Infant Capacities Related to Building Internal Working Models
of Attachment Figures: A Theoretical and Empirical Review

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The authors would like to thank Amanda Woodward, Tracy Riggins, Lea Dougherty,
Jonathan Beier, and Melanie Killen for their thoughtful comments on earlier drafts of this
manuscript.

Manuscript preparation was supported by the Janet Johnson Summer Fellowship and the
Ann G. Wylie Dissertation Fellowship awarded to Laura J. Sherman and a National Science
Foundation Graduate Research Fellowship awarded to Katherine Rice. The funding sources had
no role in the writing of the report or in the decision to submit the article for publication.

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Abstract

According to attachment theory (e.g., Bowlby, 1969/1982, 1973, 1980), infants develop cognitive models (termed internal working models, IWMs) of their attachment figures during the first year of life. Bowlby proposed his initial thinking about IWMs as more of an outline than a fully defined concept (Bretherton & Munholland, 2008). As such, considerable subsequent theoretical and empirical work has aimed to increase understanding of how IWMs operate (e.g., Bretherton & Munholland, 2008; Main, Kaplan, & Cassidy, 1985). To date, however, relatively little research has explored infant cognition with respect to the development of the IWM. In this review, we summarize the IWM concept as it applies to caregiver-specific attachment representations in infancy, review research examining cognitive capacities relevant to building these caregiver-specific representations, and provide directions for future research. We bridge social and cognitive developmental literatures and suggest ways in which researchers can continue to examine these representations. Both attachment researchers and social cognitive researchers can learn from each others' theoretical models and methodologies to understand development at the intersection of social, emotional, and cognitive development in infancy.

Keywords: attachment; internal working model; cognition; infancy; representations; memory; social cognition

Infant Capacities Related to Building Internal Working Models of Attachment Figures: A Theoretical and Empirical Review

During the first year of life, infants undergo significant physical, social, emotional, behavioral, and cognitive development while simultaneously forming enduring, person-specific, emotionally salient relationships with their primary caregivers, known as attachment bonds (Bowlby, 1969/1982; Cassidy & Shaver, 2008). Although virtually all infants form attachments to their primary caregivers, the patterns of the attachments differ, and these patterns are significantly affected by a variety of factors, including differences in the quality of caregiving (Weinfield, Sroufe, Egeland, & Carlson, 2008). Infants who experience sensitive and responsive care tend to develop secure attachments, whereas infants who experience rejecting, hostile, punitive, inconsistent, frightening, or intrusive care often develop various forms of insecure attachment (Weinfield et al., 2008). According to attachment theory, the mechanism through which children translate caregiving experiences into an attachment pattern is via experience-based mental representations of their caregivers' likely behavior (known broadly as *internal working models*, IWMs; Bowlby, 1969/1982, 1973, 1980; see Bretherton & Munholland, 2008). As a result of receiving sensitive and responsive care, infants with a secure pattern of attachment build an IWM that represents confidence in their caregivers' ability to serve as both a *secure base* from which to explore and as a *haven of safety* to return to in times of need (Ainsworth, 1967; Ainsworth, Blehar, Waters, & Wall, 1978; Bowlby, 1969/1982), whereas insecurely attached infants lack confidence in one or both of these caregiving roles.

To date, the majority of research on the IWM concept has focused on adults and verbal children, with very little research examining the development of these mental representations in infancy. In fact, the IWM concept was overlooked for many years by infancy researchers

(Thompson, 2008). In this review, however, we suggest, as have others (see Johnson et al., 2010), that infants' IWMs can be studied, especially given methodological advances and accumulating research on infant memory and social cognition. Applying the insight yielded by these advances in understanding infant cognition to the formation of attachment bonds dovetails with psychology's recent increasing interest in bridging traditional social-emotional and cognitive development research (e.g., Calkins & Bell, 2010; Olson & Dweck, 2008). Both attachment researchers and social cognitive researchers can learn from each others' theoretical models and methodologies to understand child development at the intersection of social, emotional, and cognitive development in infancy.

Accordingly, the purpose of this paper is to (a) describe the features and formation of the infants' IWMs from the perspective of attachment theory, specifically focusing on infants' mental representations of *specific* caregivers' likely behavior; (b) review empirical research examining cognitive capacities relevant to building these models in the first year of life (see Thompson, Laible, & Ontai, 2003, for a discussion of relevant cognitive capacities during the preschool years) and (c) provide suggestions and recommendations for future research to examine the capacities in relation to IWMs of attachment. In doing so, the goal is not to provide a comprehensive review of each cognitive capacity (especially given that many of these capacities have been comprehensively reviewed elsewhere; e.g., see Bauer, 2006, for event memory), but instead to highlight aspects of the infancy literature that are relevant to the IWM concept (we use the terms *infancy* and *infants* to refer to the first year of life). This is the first review to critically examine whether existing research supports the hypothesis that infants can form experience-based caregiver-specific mental representations of the caregiver's likely behavior.

Attachment Theory: The Internal Working Model Concept

What are Internal Working Models (IWMs) and How do they Develop?

Internal working models (IWMs) of attachment are experience-based mental representations about attachment figures, the self, and relationships. Bowlby (1969/1982) used the term *attachment figures* to describe the principal people to whom one becomes attached (noting that the initial [i.e., primary] attachment figures are typically the parents, grandparents, and other family members). According to Bowlby (1969/1982), these representations form during the infant's first year of life:

Starting, we may suppose, towards the end of his first year . . . a child is busy constructing working models of how the physical world may be expected to behave, how his mother and other significant persons may be expected to behave, how he himself may be expected to behave, and how each interacts with the other. (p. 354)

According to Bowlby (1969/1982), the infant attachment system is activated when the infant is frightened, distressed, or uncertain about the availability of an attachment figure when that figure is needed. Bowlby noted that to be useful in predicting an attachment figure's behavior in attachment-related situations (e.g., when the infant is scared or distressed, which activates the attachment system), these models must be based on the actual behavior of the caregiver during past attachment-related interactions. (Note: Throughout, we use the term *caregiver* interchangeably with *attachment figure*.) Interactions during nonattachment-related moments (e.g., while caregivers are serving as a playmate or teacher) may contribute to the IWM, yet are generally thought to be less centrally influential. In these attachment-related moments, infants engage in a set of behaviors (called *attachment behaviors*) that have evolved over the course of human history because they have the reliable outcome of gaining proximity to

caregivers (e.g., signaling or seeking proximity; Bowlby, 1969/1982). Individual caregivers may respond to these infant attachment behaviors in a variety of ways - by being sensitively responsive, rejecting, inconsistent, or frightened/frightening. These responses shape not only the infant's behaviors and emotions, but also the infant's cognitions about specific attachment figures. An infant with a predominantly sensitive and responsive caregiver will form representations of that caregiver as being available when needed and will come to expect that caregiver to respond appropriately to his or her signals. As Bowlby (1973) suggested, "the varied expectations of the accessibility and responsiveness of attachment figures that different individuals develop during the years of immaturity *are tolerably accurate reflections of the experiences those individuals have actually had* [italics added]" (p. 202). Thus, according to attachment theory, IWMs are principally based on past experiences with caregivers during attachment-related interactions.

It is important to note that many factors contribute to children's experiences with caregivers, and thus may influence the child's representations of their caregivers. These include factors related to caregiver behavior (e.g., sensitivity, responsiveness), to infant contributions (e.g., genetics, temperament, sex), to broader contextual factors (e.g., culture, socio-economic status), and the interactions between these factors (e.g., epigenetic processes). It is also likely that there are factors that contribute to the formation of working models of specific attachment figures that are not mediated by experiences with that attachment figure. For instance, infants vary in how experiences influence them. The concept of differential susceptibility highlights the possibility that some infants are more impacted by their caregiving experiences than others (Belsky, 1997, 2005; Belsky, Bakermans-Kranenburg, & van IJzendoorn, 2007; see also Boyce & Ellis, 2005). Differences among infants can affect both the caregiver behaviors that influence

IWM formation (e.g., irritable infants display fewer attachment behaviors and their caregivers show lower levels of sensitivity; van den Boom 1991; van den Boom & Hoeksma, 1994), and also the behavioral consequences of different attachment styles. For example, the effect of attachment quality on toddler exploration has been found to vary as a function of child temperament (i.e., high vs. moderate newborn irritability; Stupica, Sherman, & Cassidy, 2011). Relatedly, Frankenhuys, Gergely, and Watson (2013) recently discussed the consequences of individual variation in infants' use of conditional probabilities as a basis for expectations, including inferences about social behavior; these variations might influence the formation of IWMs. As such, it would be a mistake to assume that all infants experience all environmental input in the same way, and/or that they use that input in the same way to create their IWMs. Attachment theorists join developmentalists more broadly in assuming that many factors impact the parent-child relationship (from "neurons to neighborhoods;" Shonkoff & Phillips, 2000). With these qualifying considerations in mind, we focus in this paper on Bowlby's theoretical notion of IWMs as experience-based. Space limits preclude our fully considering all potential contributors to IWM formation in this initial review.

The experience-based representations and expectations of the caregiver's likely behavior are adaptive and useful for the infant, as they shape the behavior of the infant during current and future interactions with that caregiver. The canonical laboratory test of infant behavior toward the caregiver is the Strange Situation (Ainsworth et al., 1978; see Solomon & George, in press). In this 20-minute structured observation, the infant and caregiver are twice separated and then reunited, and the infant's behavior during the two reunions is videotaped and later coded to identify the infant's attachment pattern. Infants who are securely attached to their caregiver, having formed representations that that specific caregiver will provide comfort during times of

distress, will behave in accord with these expectations. For example, although infants may become distressed when their caregiver departs, crucially, when she returns, they will seek contact and comfort and be willing to signal their distress (e.g., an infant who was crying in his mother's absence will approach her upon her return and allow himself to be soothed by her). Alternatively, infants who have formed insecure attachments will behave differently. Infants who have formed insecure-avoidant attachments with their caregivers have formed the representation that their attachment behaviors will be rejected, and will thus begin to minimize their attachment needs with those caregivers in order to avoid the painful experience of rejection (see Cassidy, 1994; Sherman, Stupica, Dykas, Ramos-Marcuse, & Cassidy, 2012). For example, when the caregiver returns to the room, these infants may ignore their caregivers, avoid eye contact, and avoid contact or comfort from their caregivers (Ainsworth et al., 1978). Infants with insecure-ambivalent (also termed insecure-resistant) attachment to their caregiver will have formed a representation that their caregiver responds inconsistently, and will thus maximize their attachment needs in order to ensure a response from that inconsistent caregiver (see Cassidy, 1994; Cassidy & Berlin, 1994; Sherman et al., 2012). For example, when the caregiver returns, these infants typically show extreme distress, seek contact and comfort from their caregivers, yet fail to calm down and return to play after receiving contact and comfort (Ainsworth et al., 1978). Although most frequently assessed in the Strange Situation, these general patterns of behavior are observable in a variety of attachment-relevant contexts, as the IWM, like any cognitive schema (see Piaget, 1952), is an efficient means of understanding and interacting in subsequent interactions. When facing new attachment-related situations, infants can apply their IWM based on their specific caregiver's past behavior to draw expectations about how that caregiver will respond in the new situation.

Infants are thought to have separate representations of each attachment figure based on experiences with that person. This notion is supported by behavioral evidence showing that infants can have different attachment patterns toward different parents (see Berlin, Cassidy, & Appleyard, 2008) and that siblings can show different attachment patterns to the same parent (van IJzendoorn et al., 2000), even when siblings are monozygotic twins (O'Connor & Croft, 2001). According to the theory, these caregiver-specific representations guide how the infant perceives, feels, and acts toward each caregiver (Bowlby, 1969/1982, 1973; Main et al., 1985).. Another aspect of the IWM of attachment is a general framework for representing relationships more broadly, which guides a person's behavior, emotions, and cognitions during interactions with other people beyond those from which the model was formed. The exact mechanisms, timing, and development of the caregiver-specific and general representations are theoretically and empirically unknown. In this review, we focus on how infants are able to represent their specific attachment figures' behavior, a focus that reflects the aspect of representations that has received the most extensive conceptual and empirical base within the attachment field.

At the same time that an infant is forming mental representations of a caregiver, he or she is also forming complementary mental representations of the self, and it is thought that how a caregiver treats an infant affects how the infant comes to view his or her self. Bowlby (1973) proposed that an infant who has a sensitive and responsive caregiver will form a positive model of the self as lovable and worthy of care, whereas an infant with a rejecting, inconsistent, or frightening caregiver will form a negative self perception, given the large role caregivers play in shaping how the infant sees the world. Although understanding the development of models of the self is important, we focus in this paper on infants' mental representations of their caregivers' likely behavior, and as such, exploration of models of the self is beyond the scope of this paper

(see Cassidy, 1988, and Verschueren, Marcoen, & Schoefs, 1996, for investigations of kindergarteners' models of the self in relation to their models of child-mother attachment).

Can IWMs change?

Given his view that IWMs are "tolerably accurate" perceptions of reality, Bowlby (1969/1982, 1973) suggested that IWMs are constantly being both reinforced and updated/revised based on new experiences. . Infants can interpret or re-interpret the new experience to fit into the existing representation, or the representation can change (which is thought to be much more difficult; cf. Piaget, 1952). New experiences must occur at sufficiently high frequency to bring about a change in the model. For example, relatively infrequent instances of parental insensitivity will not challenge an infant's representation of the parent as typically responsive (see Cassidy et al., 2005, for related thinking). Relatedly, data from parenting interventions support the notion that in some cases infant attachment patterns change when caregiving experiences change, presumably because of altered infant expectations of the caregiver's likely behavior (see Berlin, Zeanah, & Lieberman, 2008).

Change in the IWM may also occur when the child's development contributes to change in the parent-child relationship. For instance, parental behavior changes in response to children's locomotor development (Thompson, 2006), typically becoming more negative and disciplinary once children's new crawling and walking capabilities lead them to venture away and explore. As a result of this constant incorporation of new information, there may be a time-lag in the accuracy of the IWM as the child undergoes developmental transitions or the parent changes his/her behavior while the model is updated (Bowlby, 1988; Bretherton & Munholland, 2008). Alternatively, if parental behavior shifts only temporarily, the model may never require alteration.

Although IWMs are expected to change lawfully with changing environments, they become increasingly resistant to change over time. Bowlby (1973) borrowed Waddington's (1957) concept of developmental pathways to illustrate the increasing canalization and stability of IWMs over time. That is, with development, the threshold for incorporating new experiences into the model becomes higher, as these experiences become more difficult to assimilate into the existing model (Bowlby, 1980; Cassidy, Ziv, Mehta, & Feeney, 2003).

Main and her colleagues (1985) pointed out that internal working models can be revised even when the infant is not in the presence of the attachment figure (e.g., during prolonged absences from the attachment figure). That is, because IWMs are based on infants' experiences of having their attachment figure respond to their attachment signals, if the attachment figure is absent across a long enough period of time to render the infants' expectations about caregiver behavior inaccurate, then infants' expectations about the availability and accessibility of that figure may be altered (Bretherton & Munholland, 2008). Specifically, Main et al., (1985) theorized that "because event representations are defined to include 'attempts and outcomes,' they will necessarily include the outcome of, for example, the infants' efforts to gain the caregiver in the caregiver's absence. Thus the internal working model of a relationship may change over the course of the partner's absence" (p. 77). Although the exact length of the absence required to alter the IWM is an open question, it is clear from extensive research that the time-frame is not in terms of hours (e.g., the daily absences of 8-10 or more hours that many infants experience in routine child care; NICHD Early Childcare Research Network, 2005). Further, Bowlby's clinical observations suggest that a time-frame of weeks to months would be more likely to have an impact (Bowlby, 1973).

Children themselves also contribute to the continuity of the IWM, both passively and actively (Bowlby, 1988; see Scarr & McCartney, 1983, for a general discussion of children's contribution to their own development). For instance, once infants have formed expectations of their attachment figures' likely behavior, they will behave in ways that align with those expectations (e.g., an infant will be less likely to approach a rejecting caregiver). These behaviors then elicit responses from the caregiver that will likely reinforce the pattern of parent-child interaction that led the child to the original IWM.

Theoretical Summary

In sum, attachment theory suggests that, based on attachment-related interactions with an attachment figure, infants construct internal working models of that attachment figure in the form of expectations about the attachment figure's availability, responsiveness, and likely behavior in novel situations. Consistent with this theory, attachment theorists and researchers assume that infant behavioral attachment patterns (typically assessed in the Strange Situation, reviewed above) are manifestations of the representations and expectations that infants have formed from past interactions with their attachment figures. To date, few researchers have investigated the cognitive aspects of the formation of the IWM in infancy. Advances in the study of infant cognition, however, have provided the opportunity to empirically understand infant representational capacities and to investigate whether and how these capacities scaffold the development of the IWM as predicted by attachment theory. Developmental psychology is poised to explore the cognitive components involved in the development of infants' IWMs of attachment figures by utilizing controlled laboratory studies and experimental procedures designed to assess infant cognition.

IWMs in Infancy: Empirical Evidence?

When articulating the theory of attachment, Bowlby never wrote one definitive work on internal working models. Rather, his formulation of the building, revising, and maintenance of IWMs is distributed across multiple works, including each volume of the Attachment trilogy: *Attachment* (1969/1982), *Separation* (1973), and *Loss* (1980), as well as several other works (Bowlby, 1979, 1988). As such, Bretherton and Muholland (2008) noted that Bowlby's conceptualization about the "the role of representation in attachment relationships . . . was not a fully worked-out theory, but a promising conceptual framework to be filled in by others" (p. 103). As such, students of attachment theory have offered varied definitions, interpretations, and conceptualizations, and research explaining IWM of attachment (Bretherton, 2005; Main et al., 1985; Sroufe, 1996; Thompson, 2006; Weinfield et al., 2008). Most of the theoretical and empirical work that followed Bowlby's theory focused on verbal children and adults because of methodological limitations of the time. As such, empirical work from the attachment field on mental representations during infancy has been limited.

Despite the lack of empirical work on IWMs during infancy, one set of groundbreaking studies has provided evidence that infants possess *general* mental models of attachment-related interactions (Johnson et al., 2010; see also Johnson, 2007, for initial exploratory findings). One of these studies (study 1) tested the infants' representations of caregivers' behavior. (Studies 2 and 3 will not be discussed here because their examination of representations of *children's* behavior is outside the scope of this paper.) In study 1, Johnson and colleagues (2010) related 13-month old infants' attachment classifications in the Strange Situation to their looking time during habituation events designed to assess their expectations for caregiver behavior during an attachment-related situation. Specifically, infants were habituated to a display of a small oval (which the authors referred to as representing the "child") and a large oval (which the authors

referred to as representing the “mother”) at the bottom of a hill. The infants were repeatedly shown a video of the large oval climbing the hill and the small oval “crying” (pulsating, with audio of infant cry sounds) until infants’ looking time declined to half the original trial (visual habituation paradigm; see Colombo & Mitchell, 2009, for a detailed account of visual habituation paradigms). Infants were then shown test events of the large oval’s behavior during a “responsive” condition: the large oval went down the hill approaching the small oval and an “unresponsive” condition: the large oval continued up the hill away from the small oval. Longer looking times during specific test events suggest “surprise” or violation of expectations for the event outcome. The results suggested that securely attached infants expected the “caregiver” oval to be responsive whereas insecure-avoidant infants and insecure-ambivalent infants expected “caregiver” oval to be unresponsive. Thus, these findings provide evidence that infants have general representations for the likely behavior of caregivers during attachment-related situations.

The important findings of Johnson and colleagues (2010), however, do not indicate whether infants’ representations are the direct result of the infants’ own attachment-related experiences with their caregivers or whether infants have the same expectations for each of their own attachment figures. Thus, these studies cannot be used to speak to the caregiver-specific mental representations of the caregiver’s likely behavior that is the focus of this paper. The link between an infant’s attachment *behavior* and the infant’s experiences with that attachment figure is well validated (initially by Ainsworth and colleagues, 1978). The link between an infant’s attachment *representations* and an infant’s experiences, however, has yet to be empirically validated. Moreover, this body of research does not address the development of the mental

representations – how and when they form during the first year of life – as this study was a cross-sectional investigation of 13-month-old infants.

In summary, the field of attachment and development in general, knows very little about the formation of the cognitive component of attachment. We have decades of research on the behavioral, emotional, and social levels, but very little on the cognitive level. Therefore, in this review, we cannot offer a systematic overview of the developmental milestones of IWM formation. Rather, we turn toward the cognitive and social cognitive fields of infant development to examine evidence of the cognitive abilities of infants related to building mental representations of attachment figures, with the hopes that the intersection of these fields can provide a fruitful foundation for future research. In that vein, we first review a set of cognitive capacities related to the IWM and then focus on important future directions.

Cognitive Capacities Related to the IWM

In order to investigate the formation of IWMs, it is important to understand and examine infant cognitive capacities that would be related to building mental representations of a caregiver's likely behavior. Bowlby (1973) proposed that "in the working model of the world that anyone builds, a key feature is his notion of who his attachment figures are, where they may be found, and how they may be expected to respond" (p. 203), with those expectations being experience-based. Implicit in Bowlby's proposition is the idea that several cognitive capacities are relevant to building an IWM of an attachment figure, including: the capacities to (a) discriminate and recognize individual people, (b) understand the permanence of people, (c) remember experiences with attachment figures, (d) generate novel expectations for attachment figures' behavior based on previous experiences with them, and (e) understand the meaning of attachment figures' emotions and behaviors. These capacities represent a host of advanced

mental processes to support the formation of an IWM. Despite the dearth of research examining the cognitive aspects of infants' IWMs of attachment relationships, there is substantial work studying infant memory and social cognition suggesting that infants possess cognitive capacities related to building IWMs of others.

Discrimination and Recognition of People

Person discrimination is the ability to distinguish the difference between people (i.e., to tell two or more people apart) and person recognition is the ability to recognize or recall a person previously seen. Recognition implies discrimination because a distinction has been made between a familiar person and an unfamiliar person; discrimination, however, can occur without recognition by simply noticing the difference between two faces. These abilities are important for social development in general, but particularly relevant to developing representations of attachment figures because "in the working model of the world that anyone builds, a key feature is his notion of who his attachment figures are" (Bowlby, 1973, p. 203). Furthermore, in order to develop specific representations of each attachment figure, infants need to discriminate between two or more people. Infants would otherwise be unable to separate the attachment-related experiences with one caregiver from those with another. Relatedly, infants must be able to remember and recognize familiar people in order to incorporate their new experiences with that person into their existing mental representations. Otherwise, each experience with a caregiver would be as if it were the infant's first experience with that person. The capacities to tell people apart and recognize familiar people are thus basic building blocks of the IWM and should be present early in the first year of life.

Human infants seem prepared to obtain information from and about faces immediately after birth; newborn infants have a preference for faces and face-like stimuli (Morton & Johnson,

1991; Mondloch et al., 1999; Simion, Valenza, & Umiltà, 1998) and will imitate facial movements and expressions (Meltzoff & Moore, 1977; Reissland, 1988). Whether these behaviors represent an early face-specific learning module or an innate understanding of faces (see Nelson, 2003, for a review of theoretical positions on face recognition), it is evident that newborn infants have a unique aptitude toward processing faces. Moreover, shortly after birth, infants can discriminate and recognize their mother's face from an unfamiliar adult's face and prefer looking at their mother's face (Bushnell, 2001; Bushnell, Sai, & Mullin, 1989; Field, Cohen, Garcia, & Greenberg, 1984; Pascalis, de Schonen, Morton, & Deruelle, 1995; Sai, 2005; Slater & Quinn, 2001). The early recognition of their mother's face may result from an early association between their mother's voice, which infants began learning in utero, and their mother's face (DeCasper & Fifer, 1980; Fifer & Moon, 1988; Sai, 2005; Streri, Coulon, & Guellai, 2013). Once infants pair their mother's voice and face, they can recognize their mother's face without auditory support (Field et al., 1984; Sai, 2005). Thus, just hours after birth, infants have the capacity to discriminate and recognize their mother – a capacity that they will need to develop an IWM of her. Whether in visually impaired infants the timing of the capacity to discriminate and recognize their mother influences the development of IWMs has not been examined.

In addition to discriminating and recognizing their mother, infants should be able to discriminate and recognize other people because they form IWMs about each of their attachment figures (e.g., fathers, grandmothers). Research indicates that infants as young as 1 month old can discriminate between two unfamiliar adult faces (de Haan, Johnson, Maurer, & Perrett, 2001). Whether faces are presented as static images or live models, infants between 3 and 5 months are able to discriminate between unfamiliar adults and recognize familiar adults (Bahrick & Newell,

2008; Blass & Camp, 2004; Otsuka et al., 2009). By 6 months of age, infants are able to recognize familiar faces that were presented and tested at differing angles (Pascalis, de Haan, Nelson, & de Schonen, 1998) and with differing emotional expressions (Bornstein & Arterberry, 2003). Research does indicate that infants are less effective at processing, discriminating, and recognizing male faces than female faces (Ramsey, Langlois, & Marti, 2005), and do not show the same early discrimination between their father and a male stranger's face that they do between their mother and a female stranger (Walton, Bower, & Bower, 1992). One hypothesis is that maternal interactions direct more attention to the face, or even that male faces show more variability, which makes it more difficult to form category boundaries (reviewed in Ramsey et al., 2005). There is evidence, however, that when fathers are the primary caregiver, infants prefer male faces over female faces (Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002; Ramsey et al., 2005).

As these findings suggest, face processing changes dramatically over the first year (reviewed in Wagner, Luyster, Yim, Tager-Flusberg, & Nelson, 2013). Very young infants (i.e., under two months) tend to direct attention to the outer regions of the face and head (Maurer & Salapatek, 1976), but by three to four months of age, children direct a majority of their visual attention to the eye region (Jones & Klin, 2013). In complex displays, however, faces do not capture the attention of children until around six months of age (di Giorgio, Turati, Altoe, & Simion, 2012). Eye-tracking studies have indicated a shift in looking to the mouth region as children begin to learn language in the second half of the first year, and a shift back to the eyes around 12 months (Lewkowicz & Hansen-Tift, 2012), although the impact of this shift on interactions with caregivers is unclear. During the first year, infants are also gaining experience with faces. As this happens, they become better at discriminating the differences between faces by using more subtle cues to determine differences (e.g., Bhatt, Bertin, Hayden, & Reed, 2005;

Hayden, Bhatt, Reed, Corbly, & Joseph, 2007) and recognizing familiar faces over longer delays and with less familiarization time (e.g., Bahrick & Newell, 2008; Rose, Jankowski, & Feldman, 2002). Thus, the first year represents a time in which infants develop face processing skills that are instrumental to identifying caregivers and directing attention to regions of the face that provide salient information.

Infants' recognition of and preference for familiar adults can be enhanced through the nature of infant-adult interaction. Blass and Camp (2001) found that 9 and 12-week-old infants developed a preference for a female experimenter who maintained eye contact and delivered a sweet, sucrose solution over an unfamiliar female experimenter, although this effect was only present in calm infants. Similarly, Farroni, Massaccesi, Menon, and Johnson (2007) found that direct gaze from an adult supported infants' subsequent recognition of that adult. Further, infant face discrimination at three months is assisted by positive, but not negative, facial expressions (Brenna, Proietti, Montirosso, & Turati, 2012). These interactive components that support face recognition may support infants' ability to identify who their attachment figures are.

Person Permanence

In addition to discriminating and recognizing people, the capacity to represent people who are not present is an important cognitive capacity developed in infancy. Person permanence refers to the knowledge that a person continues to exist when he/she can no longer be seen or heard. Although similar to object permanence, person permanence is specific to people instead of objects (Piaget, 1954).

Person permanence is relevant to two aspects of the IWM. First, Bowlby (1973) stated that "a key notion in the internal working model of the world that anyone builds . . . is where [his attachment figures] may be found" (p. 203). If infants do not understand that people continue to

exist outside of their own awareness, then infants would not know where to find their attachment figures because, in their minds, their attachment figures have ceased to exist. Additionally, attachment theory suggests that internal working models are updated not only through additional experiences with the caregiver, but also during times of prolonged separation when children may attempt to seek proximity to and comfort from unavailable caregivers (Bowlby, 1973; Bretherton & Munholland, 2008; Main et al., 1985). If in the minds of infants, people cease to exist when not present, then infants could not update the IWMs of their caregivers in the caregivers' absence because they would never think about these people. As such, the cognitive capacity to understand that people continue to exist is related to forming an IWM.

When using traditional tasks for studying object permanence (i.e., search for hidden items) to test whether infants are capable of person permanence, studies find evidence that infants between 6 and 14 months search for hidden persons and are often better at finding hidden persons than hidden objects; infants are especially good at finding their mothers (e.g., Bell, 1970; Legerstee, 1994; Slaughter & Boh, 2001; see Krøjgaard, 2005, for a review). The ability to find their mothers better than other persons suggests that by 6 months of age, infants have, in a very literal, experimentally contrived setting, a notion of where their attachment figures may be found. More recent studies testing infants' abilities at object permanence have used newer methods for studying infant cognition, such as visual preference techniques and the violation-of-expectation method. These studies suggest that infants as young as 3 months of age demonstrate knowledge of object permanence (e.g., Aguiar & Baillargeon, 2002; see Baillargeon, 2002, for a review). As such, it is possible that infants are capable of representing people who are not visually present earlier than 6 months of age. To date, however, there are no published studies on person permanence using visual preference techniques or the violation of expectation method.

Memory for Past Experiences

Thus far, we have reviewed research indicating that infants have the capacities to know who their attachment figures are and where they may be found. Given that IWM of an attachment figure is theorized to be based on cumulative experiences with that individual, the next question relevant to building the IWM of an attachment figure is: Do infants have the capacity to remember aspects of their attachment-related interactions? Infants must possess some capacity for remembering experiences with each of their caregivers if they are to develop IWMs of their caregivers.

Dichotomous memory systems. The memory system is commonly divided into two types of memory: implicit (or procedural) and explicit (or declarative) memory (Schacter & Tulving, 1994). Implicit memory refers to memory processes that are largely inaccessible to consciousness and is slow, reliable, inflexible, and requires the specific context from which the memory was formed (Bauer, 2006). Explicit memory, in contrast, is fast, fallible, and representationally flexible, and is traditionally defined by its accessibility to consciousness (Bauer 2006; Eichenbaum, 1997). Both recall and recognition (briefly reviewed in the section on face recognition) are supported by explicit memory and contain information concerning the particulars of an experience (Bauer, 2004). We address the role of both explicit and implicit memory in forming IWMs of attachment, although questions about the relative role of each system in the formation of IWMs and potential interactions of the systems remain underexplored.

Explicit memory. In formulating attachment theory, Bowlby (1969/1982) cited semantic and episodic memory in his discussions of IWMs, suggesting that explicit memory is particularly relevant to forming an IWM. Relatedly, Bretherton and Munholland (2008) drew connections between the IWM and Nelson and Gruendel's (1981) conceptualization of event representations

and generalized event representations. Infants need to combine memories of unique experiences in order to remember who their attachment figures are, how each of their attachment figures behaved in specific past contexts, and how the attachment figures typically behave. The memories need to be recalled in later interactions to facilitate adaptive responding in new situations and to form expectations about how their caregivers will respond in new situations. These features are all characteristic of representational flexibility, which suggests that explicit memory is a relevant capacity to building an IWM.

Although it was once believed that infants could not develop or possess explicit memories because they did not possess the necessary representational capacity (Piaget, 1952), researchers now recognize that infants are able to remember events and complete tasks believed to tap explicit memory capacities (reviewed in Mullally & Maguire, 2014). According to Nelson (1995), although a form of “pre-explicit” memory that supports recognition memory is evident during the first months of life, the capacity for explicit memory develops between 8 and 12 months. Using a deferred imitation task, several studies have shown that infants between 6 and 9 months show memory for events after delays as long as 24 hours (e.g., Barr, Dowden, & Hayne, 1996; Collie & Hayne, 1999; Meltzoff, 1988). With development, infants between 9 and 11 months become able to remember more about events, for longer periods of time, and with less exposure to the events (Bauer, 2006). Further improvements in explicit memory occur after the first year, but are not discussed here (see Bauer, 2004, 2006).

Implicit memory. Although Bowlby (1969/1982) focused on the role of explicit memory in attachment representations, it is likely that aspects of the attachment relationship are remembered through implicit memory processes and that these implicit memories contribute to the infants’ IWM. In particular, attachment theorists have emphasized the role of procedural

representations, which are “rule-based representations of how to proceed, of how to do things” (Lyons-Ruth et al., 1998, p. 284; see Beebe & Lachmann, 1994; Main et al., 1985; Waters & Waters, 2006). After repeated interactions with their attachment figures, infants develop an implicit knowledge of the cause-effect contingency between their attachment behavior and their caregivers’ subsequent sensitivity or insensitivity (Beebe & Lachmann, 1994). These procedural representations, which have been referred to as “implicit relational knowing” (Lyons-Ruth et al., 1998), require the infant to be in the original social context (i.e., interacting with their caregiver; Fogel, 2004) and they follow a script about what happens when the infant approaches an attachment figure (e.g., the caregiver responds insensitivity). Further, evidence from non-social paradigms suggests that operational implicit memory begins in infancy (Fogel, 2004). Infants as young as 8 weeks pass the mobile conjugate reinforcement task (see Rovee-Collier, 1999), which tests for infant memory of the contingency between kicking and operating a mobile tied to their leg. These findings show that from early in life, infants represent the relations between their behaviors and the environmental consequences. These implicit memory processes relate to a key feature of an infants’ IWM of their attachment figure: how their attachment figure is likely to respond to their varied attachment behaviors.

Memory for social-emotional interactions. Of particular relevance to the formation of the internal working model of attachment is memory for social-emotional interactions. Representations of caregiver behavior are formed during attachment-relevant events when the infant’s attachment system is activated and the infant seeks proximity to the caregiver (Bowlby, 1969/1982, 1973). Thus, the most relevant experiences for infants to remember are those that occur during times of heightened emotion, particularly negative emotion because these are the times when the attachment system is activated. Furthermore, the social interaction between the

infant and caregiver that follows the attachment system activation is foundational in forming the representation and expectations of the caregiver's behavior.

Although most examination of infants' memory for events provides infants with non-valenced experiences to remember, it is possible that memory for social-emotional events operates differently from memory for non-valenced experiences. Only a few studies have investigated infants' memory for such experiences. Each of these studies utilized visual-paired comparison (VPC) methods to tap infants' recognition memory, two using puppets as the stimuli and two using adult experimenters. Although infant memory is typically inferred based on infants' longer looking toward novelty, factors such as age, exposure duration, length of delay, and stimulus complexity affect whether infants will express the typical novelty preference or whether infants will express a preference toward familiarity or even no preference following familiarization (Rose, Feldman, & Jankowski, 2004). As such, *any* systematic looking time differences observed between looking toward familiar or novel stimuli are taken as evidence of infant memory, which can be a limitation of traditional looking time studies.

In one of the first studies assessing infant memory for emotional events, Nachman, Stern, and Best (1986) randomly assigned 7-month-old infants to either a "rousing," positively valenced interaction with a puppet or a neutral, non-emotionally valenced interaction with a puppet. Infants were later tested with a VPC task with the familiar puppet and a novel puppet following a 2-minute and 1-week delay. If infants simply recognize familiar objects, then infants in both conditions should look longer at a novel puppet. If, however, infants remember the emotional nature of the interaction, then infants should differentially respond to the emotionally valenced puppet compared to the neutral puppet. The latter pattern emerged at the 1-week post-test. Infants in the neutral condition looked longer at the novel puppet and displayed no positive

affect, whereas infants in the positive condition looked longer at the familiar puppet and smiled toward the puppet. These findings suggest that infants have the capacity to remember positive aspects of their interactions with others.

In a similar study using five infant age groups (6-, 9-, 12-, 18-, and 24-month-olds), all infants were familiarized to a similarly “rousing,” positive puppet (Brown, Robinson, Herbert, & Pascalis, 2006). Immediately following the interaction, infants’ recognition memory was tested in a VPC with the familiar puppet and a novel puppet. Infants aged 6, 9, and 12 months displayed no preference for either puppet, whereas older infants looked significantly longer at the familiar puppet. Again, these findings suggest that infants remember the positive aspects of their interactions with others. At first glance these findings appear to contradict the age at which Nachman et al. (1986) discovered this ability and to contradict the proposition of attachment theory that infants remember emotional experiences during the first year; however, several differences in the design of these studies should be noted. First, Brown et al. (2006) assessed infants immediately following presentation and found that infants under 12 months of age showed no evidence of memory. Similarly, Nachman et al. found no visual preference in 7-month-olds two minutes after presentation. These short delays may provide insufficient time for the infant to represent and consolidate the information from the events. Older infants, on the other hand, may be able to represent and consolidate the information in these shorter time frames. Second, in Brown et al.’s study, the experimenters were present and visible to the infants during the puppet interaction. The presence of the experimenter may have distracted younger infants from focusing on the puppet. Third, Brown et al. presented photographs of the puppets during post-test, rather than the actual puppets: this methodology may have contributed to differences across studies (see Carver, Meltzoff, & Dawson, 2006, for evidence that 18-month-

olds have difficulty recognizing two-dimensional images of objects that they learned in three-dimensions).

Infants have also demonstrated the capacity to remember social-emotional interactions with human interaction partners. Bigelow and Birch (1999) conducted a study investigating infant preference for contingent social interaction and memory for such interaction a week later. Four- to five-month-old infants were presented simultaneously with two adult strangers on video screens. One of the strangers was receiving live video feedback of the participating infant and interacted contingently with the infant. The other screen displayed a recording of a stranger who had been previously videotaped while interacting with another infant (i.e., this interaction with the participating infant was non-contingent). During familiarization, infants looked significantly longer at (i.e., preferred to look at) and displayed more positive affect toward the contingent stranger than the non-contingent stranger. Six days later, infants returned to the laboratory and were tested with a similar display of the same two strangers; this time, however, both strangers acted contingently. Infants preferred to look at the adult who had acted contingently in the first session. In addition, infants displayed more positive affect toward the previously contingent adult than the previously non-contingent adult as the test session progressed. Again, this study indicates that infants remember positive aspects of their interactions. If the infants had remembered only the identity of the experimenter without the associated emotional valence, a novelty preference would have been likely. Because infants were familiarized and tested with both the contingent and non-contingent adults, it is unclear from these findings whether the infants prefer the previously contingent adult or avoid the previously non-contingent adult, or both.

Similarly, Bornstein, Arterberry, & Mash (2004) tested infants' long-term memory for an emotional interpersonal interaction by varying the adult's contingent behavior. At 5 months of age, a group of infants participated in the "still-face" procedure (Tronick, 1989) with an unfamiliar female adult – a procedure that includes both positive (contingent interaction) and negative (still-face) interaction experiences. Fifteen months later, these infants, compared to another group of 20-month-olds who had not participated at 5 months, looked significantly *less* at the familiar woman compared to two new women. Given the design of this study, it is difficult to establish whether the infants simply recognized the woman or whether they remembered the emotional aspects of the initial interaction. A more recent study, however, compared the response of two separate groups of four-month-old infants to a maternal still-face procedure: one group was experiencing the still-face paradigm for the first time, and the other group had already experienced the paradigm two weeks before (Montirosso, Tronick, Morandi, Ciceri, & Borgatti, 2013). Researchers found different cortisol responses in the group with previous exposure, and argued that this suggests some memory effect for the previous salient social-emotional experience. There is also some limited evidence that at three years of age, children show some implicit memory effects for an experimenter they met at 12 months of age (Kingo, Staugaard, & Krojgaard, 2014), although this prior interaction did not have strong emotional valence.

Expectations for Others' Behavior

According to attachment theory, infants use their memory of past interactions with their attachment figures as the basis for their expectations about the likely behavior of their caregivers in new interactions (Bowlby, 1973; Bretherton & Munholland, 2008; Main et al., 1985). Attachment researchers suggest that infants' differential behavioral patterns in the Strange Situation procedure are the result of differential expectations about their caregivers' behavior

(Ainsworth et al., 1978; Main et al., 1985; Waters & Deane, 1985). For example, infants who approach their caregivers for comfort do so because they expect that their caregivers will respond sensitively, whereas the behavioral patterns of insecurely attached infants reflect expectations that their approach will be rejected or responded to inconsistently. It is possible, however, that infants behave in these ways, not because they have expectations about their caregivers' future behavior, but because they have developed experience-based feelings about their caregivers. For example, infants with a secure attachment to a caregiver may simply like to be with their attachment figure because of the caregiver's sensitivity; whereas infants with an insecure-avoidant attachment to a caregiver have been rejected by that caregiver in the past, and therefore, may not like being with their attachment figure, and infants who have insecure-ambivalent attachment to a caregiver have mixed feelings about that person. Given these alternative routes to manifest behaviors, which do not operate through expectations, there are limits to the extent to which these naturalistic observations can be used to support the existence of experience-based expectations. The next cognitive capacity we discuss is the infant capacity to use information from past experiences to guide their expectations of others in new situations. This set of research helps to strengthen claims that infant behavior in the Strange Situation is guided not by feelings about caregivers, but rather by experience-based expectations.

Non-social expectations. Considerable research has demonstrated that infants – in some cases as young as 2 months of age – form expectations for non-social events. Evidence suggests that infants can reason about both physical objects and action-effect contingencies, including situations where their own actions produce environmental effects (for the former, see Baillargeon, Li, Ng, & Yuan, 2009, and Spelke, Breinlinger, Macomber, & Jacobson, 1992, for reviews; for the latter see e.g., Hauf & Aschersleben, 2008, and also Rovee-Collier, 1997, for a

review of studies using the mobile conjugate reinforcement paradigm). The ability to predict event outcomes in non-social domains may support the prediction of future events in the social domain. Research indicates, however, that infants reason about the behavior of humans and animate objects quite differently from that of inanimate objects (Rakison & Poulin-Dubois, 2001), suggesting that different capacities may exist for predicting social events.

Social expectations. Research on infants' social expectations has been divided into two main areas that provide data relevant to the IWM concept: (a) infants' expectations during their face-to-face interactions with others, and (b) infants' expectations for other peoples' behavior after observing their previous behavior. Both sets of research lend support to the infant capacity to form an IWM, yet both sets have limits in this regard. Face-to-face paradigms often assess interactions with familiar partners (caregivers), and as such these studies have direct relevance for the development of the caregiver-specific IWM; these paradigms, however, may not directly measure expectation formation. Other studies of novel expectation formation typically do not involve a caregiver and instead involve infants viewing visual displays or an experimenter's actions. As such, these paradigms speak more directly to the infant capacity to generate expectations about future behaviors from viewing a set of past actions, and the predictive capacity is another key feature of the IWM. The real world context of these studies, however, is limited. Nonetheless, both sets of literature on social expectation can be viewed as providing important information about the formation of the IWM.

Expectations during face-to-face interactions. In addition to more basic paradigms that investigate the role of face-to-face interactions in conspecific recognition (e.g., Blass & Camp, 2001), some researchers have employed the still face paradigm (Tronick, 1989) and double-video procedures (Murray & Trevarthen, 1985) to study social expectations, under the assumption that

infant reactions during non-contingent interactions reflect infants' expectation for continued contingent interaction (e.g., Bigelow & Birch, 1999; Mesman, van IJzendoorn, & Bakermans-Kranenberg, 2009; Tronick, 1989). Particularly relevant to the IWM concept are those expectations that develop based on past interactions with a specific person. Starting at approximately 3 months of age, infants respond differently in face-to-face interactions with their mothers, fathers, and strangers (e.g., Kisilevsky et al., 1998), although there is evidence that this effect can begin by one month if infants have experienced extensive prior skin-to-skin contact with their mother (Bigelow & Power, 2012). Starting at approximately 4-5 months of age, infants respond more negatively when their mother, compared to a stranger, fails to pick them up during distress-relief sequences (e.g., Gekoski, Rovee-Collier, & Carulli-Rabinowitz, 1983; Lamb & Malkin, 1986) and stops interacting while assuming a "still-face" (Mesman et al., 2009). In addition, naturally occurring differences in maternal sensitivity and positivity during the baseline face-to-face interaction were positively correlated with infants' negative responses. Taken together, these results suggest that infants have different expectations for the behavior of different adults that appear to be based on their past experiences (or at least familiarity) with that person. Such face-to-face paradigms are important in that they include the attachment figure, rather than an experimenter, but they do not directly examine typical attachment-related situations (e.g., when the infant is distressed, scared, or hurt). This gap is important because attachment IWMs are based on the information that infants gain from attachment-related experiences with attachment figures. Thus, paradigms with an attachment-relevant interactive component may better capture the cognitive underpinnings of IWMs.

Additionally, although these results can be interpreted as supporting the capacity for infants to develop relationship-specific expectations, they do not speak to infants' capacity to

form flexible, novel expectations of their caregivers' likely behavior in new situations. The expectations for these face-to-face interactions may simply be built from past experiences in the same type of interaction. In order to support the IWM concept, research must test whether infants are capable of forming *novel* expectations of others' behavior based on past experience.

Expectations after viewing previous behavior. The past decade has seen remarkable advances in the methodologies and research designed to assess pre-verbal infants' understanding of other people. Much of this research has asked whether infants have the ability to predict the likely behavior of others based on those peoples' past behavior, which is a key component of the IWM that infants build of their attachment figures. In fact, Rochat and Striano (1999) defined social cognition as "the process by which individuals develop the ability to monitor, control, and *predict* the behavior of others (p. 4; italics added)." Attention to this body of research, therefore, should provide information relevant to infant capacities relevant to building an IWM. The social-cognitive research, just like the cognitive research on infant expectations in non-social domains, indicates that infants use a variety of information about people in past events to predict the likely behavior of those people in future events, including the observed person's past dispositions toward specific objects, agents, and actions.

Research on infants' understanding of intentionality and goal-directed action suggests that infants expect adults to behave in accord with their previously executed goals. For example, Woodward (1998) repeatedly presented infants with a display of an adult reaching for a target object while ignoring a distracter object until infants were habituated. Then, in the test trials, the location of the objects was changed and the adult either reached for a new object on the old path (new object choice, familiar action) or the old object on a new path (familiar object choice, new action). Under these conditions, infants as young as 6 months looked significantly longer at the

displays when the adult reached for the new object. These results are interpreted as the infants understanding that the adult had a goal of obtaining a specific object. Further studies confirm that if the environmental constraints surrounding the goal object change (i.e., the objects are in new locations, or obstacles are removed from obstructing the goal), infants look longer when adults persist in an old action pattern compared to when they simply reach directly for the goal-object (Csibra, 2008; Gergely, Nádasdy, Csibra, & Bíró, 1995; Kamewari, Kato, Kanda, Ishiguro, & Hiraki, 2005; Southgate, Johnson, & Csibra, 2008). When infants are nine months of age, neuroimaging measures are able to distinguish between infant observations of novel versus repeated goals (Southgate, Begus, Lloyd-Fox, di Gangi, & Hamilton, 2014).

Furthermore, infants as young as 5 months of age appear to understand these object-directed actions not only as intentional, but also as representing underlying preferences (e.g., Luo & Baillargeon, 2005, 2007). For example, Luo & Baillargeon (2007) habituated infants to an actor reaching toward an object rather than a distracter object that was either (a) visible to the actor and the infant (thus, the actor's choice could be interpreted as indicating her preference between the two objects) or (b) visible to the infant only (thus, the actor's choice could not indicate a preference because the actor was unaware that the other object was available). In test trials, infants' looking time patterns were consistent with the hypothesis that infants attribute preferences to people while observing their goal-directed actions and generate predictions about their behavior in new situations: Infants were surprised when the actor who saw both objects subsequently reached for the distracter object, but not when the actor who only saw one object reached for the distracter object. Further, at nine months, infants do not generalize preferences across actors, although they do generalize object labels, indicating an understanding of common and disparate internal states (Henderson & Woodward, 2012). Recent evidence does suggest,

however, that although infants can incorporate preference information, such information is not necessary for infants to make inferences about goal directed actions (Hernik & Southgate, 2012).

In addition to using adults' goal-directed actions as the basis for predicting behavior, infants use their understanding of adults' emotional signals and attentional cues (see Caron, 2009) to make predictions about people's likely behavior (Vaish & Woodward, 2010). Across two studies (Barna & Legerstee, 2005; Phillips, Wellman, & Spelke, 2002), infants aged 9-, 12-, and 14-months witnessed an adult look toward and positively comment on a target object. In test trials, the adult was shown either holding the target object (consistent with their emotional and attentional cues) or holding a new object (inconsistent event). In each study, infants looked longer at the inconsistent event, suggesting that infants expect people's actions to coordinate with their previous emotional and attentional signals. Despite this result, others have argued that infants do not understand adults' emotions in these contexts based on findings that 14-month-old infants were not surprised when adults approached a disgusting object (Vaish & Woodward, 2010). It is difficult, however, to draw conclusions from this study. There are several possible explanations for why an adult would approach a disgusting object and infants may have witnessed adults act in this seemingly inconsistent way (e.g., when changing their diapers or cleaning messes), leaving these findings open for multiple interpretations. Furthermore, they do not preclude the possibility that infants may use cues of emotions other than disgust to make predictions about a person's behavior (for example, fear and anger, two emotions particularly relevant to attachment behavior and IWMs). Substantial research is needed to clarify how infants interpret emotions more central to their attachment-related interactions with their caregivers.

Not all actions are performed toward objects as goals. Sometimes a person's goal is simply to perform the action. Song and Baillargeon (2007) investigated infants' (aged 9.5 months) ability to predict another person's behavior after witnessing that person engage repeatedly in an action (sliding multiple toys). During test events, infants watched the adult choose between two identical novel toys that were constrained by a wood frame that either allowed for sliding (long frame) or did not (short frame). Infants looked longer during the short frame events, suggesting that they expected the adult to select the "slidable" object and were surprised when they chose the "nonslidable" object.

Especially relevant to the claims of attachment theory, Buresh and Woodward (2007) have shown that 9- and 12-month-olds are capable of tracking specific people's goals. Using words that could come directly from a page of Bowlby's writings on caregiver-specific IWMs of attachment figures, these authors explain that tracking people's actions, goals, and intentions allows humans "to predict and interpret actions on-line by relating a person's prior and current behaviors, and distinguishing them from the behaviors of other persons" (p. 287). In a series of studies, Buresh and Woodward found a pattern of results suggesting that infants understand that different people have different goals, and infants use their knowledge of those specific people's past behavior to anticipate the people's likely behavior. As such, infants may be able to understand goals, even complex goals that occur during attachment related experience, and may use that information to expect how each parent will respond when the child shows attachment behavior in the future.

A recent paper by Licata and colleagues (2013) examined the link between seven-month-old infants' success at encoding an actor's goals and maternal emotional availability during a ten-minute free play session. Maternal emotional availability, but not infant temperament or

maternal education, predicted infant success at goal-encoding, as measured by looking times during the test phase of a Woodward (1998) habituation task (the ratio of looking time for the new goal to total looking time across both the new goal and the new reaching path outcomes). Although emotional availability was not measured in an attachment context, this is a promising new direction for research; this is one of the first papers to directly link infant behavior on a traditional cognitive development paradigm to caregiver behavior. The direction of causality is unclear, as is the age at which these links first emerge, but longitudinal studies could help parse apart some of these important questions.

Lastly, infants make predictions about the likely behavior of actors based on the way those actors have interacted with others. Although the studies reviewed here did not use human actors, previous research indicates that infants attribute human characteristics to human-like objects that are self-propelled and appear to have free choice (e.g., Gergely et al., 1995; Luo & Baillargeon, 2005). These studies are particularly relevant to the IWM of an attachment figure because they include relational and valenced information about others. In a pioneering study, Premack and Premack (1997) randomly assigned 12-month-old infants into four distinct value conditions, two positive and two negative. During habituation, infants viewed a computer-animated display where an agent (a self-propelled circle) either helped or hindered another agent pass through a hole. During the test event, all infants were shown a display where an agent hit another character (importantly, the hinder and hit actions were visually distinct, but conceptually similar). Infants who had been habituated to the helping event looked longer during the test than infants who had been habituated to the hindering event. These findings are consistent with the possibility that infants assign positive and negative value to agents' actions and expect agents to act in accordance with the assigned value. Consistent with these findings, Kuhlmeier, Wynn,

and Bloom (2003) and Hamlin, Wynn, and Bloom (2007) familiarized infants to a display where an agent (circle) was either helped or hindered in its goal to climb a hill. In later test events, 10- and 12-month-old, but not 6-month-old, infants discriminated test events in which the circle approached the helper versus the hinderer. In a separate forced choice task after viewing the same display, six-month-olds did show a robust preference to reach for the helper over the hinderer and neutral agents, as well as a neutral agent over the hinderer. Eye-tracking measures have also revealed that in a helper-hinderer task, 12-month-olds show anticipatory looking patterns consistent with expectations about social goals (Fawcett & Liszkowski, 2012).

One important consideration in reviewing the extant research is that there is debate in the infant cognition literature about the extent to which such habituation studies offer insight into the online processes of the infant while viewing a particular scene (Aslin, 2007). That is, surprise at an outcome may differ from real-time expectation generation. This distinction is especially important when considering IWMs, because a key feature of these representations is the infant's ability to generate expectations of how a caregiver is likely to respond (Bowlby, 1973).

According to attachment theory, it is the infant's expectations of the caregiver's behavior that guide the infant's behavior in interaction with that caregiver. Thus, the expectation must be generated prior to the caregiver enacting a behavior. There is some evidence from anticipatory looking paradigms using eye-tracking methods (including in the original Woodward, 1998, paradigm [Cannon & Woodward, 2012]) that infants may generate expectations. There is also evidence that this ability becomes more sophisticated in the second half of the first year of life (Falck-Ytter, Gredebäck, & von Hofsten, 2006). Further, at least by ten months, infants appear to show anticipatory looks toward the object an actor attempts to pick up, even if the attempts are unsuccessful (Brandone, Horwitz, Aslin, & Wellman, 2014). These studies present evidence that

infants may be generating expectations, and that these expectations may extend to situations the infant has never personally witnessed. From a non-social domain, 12-month-olds expected a blue ball to roll out of a lottery machine (even though they were never shown this type of outcome) when the blue ball was shown to be more common than a red ball (Téglás et al., 2007). Although forecasting the likely behavior of people may be more difficult, the research reviewed here suggests that infants begin using some information about the past behavior of others between 2 and 6 months, and that by 9 months of age infants are capable of using diverse information about the past behavior of others to anticipate those people's behavior.

Studies on infant capacity to predict behavior indicate that the second half of the first year of life is a time of substantial changes in goal understanding. Interesting work is currently being conducted on the potential of motor experiences to help produce more sophisticated action understanding in infants as young as three months (e.g., Gerson & Woodward, 2013; Sommerville, Woodward, & Needham, 2005), although evidence suggests that motoric experience alone does not explain action understanding (Skerry, Carey, & Spelke, 2013). The role of physical constraints and experiences on these cognitive systems is especially relevant for attachment researchers, as attachment is most often measured in the behavioral Strange Situation paradigm, which requires some motoric capabilities in the infant. It is possible that measures of attachment that better capture underlying cognitive systems could capture the formation of attachment patterns at an earlier age than is currently postulated (cf. Smith & Thelen, 2003, for examples of this from other cognitive domains).

The research with infants and toddlers reviewed here should be considered alongside the considerable research with preschoolers and school-age children that indicates that, before the age of approximately eight years, children have difficulty understanding the link between

personality traits and behavior (Alvarez, Ruble, & Bolger, 2001; Ruble & Dweck, 1995) and instead rely on broad evaluative judgments (i.e., he/she is a good or bad person). Preschoolers also have difficulty making behavioral predictions when an agent's actions result in an unexpected outcome (Zelazo, Helwig, & Lau, 1996). This literature, however, is not inconsistent with the findings in infants; rather, robust evidence indicates that the cognitive capacity for behavioral predictions of infants can scaffold the creation of IWMs, *and* that behavioral prediction is a multi-faceted process that continues evolving into childhood.

Understanding Interactions with Caregivers

Thus far, we have examined four core cognitive capacities relevant to various theoretical aspects of building an IWM of an attachment figure: discrimination and recognition of people (who attachment figures are), person permanence (where attachment figures are found), memory for past experiences (representations as experience-based), and expectations of other people's behavior (how caregivers are likely to respond). The final concept that we turn our attention toward – understanding interactions with others – is one that may be less centrally related to infants' core ability to *form* IWMs, but is relevant to the development of IWMs because when infants can understand nuances in their caregivers' behavior, they are better able to create accurate representations of and predictions about their caregivers. Specifically, we review the theoretical connection and empirical research relevant to IWMs for two additional capacities: understanding other people's emotions and understanding other people's intentions.

Understanding other people's emotions. During interactions with others, adults convey important information through their emotional expressions. A key task for infants is to develop the ability to discriminate among the many emotional expressions of others and to understand that these different expressions convey different emotional meanings (Stern, 1974). These

abilities are important for the formation of infants' internal working model of their caregiver because, according to Bowlby (1973), IWMs are based on infants' repeated attachment-related experiences with their caregivers, which are often highly emotionally charged experiences when the infant is scared, upset, hurt, distressed, and in need of comfort (Bowlby, 1969/1982). The caregivers' emotional response to infants' attachment signals (e.g., whether caregivers display positive or negative emotions) should contribute to infants' IWMs. Consider for instance, two infants who are wary of an unfamiliar person and each infant's mother responds by picking her child up. One mother displays her annoyance and disdain while holding her infant; the other smiles reassuringly and calmly. According to attachment theory, the internal working models that these two infants develop of their mothers should be quite different, even though both infants experience the same physical maternal behavior (i.e., both are picked up); this would only be possible if infants can appreciate the emotional expressions of others as meaningfully distinct.

Emotion discrimination. Considerable research indicates that even young infants can discriminate the major emotions, but that with development, infants become better at discriminating additional emotions and at recognizing similarities between different faces expressing similar emotions (Grossmann, 2010; Nelson, 1987; Walker-Andrews, 1997). Classic habituation studies have indicated that by 4 months of age, infants can discriminate among happy, angry, surprised, fearful, and sad expressions (e.g., Barrera & Maurer, 1981; Bornstein & Arterberry, 2003; Nelson, 1987; Young-Brown, Rosenfeld, & Horowitz, 1977). By 6 months of age, infants recognize similar emotions despite changes in intensity or age and gender of the model (e.g., Bornstein & Arterberry, 2003), and can even recognize emotions from bodily movements alone (Zieber, Kangas, Hock, & Bhatt, 2014). These emotional discrimination skills are not limited to the visual domain; recent work with neonates has indicated differential

responses to fearful, happy, and angry syllables, but not to nonvocal sounds controlled for low-level audio characteristics (Cheng, Lee, Chen, Wang, & Decety, 2012).

Emotion meaning. Emotional expressions are not simply visual stimuli to be differentiated. The studies reviewed above indicate that infants are highly skilled at detecting the difference between other people's facial expressions, but people's expressions convey a wealth of information about the people expressing them such as their motivations, goals, current dispositions, intentions, and future behavior (Walker-Andrews, 1997). Once the emotion is discriminated, the meaning of the emotion must be understood in order to be of any use to the observer (in this case, the infant).

Several studies show that young infants respond in meaningfully different ways and affectively match the different facial expressions of others (e.g., Bigelow, 1998; Cohn & Tronick, 1987; Mesman et al., 2009). For example, infants as young as 2.5 months expressed unique behavioral responses when viewing their mothers' live displays of joy, sadness, and anger (Haviland & Lelwica, 1987). When viewing happy and angry expressions, infants' facial expressions were influenced by the mother's emotion (e.g., increased "no movement" in response to mother's anger, increased joy and interest in response to maternal joy), indicating that infants respond to their mother's emotions beyond simple imitation. Similarly, Montague and Walkers-Andrews (2001) found that 4-month-olds produced unique looking patterns and facial expressions to each emotional expression of an unfamiliar experimenter. From baseline (i.e., an experimenter's happy expression during peak-a-boo), infants' looking time initially increased and then decreased across trials for fearful expressions, consistently increased across trials for angry expressions, and decreased across trials for sad expressions. Infants' affective responsiveness (i.e., interest/surprise, matching of discrete emotions, lability, and facial

expression time) also changed when the experimenters changed their expressions from happy to fearful, angry, and sad.

Further, by four months, infants are able to integrate emotional and eye gaze cues, which may be relevant for interpreting caregiver behavior. Four-month-olds are also sensitive to the matching of gaze direction and emotion, as when approach emotions (e.g., happy) are paired with direct gaze (Rigato, Menon, Farroni, & Johnson, 2013). By seven months infants are sensitive to the congruency between verbal and facial emotions, looking longer at congruent videos for both positive and negative emotions (reviewed in Walker-Andrews & Dickson, 1997). Attesting to developmental change in integrating emotional information with other cues, by fourteen months, but not at ten months, infants are sensitive to the congruency between an actor's emotional valence and his/her actions (e.g., happy actors portray positive actions; Hepach & Westermann, 2013). Findings that infants anticipate some concordance between emotion and behavior further supports the idea that infants may incorporate detection of caregiver emotion with predictions for likely behavior, which is a feature of IWMs. Future research should explore infant understanding of other people's emotional signals specifically as they relate to the infant's attachment signals.

In addition to differentially responding to others' emotions, infants use adults' emotional responses to learn about ambiguous objects and events in their environment. For example, 12-month-olds saw an experimenter direct either positive, negative, or neutral affect toward a target object and ignore a distracter object. In later play sessions, infants in the negative condition subsequently avoided the target toy and displayed more negative affect than infants in the other emotional conditions (Mumme & Fernald, 2003). Relatedly, 12-month-olds preferred objects that adults had displayed positive affect toward after a 5-minute and 1-day delay (Flom &

Johnson, 2011). The effect of adults' emotional responses also extends beyond behavior. Evidence from two studies examining event related potentials (ERPs) indicates that at 12 months, infants' neural responses when viewing objects is differentially affected by whether an adult has previously indicated positive, negative, or neutral emotion toward the object (Carver & Vaccaro, 2007; Leventon & Bauer, 2013). Further, both ERP studies found that increased infant visual attention was related to increased neural response to negative condition stimuli, indicating important links between brain and behavior that merit further investigation.

Infants also use the emotional information provided by others about objects to make inferences about how those people will behave in subsequent interactions with the objects. Barna and Legerstee (2005) exposed 9- and 12-month-old infants to either a Happy or Unhappy person who looked at an object and said either "Ooo, I like objects" or "Oh, I don't like objects," respectively. Then, infants were habituated to a display of that person holding the object, but the person's face was obscured. After habituation, infants were shown either the person holding the object with a happy expression (consistent event for the Happy condition) or an unhappy expression (inconsistent event for the Happy condition). Infants looked significantly longer at the inconsistent events in the Happy and Unhappy conditions, suggesting that the infants expected the person to show consistent emotions when holding the target object. One interpretation of these data is that the infants understood the person's emotional feeling toward the object, but it is also possible that infants were simply surprised when the person changed expression. Either way, there is evidence that infants expect a person's emotions to remain consistent when the situation (i.e., the objects) remains consistent.

Not only do infants use available social information to interpret situations, but considerable research now indicates that infants actively seek such information through

referential looking as young as 7 months of age (e.g., Baldwin & Moses, 1996; Striano & Rochat, 2000). This research consistently shows that infants look toward adults in the environment and – particularly in ambiguous settings – behave as a function of the emotional signals that the adult conveys (e.g., Feinman & Lewis, 1983; Gunnar & Stone, 1984; see also Carver & Cornew, 2009). The visual cliff is an apparatus commonly used in studies to evaluate infant social referencing. In these studies, infants are placed on one side of a divide and an adult (either mother or experimenter) is on the other side of the divide. The distance and height of the divide can be visually manipulated such that infants clearly know it is safe, clearly know it is unsafe, or are unsure whether it is safe to cross. Studies show that when infants are unsure whether crossing the divide is safe, they will cross if their mother signals that it is safe, but will not cross if their mother expresses fear (e.g., Sorce, Emde, Campos, & Klinnert, 1985). Using a socially ambiguous event (as opposed to an environmentally ambiguous event), Striano and Vaish (2006) found that 7- and 9-month-old infants looked toward an adult experimenter's face during an ambiguous interaction (when she teased the infants with a toy), but not when her actions were clear (she gave the toy to the infants). Furthermore, in the ambiguous interactions, both 7- and 9-month-olds looked longer at the adult when her expression was neutral than when it was happy. The authors suggested that the infants may have been searching the experimenter's face for information to interpret these ambiguous interactions and may have needed more time to interpret her behavior when paired with a neutral expression.

Infants also engage in social referencing during distressing situations. Striano and Rochat (2000) found that between 7 and 10 months of age, infants develop selective social referencing. The researchers exposed 7- and 10-month-old infants to a mechanical barking dog while an experimenter either looked toward the infant or looked away. Seven-month-olds referenced the

experimenter after the dog barked in both the looking toward and looking away conditions, whereas 10-month-olds referenced the experimenter after the dog barked only in the looking toward condition. These results suggest that infants in this age range seek out the emotional signals of social partners and that by 10 months of age, infants can appreciate the subtlety in the availability of adults during distressing situations.

Understanding other people's intentions. Understanding the intentions of others is an important development that supports survival, social affiliation, and culture (Tomasello, Carpenter, Call, Behne, & Moll, 2005). By recognizing that other people's behavior is not random, but that it is instead executed with specific goals in mind, individuals can better understand people's current behaviors and their likely behavior in the future. In this section, we focus on infants' understanding that other people act intentionally (as opposed to randomly) and infants' ability to determine another person's intention.

With respect to the IWM, infants who understand that caregivers' responses to their attachment signals are not random, but are executed intentionally, will be better able to accurately represent their own past experiences and predict their caregiver's future behavior. For example, parents who are uncomfortable with closeness and infant dependency may respond to their infants' distress by distracting them with toys or telling their infants that they are fine while failing to comfort them. Both behaviors, although quite distinct from each other perceptually, signal to the infant that the parent does not intend to directly soothe the infant. If infants can ascertain the intentions that underlie their caregivers' behavioral responses, then they can develop more accurate representations and expectations for their caregivers' likely behavior. In addition, individual caregivers vary in their responsiveness across time and context. Caregivers might have the intention of comforting their infants, but be unable to respond sensitively due to

environmental constraints (e.g., driving a car) or inability to ascertain the infants' needs. Infants who can decipher the difference between their caregivers' intentional insensitivity from accidental or unavoidable insensitivity can make better sense of their caregiver's behavior and make more accurate predictions in the future. A caregiver who accidentally or unintentionally acts insensitively should not be expected to be insensitive in the future, whereas a caregiver who intentionally responds in an insensitive way would be expected to be so in the future. One reason why infants might ignore their caregiver's model-inconsistent behavior is that they recognize the unintentional nature of these uncommon instances. It is important, therefore, to uncover the intentions of other people to develop accurate representations of their general behavioral patterns and their specific behaviors.

Infants' understanding of others as intentional agents has been well studied in the social cognitive literature and reviewed extensively (see Csibra, 2010; Tomasello et al., 2005; Vouloumanos & Onishi, in press; Woodward, 2009; Woodward, Sommerville, Gerson, Henderson, & Buresh, 2009). As Woodward (2009) noted, research using diverse methodologies converges on the notion that infants do not simply view others' actions as chaotic movements, but rather that infants understand others' actions "as structured with respect to external goals and objects of attention (p. 228)." Studies assessing infants' looking times during familiarization and habituation suggest that infants, beginning between 5 and 6 months, understand actions as goal-directed rather than random (e.g., Legerstee, Barna, & DiAdamo, 2000; Woodward, 1998). Specifically, infants encode the end goal-state as important to the adult rather than the specific nature of the movement made to achieve that goal (e.g., Carpenter, Call, & Tomasello, 2005; Csibra, 2008; Verschoor & Biro, 2012). In the second half of the first year of life, and into the second year, the ability of infants to understand intentionality continues to improve and grows

more sophisticated. For example, 10-month-olds, but not 8-month-olds, show anticipatory looking during goal-directed actions, even if the actor never achieves his goal (Brandone, Horwitz, Aslin, & Wellman, 2004).

In a series of studies, Behne, Carpenter, Call, and Tomasello (2005) assessed 6-, 9-, 12-, and 18-month-old infants' reactions to conditions in which an experimenter ceased giving toys to the infant because she was either "unable" or "unwilling" to do so. The unable adult began to hand the infant a toy and then she accidentally dropped the toy, whereas the unwilling adult began to hand the infant a toy and then pulled the toy back. In both conditions the infants did not receive the toy, but the adult's behavior was quite different. Starting at 9 months of age, compared to infants in the "unable" condition, infants in the "unwilling" condition responded with more negativity and frustration. These results were replicated and extended using slightly different assessments to show that even the 6-month-old infants differentiated the unwilling and unable intentions of adults (Marsh, Stavropoulos, Nienhuis, & Legerstee, 2010). The ability to detect goals and intentions also intersects with the emotion recognition ability discussed in the previous section. By eight months of age, infants are sensitive to emotional reactions that are congruent or incongruent with the outcome of goal directed action (Skerry & Spelke, 2014). Although there is some evidence that intentional inferences in infancy may require explicit behavioral cues (Legrain, Destrebecqz, & Gevers, 2012), together, these studies indicate that infants can interpret other people's intentions and are more forgiving of accidental mishaps than intentional withholding.

Extrapolating from the findings reviewed in the previous paragraph, it seems possible that infants would understand their caregivers' unwillingness to respond to certain infant emotional states or attachment needs. Furthermore, when parents are temporarily inaccessible or

unable to respond sensitively, infants may understand that these responses are not intentional, and thus refrain from integrating them into their IWM; such infant understanding may partly explain why IWMs become increasingly resistant to change. Woodward (2009) concluded her review of intentionality understanding in infants by highlighting three aspects of intentionality understanding that have not yet been fully explored; and each of these three aspects is particularly relevant to forming an IWM of an attachment figure: infants' understanding of (a) others' social intentions, (b) how others' emotions relate to the others' actions and intentions, and (c) others' intentions and actions over time. At the time of Woodward's review, there had been some relevant work in these areas (e.g., for social intentions see Hamlin et al., 2007, and Kuhlmeier et al., 2003; and for emotion understanding see Phillips, Wellman, & Spelke, 2002); more recent research has also tackled these topics (e.g., Hamlin, Wynn, & Bloom, 2010; Hamlin & Wynn, 2011; Hamlin, Wynn, Bloom, & Mahajan, 2011; Hamlin, 2013; Vaish & Woodward, 2010). These studies, however, do not fully explain the development of these cognitive capacities, especially as they relate to attachment theory, and future research on the infancy period will be informative.

Studies with older infants and toddlers also indicate that children understand the distinction between adults' intentional and accidental actions. In some of the first such studies, 14-month-olds were more likely to imitate the actions of an adult when the action was marked as intentional ("There!") rather than accidental ("Whoops!"); Carpenter, Akhtar, & Tomasello, 1998) and 18-month-olds were more likely to imitate the goal-directed aspects of an action (i.e., pushing a button) rather than the failed attempts at an action (Meltzoff, 1995). In these two studies, younger infants were not tested, but follow-up studies have demonstrated that 12-month-olds also imitate the goal-relevant aspects of adults' actions rather than the motions themselves,

suggesting that infants understand the intentions of the adult (e.g., Carpenter et al., 2005; Schwier, Van Maanen, Carpenter, & Tomasello, 2006). Further, there is evidence of intention understanding in young children from an observational paradigm involving infants watching puppet displays. Hamlin (2013) found that 8-month-old, but not 5-month-old infants, prioritize an actor's intentions over outcomes when choosing a puppet in a post-test forced choice selection (i.e., placing a hand on the puppet). The older infants pick a puppet who attempted to help, rather than one who attempted to hinder another puppet, regardless of the puppet's success.

Directly speaking to the parent-child relationship, Legerstee and Markova (2007) conducted an extension of the classic still-face paradigm with two novel conditions: cladding the mother in a mask and having the mother drinking from a bottle. Both conditions duplicated the lack of interaction during the control still-face condition, but crucially provided a reason for the change in the mother's behavior. Consistent with the hypothesis that infants are sensitive to intentionality considerations, infants as young as three months showed significantly less distress when the mother's responsiveness was externally constrained than when she was presenting a still-face with no external justification.

Summary of Changes Across Social Cognitive Domains

In summary, the existing research indicates that infants have the social-cognitive capacities to support the formation of IWMs in the first year of life. First, by at least five months of age, infants have the ability to discriminate between adults and recognize familiar adults (e.g., de Haan et al., 2001; Pascalis et al., 1995, 1998), supporting the notion, foundational to the IWM, that infants know who their attachment figures are (Bowlby, 1973). Second, data indicate that infants have the capacity to know where their attachment figures may be found (i.e., person permanence), which is a key notion of the IWM (Bowlby, 1973). Third, studies of infant

memory for social-emotional interactions suggest that infants within the first year possess the capacity to remember some emotional aspects of their interactions. The looking time patterns and affective responses exhibited by infants after receiving a single social-emotional experience indicate that infants remember key aspects of these interactions related to building an IWM: the “who” (specifically the findings of Bigelow & Birch, 1999) and “what” (positive, contingent, non-contingent) of experiences. Future research should investigate how repeated and/or varied types of emotional interactions are represented for a single person. Fourth, reviewed literature, principally employing habituation studies, indicates that infants are sensitive to the behaviors of others and to whether this behavior deviates from expected patterns. Especially important in determining the link between this capacity and IWM formation will be more interactive, anticipatory paradigms that determine infants’ abilities to generate novel predictions for the likely behavior of others based on their past social-emotional interactions with those people. Finally, in the first year of life, infants demonstrate significant improvements in understanding others across two domains: emotion and intention. Several open questions remain about whether emotion or behavior take primacy in shaping IWMs (e.g., perhaps the angry mother still rocks the infant compared to a happy mother who refuses tactical contact), but infant emotion understanding is likely foundational to IWMs. In terms of intention understanding, evidence from a wide variety of paradigms converges to suggest that during the last half of the first year, children become better able to represent the intentions of others, although these skills continue to mature and refine through development. Thus, across the first twelve months of life, infants experience developmental changes across a variety of capacities fundamental to the formation of the IWM.

Future Research Directions and Conclusions

The notion that infants develop experience-based mental representations called internal working models (IWMs) of specific attachment figures to predict that figures' likely behavior in future interactions is a core part of attachment theory. This review has shown that infants possess many cognitive capacities relevant to forming internal working models of their attachment figures, but the mechanisms for how these capacities dynamically scaffold the real-world creation of caregiver-specific IWMs are unexplored. Thus, we now review several perspectives and methodologies that will be fruitful for future research. Specifically, we review how future research should address developmental perspectives (with a focus on how statistical learning may be a relevant developmental mechanism for building the IWM), consider biological perspectives, employ interactive paradigms, and examine multiple influences on the IWM.

Developmental Perspectives

Development of attachment and representations. On the basis of observational data available at the time, Bowlby (1969/1982) proposed three phases of normative attachment formation during the first year: preattachment, attachment-in-the-making, and clear-cut attachment. During preattachment (approximately birth – 6 weeks) infants' behavior is characterized by non-discriminating social responsiveness. During attachment-in-the-making (approximately 6 weeks – 6 to 8 months) infants show differential responsiveness to their familiar caregivers. Finally, clear-cut attachment (approximately 6 to 8 months – 18 months) is characterized by the infant's active attempts to gain proximity to their caregivers and separation anxiety. These phases are highly tied to infants' motor and locomotor skills and detail developments in the formation of observable attachment behaviors rather than the infants' cognitive representations. The reliance on infant motor skills to establish the presence of cognitive models, however, is unreliable. Much like Piaget's classic A-not-B task for

establishing object permanence, it is possible that the timing of these phases may not match the development of representational models (cf. Smith & Thelen, 2003). A fruitful avenue for future research would be to examine how attachment representations either map onto this developmental timeline or challenge the timing of the phases.

It is possible that IWM formation may be evident earlier than can currently be measured behaviorally, and that individual differences may emerge before they are detected in the Strange Situation procedure. Discovering more nuanced measures of attachment, perhaps relying on eye-tracking and neural measures (e.g., EEG/ERP)—which offer real-time information about infant cognitive processes as compared to traditional looking time studies—may provide better insight into the development of individual differences that may be associated with the development of IWM. These new measures may allow for studies that can help identify necessary and sufficient cognitive abilities in the formation of attachment representations. Further, such measures are well suited for the necessary longitudinal work that can best map caregiver behaviors to IWMs.

Changing cognitive capacities over development. The cognitive development research literature considered in this review indicates that there are several domains whose developmental trajectories are well characterized, including face processing, memory, and intention understanding. For example, research from these fields indicates that basic face recognition is present in infants before intention understanding comes online (although the latter can be manipulated to occur earlier in the first half of the first year of life if specific motoric experiences are present; e.g., Gerson & Woodward, 2013; Sommerville, Woodward, & Needham, 2005). Attachment researchers could take advantage of these paradigms by designing studies that examine specific ages in which particular abilities have (or have not) developed. For example, individual variations in intentionality understanding in the 8- to 10-month window

(known as the “nine-month revolution;” Tomasello, 1999) could be related to attachment behaviors. Thus, research that examines how changing cognitive capacities support, explain, or coincide with developments in attachment will be particularly informative to both cognitive developmental scientists and attachment researchers. This avenue of research may allow for studies that can help establish necessary and sufficient cognitive abilities in the formation of attachment representations. Ultimately, longitudinal research will best answer questions regarding how changing cognitive abilities interact with developments and changes in the IWM.

Cumulative experiences. Research designs should incorporate multiple experiences with others to determine how repeated and varied experiences are remembered, represented, and used to generate expectations about others’ likely behavior. For example, research could examine how infant expectations are affected by different ratios of positive and responsive versus negative and unresponsive behaviors and the timing and order of such behaviors. A sample laboratory study might include presenting the same ratio of positive and negative interaction, but with varying order (e.g., presenting all negative vignettes at the beginning or the end). This line of research could answer questions about what patterns of interactions lead to secure attachment representations and how IWMs can change. Further, studies could more directly examine whether infant expectations about caregiver behavior are less malleable later in development, as would be consistent with the propositions of attachment theory that IWMs become more canalized and stable over time.

The idea of cumulative experiences intersects with the idea of sensitive periods in attachment. Although there has been extensive debate about sensitive periods in attachment, there is less evidence for concrete timeframes. Studies of institutionalized children (i.e., children developing in an environment that significantly disrupts their ability to form organized

attachments) indicate that early experiences can have a lasting effect on attachment behavior and general psychopathology (McLaughlin, Zeanah, Fox, & Nelson, 2012). Further, studies comparing adopted children to those who remain in institutionalized environments indicate that early adoption (i.e., before 12 months of age) does increase the likelihood of children becoming securely attached to their adoptive parents (for meta-analytic findings, see van den Dries, Juffer, van IJzendoorn, & Bakermans-Kranenburg, 2009).

Such studies, however, do not directly answer the question about relative sensitive periods *within* the first year of life. Given the developmental progression of capacities such as intentionality and goal understanding, there seems to be evidence that these abilities are much more robust in the second half of the first year of life. This leads to the interesting possibility that experiences later in the first year may be more meaningful than experiences early in the first year in terms of consolidating attachment patterns. Such higher-level cognitive paradigms, however, do not address the more biological bases of attachment (e.g., heart-rate synchronization or other “hidden regulators;” Hofer, 1994), which may be most malleable and influential earlier in infancy. At the time of his writings, Bowlby (1969/1982) proposed that infants began forming their IWMs “towards the end of his first year” (p. 354) whereas more contemporary attachment theorists have suggested that “some type of internal working model of specific relationships may be formed in the first months of life” (Main et al., 1985, p. 76). Given the ethical and practical difficulties of manipulating human infant experience, it is difficult to answer questions about fine-grained sensitive periods, and animal studies fail to capture the development of IWMs. In spite of these limitations, studies that involve sensitive parenting interventions implemented at different times in the first year of life may help address questions about sensitive periods in

attachment formation and whether early representations are more influential than later representations.

Statistical learning. The above discussion of developmental changes has focused on the body of evidence supporting the existence and development of relevant cognitive capacities, with less emphasis on the *mechanism* enabling these abilities. Yet one particularly compelling mechanism merits a brief discussion: the infant's capacity for statistical learning. Originally studied by developmental psychologists in the context of language acquisition (e.g., Saffran, Aslin, & Newport, 1996), statistical learning refers to a domain general mechanism by which the infant implicitly detects contingencies and probabilities in the world to extrapolate underlying structures and principles. Since the original work in language acquisition, statistical learning in infancy has been extended to the visual domain (Fiser & Aslin, 2002; Kirkham, Slemmer, & Johnson, 2002) and even to cross-situational contexts, with evidence for significant improvements in the second year of life (Vlach & Johnson, 2013). Statistical learning is even present in sleeping neonates, who show a different brain response to repeated versus novel sequences (Teinonen, Fellman, Näätänen, Alku, & Huotilainen, 2009). The ability of an infant to observe contingencies and thus to form expectancy models to guide the processing of future input has remarkable applications not only to the individual cognitive capacities supporting IWMs, but to the concept of IWMs themselves.

Recently, the idea of statistical learning has been extended to social domains. In a recent review, Ruffman, Taumoepeau, and Perkins (2012) discussed the relevance of statistical learning to infants' performance on theory of mind and intention understanding tasks. The authors suggest that statistical learning allows the child to predict actions, which has implications for the IWMs discussed in this review. Other work with adults suggests that statistical learning can

serve as a sufficient mechanism for understanding social signals (Turesson & Ghazanfar, 2011), and given that many of these implicit learning mechanisms may be relatively unchanged with age (reviewed in Perruchet & Pacton, 2006), such mechanisms may also explain infant social learning. Future work could extend statistical modeling to understand contingencies that an infant may extract from caregiver behavior. For example, Cassidy and colleagues (2013) explicitly addressed the potential role of statistical learning in the formation of attachment patterns, noting that this mechanism could allow infants to learn if-then contingencies and probabilistic response patterns (e.g., if I do *x*, there is a 30% chance that Mom will do *y*). Future research could include determining whether infants can take context into account, how infants construct different models for different caregivers, and how these processes change over development (Cassidy, Jones, & Shaver, 2013).

Biological Perspectives

Although this review focuses on mental representations, there is increasing awareness of the importance of understanding how developing attachment-related representations intertwine with simultaneously developing non-representational processes (e.g., calibration of the HPA axis; Polan & Hofer, 2008; Suomi, 2008). Studying how cognitive models interact with physiological processes will shed light on the IWM concept as well as on development more broadly (see Cassidy, Ehrlich, & Sherman, 2013, for extensive discussion). Including physiological measures (e.g., cortisol, heart rate, pupil dilation) in emotionally valenced paradigms could provide important information. These physiological measures could be complemented by recent advances in neuroimaging with infants (e.g., fNIRS; Ferrari & Quaresima, 2012; resting state fMRI in sleeping infants; Fransson, Aden, Blennow, & Lagercrantz, 2011). Emerging research designs that integrate social, emotional, and cognitive

development will be most fruitful in assessing the specific capacities tied to the IWM concept (see Pessoa, 2008, for discussion of the intertwining of emotion and cognition processes in the brain).

Physiological measures will also complement the looking time measures frequently employed in the social cognitive literature, given that traditional looking time studies may not directly address questions of real-time infant expectations. Further, looking time measures have been criticized for producing results that can be attributed to low-level perceptual characteristics, rather than complex, higher-order infant cognition (e.g., Bogartz, Shinskey, & Speaker, 1997; Wakeley, Rivera, & Langer, 2000, although see Wynn, 2000). In a review of infant looking time studies, Aslin (2007) argued that in spite of methodological concerns and complexities with looking time data (e.g., the measure is coarse, baseline values are unclear), combining such measures with behavioral and physiological measures may help to illuminate underlying mechanisms of infant cognition. Given that studies that best speak to the attachment IWM will include emotional components, measuring infant affective responses during traditionally more cognitive paradigms will be important.

Interactive Paradigms

In addition to incorporating developmental perspectives and biological perspectives across multiple experimental paradigms, future research should also include studies in which the infant is an interactive partner. The majority of extant studies on infant social cognition studies involve the infant observing another person, or person-like stimulus (e.g., a puppet), rather than participating in a dynamic interaction. Although studies with infant observers provide important information, interactive paradigms have particular import for questions of intersubjectivity, or the infant's awareness of and alignment with the internal states of others, which inherently

involve the unfolding, dynamic relation between the infant and the caregiver (e.g., Trevarthen, 1980; Trevarthen & Aitken, 2001). Trevarthen (2011) argues that, even in neonates, the drive to coordinate action with conspecifics is evidenced by behavioral and physiological measures. This drive for coordination intersects with the idea of attachment bonds, and may provide the impetus for some of the experiences that consolidate that bond.

Given the theory of intersubjectivity, future research on infant understanding of social expectations may benefit from including live interaction, as opposed to having the infant merely observing the experimenter. One study indicating the potential efficacy of this approach was the work of Kuhl and colleagues (2003), who exposed infants from monolingual English-speaking homes to either videos of a Mandarin speaker or sessions of live interaction with a Mandarin speaker. Only infants exposed to the live interaction preserved the contrast between Mandarin phonemes (Kuhl, Tsao, & Liu, 2003). Socially, two-month-old children are sensitive to whether they are viewing a recording of their mother versus a live videofeed (Murray & Trevarthen, 1985), and toddlers will synchronize with the drum beats of another person, but not a recording (Kirschner & Tomasello, 2009). In terms of learning about others, which is especially relevant for understanding IWMs, interacting with another person facilitates understanding and prediction of their likely behavior compared to simply observing the person (i.e., both 14- and 18-month-olds were capable of predicting the other person's behavior toward a toy when they had interacted with the person, but only 18-month-olds were capable based on observation alone; Moll, Carpenter, & Tomasello, 2007).

Thus, the theory and research reviewed above suggest that paradigms with an interactive component may better capture the cognitive underpinnings of IWMs than do traditional laboratory paradigms that involve observing others in a detached context. For example, future

studies of intention understanding could be embedded in an ongoing interaction in which the experimenter's goals are directly relevant to the infant. Further, such interactive studies would benefit from including emotional components. As discussed earlier, the most relevant experiences for infants building representations of attachment occur during attachment-related interactions, such as when the infant is distressed and seeking comfort from caregivers. As such, the situations themselves are inherently emotionally salient, and the caregiver's response to the infant's attachment behaviors (e.g., comfort, rejection, sadness) produces further emotional reactions for the infant. Thus, research studies from a cognitive perspective that do not include social and emotional components or an interactive component will be limited in their ability to fully address the development of IWMs of attachment.

Multiple Influences on IWMs

Multiple factors undoubtedly contribute to the formation of the infant's IWM, including caregiver behavior, infant characteristics, the broader socio-cultural context, and the interactions among these factors. For example, research has indicated the "match" between a parent and infant in terms of the adult's attachment style and the infant's temperament can predict infant attachment quality (Cassidy, Woodhouse, Sherman, Stupica, & Lejuez, 2011). Although a full discussion of these factors is outside the scope of this paper, the most useful future research will incorporate contributing factors at multiple levels.

Additionally, there may be common factors that influence *both* attachment-related interactions *and* the infant cognitive capacities reviewed in this paper. For instance, recent research using language paradigms with adults has suggested that individual differences in statistical learning explain differences in language processing (Misyak & Christiansen, 2012; Misyak, Christiansen, & Tomblin, 2010). Although individual differences in infant statistical

learning are underexplored, we speculate that infants with greater capacity to detect contingencies and generate expectations might be more successful at traditional laboratory cognitive tasks and show more accurate and, perhaps, earlier-emerging IWMs (see Frankenhuis et al., 2013). Also relevant is the possibility that motor development may relate to both cognitive development and IWM formation. For instance, the onset of crawling brings with it more flexible memory retrieval in cognitive tasks (Herbert, Gross, & Hayne, 2007), and also provides infants with a new means of gaining proximity to their caregivers (i.e., a new attachment behavior). It is possible, then, that the timing of infant locomotion influences the development of the IWM through multiple channels – that is, by improving infants’ ability to remember their attachment-related interactions and by providing infants with a more active strategy for seeking their caregivers – and additionally through the effect that infant locomotion has on changing caregivers’ behavior to become more negative and disciplinary (Thompson, 2006).

Beyond individual differences in infants (e.g., sex, temperament), there may be broader contextual or caregiver-based factors than also influence both infant cognitive capacities and the attachment relationship. Given the limited body of research on these questions, future research should employ models that account not only for the role of cognitive capacities in forming IWMs, but also factors that directly influence both cognitive capacities and the IWM. An especially important direction will be to consider how cognitive capacities, attachment-relevant interactions, and the IWM influence each other (e.g., infants who have experienced disorganized caregiving may come to represent the world as an unpredictable place, which could influence the ability to succeed on cognitive tasks that require sensitivity to contingencies; c.f. Frankenhuis et al., 2013).

Conclusions

Both attachment researchers and social-cognitive developmental researchers can learn from each other's theoretical models and methodologies to better understand the intersection of social, emotional, and cognitive development in infancy. Future work will help elucidate which capacities are necessary, sufficient, and supportive of the formation of the infant's experience-based internal working model of a caregiver's behavior in attachment contexts. It may be that understanding of intentions is not necessary for developing an IWM of an attachment figure, but having that understanding allows the infant to make more accurate predictions about their caregiver's likely behavior. Moreover, as infant cognition research grows more sophisticated, additional relevant capacities may be identified. In addition to identifying additional capacities for the IWM of an attachment figure, researchers should work to understand whether the model of the self develops from the same cognitive capacities, or whether additional capacities, such as self-recognition, are related or necessary for the model of self in the attachment relationship. The list of cognitive capacities in this review is not meant to be exhaustive, but is meant rather to begin a dialog between attachment researchers and cognitive developmental scientists to achieve a comprehensive understanding of infant development.

It is our hope that attachment researchers will re-focus their attention on the study of the development of the IWM. Much work has explored the important role of IWMs as a mechanism for explaining the link between early experiences and later developmental outcomes (e.g., Cassidy, Kirsh, Scolton, & Parke, 1996), yet there remains much to be learned about how and when the IWM develops in the infant mind. Moreover, when attachment researchers have attempted to understand the formation of the IWM, they have focused principally on the parent factors that contribute to the development of the infant's model, while largely ignoring the role of the infant as a social-information processor (see Dykas & Cassidy, 2011, for a review of

attachment and social-information processing). We urge researchers to consider how the infant's developing cognitive capacities contribute to the formation of the model. To do so, attachment researchers will need to tap into a toolbox of useful methodologies that have long been used by developmental scientists studying infant cognition, along with new advances in fMRI, ERP, NIRS, and pupil dilation. These new tools will allow researchers not only to explore propositions of attachment theory in new ways, but also to extend Bowlby's original theoretical ideas regarding the formation and maintenance of the IWM. Additionally, social cognitive researchers could incorporate more interactive and emotional paradigms to better capture real-world infant experience. As researchers continue to flesh out Bowlby's initial framework about IWMs, it will be particularly important to explore this concept from multiple methodological perspectives. The multiple methodologies, combined with the theoretical perspectives from a variety of disciplines, will help illuminate how infants form their earliest important relationships.

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