(1), 29-58.