REVISITING THE FIRST YEAR INVENTORY WITH A DIMENSIONAL APPROACH TO ASSESS THE PREDICTIVE VALUE OF INFANT ATTENTION BEHAVIORS

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ABSTRACT

Rebecca Louise Stephens: Revisiting the First Year Inventory with a Dimensional Approach to Assess the Predictive Value of Infant Attention Behaviors
(Under the direction of J. Steven Reznick)

Research supports a strong relationship between early attention behaviors and neurological attention networks and later cognitive and social capabilities, including impairments associated with autism spectrum disorder (ASD). The First Year Inventory (FYI) was designed to flag 12-month-olds at risk for a diagnosis of ASD. The goal of the current study was to develop new constructs from FYI items that reflect aspects of attention, through a comprehensive literature review of behavioral and neurological correlates of infant attention, feedback from other researchers, statistical analyses and associations between the new constructs and clinical outcome data. We operationalized three new constructs of attention: responding to attention coordination (RAC), initiating attention coordination (IAC) and sensory and attentional engagement (SAE). Cronbach's *alpha* analyses indicated good internal consistency, and regression analyses showed a significant relationship between scores on these new constructs at 12 months and ASD symptom severity at age three.

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To my advisor: I can't imagine a better graduate school experience. I am fortunate to have the opportunity to learn from you and am extremely grateful for your guidance and support. Here's to another two years.

To my program director: Thank you for your unwavering support through times of challenge and times of success. You have helped make this program my home.

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ASD	autism spectrum disorder
EDP	Early Development Project
EEG	electroencephalography
EF	executive function
ERP	event related potential
FYI	First Year Inventory
IAC	initiating attention coordination
IBR	initiating behavior requests
IJA	initiating joint attention
RAC	responding to attention coordination
RBR	responding to behavior requests
RJA	responding to joint attention
SAE	sensory and attentional engagement
SRS-P	Social Responsiveness Scale – Preschool Version

Chapter 1. Introduction

Current research in infant and toddler development is often based on identifying behaviors that differentiate typical and atypical trajectories of development. In recent decades, developmental psychology has begun to embrace the benefits of neuroimaging and more physiologically-based technologies and research methods with the goal of linking infant behavior to underlying biological factors. Although this type of multidisciplinary research remains relatively scarce, especially in young infants, the surge in interest stemming from researchers, funding agencies and the media in the causes and symptoms of neurodevelopmental disorders has resulted in increased emphasis on the identification of behaviors during infancy that are predictive of later cognitive development.

The First Year Inventory (FYI) (Baranek, Watson, Crais, & Reznick, 2003) was originally developed with the goal of identifying 12-month old-infants at-risk for an eventual diagnosis of autism spectrum disorder (ASD) (Reznick, Baranek, Reavis, Watson, & Crais, 2007). The FYI was created by combing through videotapes of birthday parties of infants who later received ASD diagnoses, as well as by examining the literature on potential early atypical behaviors that may be linked to risk for ASD. Using these various sources, the team was able to identify a set of 'unusual' behaviors that may be indicative of early signs of risk.

Since its development, the FYI has undergone numerous adaptations, mostly in regards to its scoring. In its first use, the FYI was scored in terms of cumulative risk percentile, balanced across eight different sub-domains of questions. Those infants who scored above a certain percentile of risk were flagged as "at risk." A subset of the initial cohort was re-contacted at age three (Turner-Brown, Baranek, Reznick, Watson, & Crais, 2013), and researchers soon determined that scoring could be improved by using specific criteria for the two primary domains of risk: social-communicative and sensory-regulatory functions. In order to be flagged as "at risk", infants needed to score above the cut-points for both domains (Reznick et al., 2007). Although this method of scoring has more accurately identified infants who do eventually receive a diagnosis of ASD, it remains to be seen how the measure may be used to identify various dimensions of behaviors for both typically and atypically-developing infants.

With a push by the NIH for more dimensionally based research (RDoC) (*NIMH research domain criteria (RDoC)*), it is important to establish measures and scoring algorithms that allow for quantitative analyses of symptomatology, in addition to, or instead of, diagnostic categorical analyses. This goal has been presented numerous times in the ASD literature, from the idea of the Autistic Continuum (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) to the Broad Autism Phenotype (Piven, 2001). Both of these considerations, among others, view autistic symptomatology as expressed along a continuum, with those individuals who are the furthest along the continuum, that is, having the most severe symptoms, being the ones who are diagnosed with ASD. To some degree, however, the point on this continuum that determines whether an individual has symptoms severe enough to warrant a diagnosis remains arbitrary. Those individuals who fall close to this point may still have severe deficits in many areas of functioning, but do not receive any type of assistance because they have not been diagnosed with a clinical disorder that warrants intervention.

The FYI remains a valuable tool for assessing infant behaviors, especially those behaviors that may be of concern or indicative of early symptoms of ASD. The goal of my project was not to discount the work currently being done based on the original scoring of the FYI in terms of assessing risk for an eventual diagnosis, but rather to expand the application of the measure by developing a scoring paradigm that provides an informative profile. The first step in this expansion was to take the items in the FYI and combine them in new constructs that would be more appropriately applied to the entire range of typical and atypical development. These new ways of scoring the FYI would also focus less on a risk cut-off and more on dimensions of behaviors. After substantial review of the research of behavioral and neurological correlates of infant behaviors, and considering the interests of those involved, it was determined that creating constructs based on different patterns of infant attention was a valuable direction to take. Much is known in the current infant and child development literature about attention, allowing for the creation and refinement of three constructs of attention derived from the FYI. My thesis will provide a background on the development of attention and the importance of infant attention in the study of typical and atypical cognitive development, describe the process of creating the definitions of the new constructs, and present initial findings based on previously collected longitudinal data.

Early Development of Attention

In early infancy, measures of looking time are some of the most commonly-used techniques for studying a variety of cognitive, sensory and perceptual constructs. Paradigms such as habituation and familiarization allow researchers to make inferences about infants' cognitive processing in terms of how much attention is paid to a particular stimulus. Preferential looking paradigms have been used in infants as young as a few days old (see, for example, Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000; Farroni, Csibra, Simion, & Johnson, 2002). As infants' visual systems continue to mature, the stimuli used in these paradigms become increasingly complex. Neonates are unable to visually process anything much more complicated than simple geometric shapes or faces, but as they mature, infants become able to process stimuli that include different colors, shapes, movement and even multimodal components.

Infant looking behaviors display drastic changes over the first year of life. Although there are individual differences in how infants perceive and process particular stimuli, research has established a consistent trajectory of duration of looking time during the first year. Between birth and about 3 ½ months, infants show increased looking time to stimuli as a result of the continuing maturation of the visual system and the increasing ability of infants to obtain and process greater loads of information. After this period, there is a steady decline in look duration until about six months of age, which is attributed to increased efficiency of the perceptual system, as infants do not require as much time to scan and process the stimuli (Colombo & Mitchell, 1990; Colombo, 2001; Colombo, 2002).

Beyond six months looking time varies based on the complexity of the stimulus, with more salient, dynamic and patterned stimuli eliciting longer looking times than static, geometric shapes. By this point the visual system is considered to be close to functionally mature, so increased looking time to more complex stimuli is thought to reflect an infant's ability to obtain and process greater amounts of information (Colombo et al., 2004; Courage, Reynolds, & Richards, 2006; Richards, 2010).

In addition to looking time, research has also focused on infants' increasing abilities to disengage from stimuli or to shift attention. In the 1960s and 1970s, researchers explored a behavior they called "obligatory looking," that is, when an infant is unable to disengage from a stimulus, which occurred in infants between birth and around two months of age (Stechler & Latz, 1966). This behavior was described later as "sticky fixation" (Hood, 1995), and the concept has been studied extensively over the past few decades (Colombo, Richman, Shaddy, Follmer Greenhoot, & Maikranz, 2001; Hopkins & van Wulfften Palthe, 1985; Hunnius & Geuze, 2004). With further development of attention networks of the brain (to be described later), infants lose the propensity to become "stuck" looking at a particular stimulus and become better able to shift attention more reliably and with shorter latencies (Hood & Atkinson, 1993; Johnson, Posner, & Rothbart, 1991).

Deficits in disengagement and/or attention shifting are commonly associated with ASD, with many studies indicating a delayed or decreased ability to disengage. These impairments are related to perseverative and repetitive behaviors present in ASD, as it is hypothesized that overfocusing may lead to sensory overstimulation and that repetitive behaviors serve as self-regulatory mechanisms (Liss, Saulnier, Fein, & Kinsbourne, 2006).

Attention and Cognitive Development

As previously described, the most widely used paradigms for studying infant behavior include looking time (i.e., habituation and familiarization). For infants who have developed voluntary control of attention, it is generally accepted that looking time to a particular stimulus reflects attention paid to it. For example, in habituation paradigms we assume that an infant will look at, or pay attention to, a stimulus until it is no longer salient or novel. Taken a step further, information-processing perspectives propose that infants who habituate more quickly to new stimuli are capable of faster processing, which is reflected in a variety of different cognitive skills later in life.

Colombo & Mitchell (1988, 1990) characterized infants as "short lookers" or "long lookers" based on individual differences in measures of fixation duration. Such classifications have reliably predicted skills such as higher IQ, faster learning, and better retention over time.

These relations support the information-processing notion that faster processing during infancy, which can be detected through simple looking time paradigms, is highly predictive of a variety of aspects of learning (Colombo, Mitchell, Coldren, & Freeseman, 1991), intelligence (Fagan, Holland, & Wheeler, 2007; McCall, 1994; Sigman, Cohen, & Beckwith, 1997) and memory (Courage & Howe, 2001; Rose, Feldman, & Jankowski, 2003).

Joint Attention

"Joint attention may be conceived of as a self-organizing system that facilitates information processing in terms of social learning" (Mundy et al., 2009). The broad construct of joint attention, defined as "the ability to coordinate visual attention with others regarding objects and events" (Mundy & Gomes, 1998) has received significant focus as an early predictor of a number of cognitive skills. The relation between joint attention and cognitive abilities is especially strong in the ASD literature, where early deficits in aspects of joint attention are strong predictors of later social and cognitive impairments. The majority of research on joint attention emphasizes two primary constructs: responding to joint attention (RJA) and initiating joint attention (IJA). Secondary constructs that are often evaluated in addition to RJA and IJA are responding to behavior requests (RBR) and initiating behaviora requests (IBR) (Mundy et al., 2007; Vaughan Van Hecke et al., 2007). Although all four of these constructs will be discussed, more emphasis is placed on IJA and RJA and the roles of these constructs in individual differences in the trajectories of cognitive and social development.

Gaze following, which involves an infant turning his/her eyes in the same direction as the eyes of another person, is considered to be a precursor to responding to joint attention (Bedford et al., 2012). This ability is often considered more perceptual than attentional, with there being a lack of understanding of intent in the shifting of gaze. Further, gaze following does not necessarily include a shift in focus towards a particular stimulus. Those who consider gaze following distinct from joint attention point this out as the main difference. Joint attention must be triadic – there must be intent to communicate that the other individual should look at a particular stimulus (see Figure 1). Gaze following, on the other hand, can be dyadic. Researchers argue that gaze following indicates that young infants are able to follow another's gaze but do not necessarily understand the purpose (Bedford et al., 2012).

Responding to joint attention (RJA) refers to a person's ability to follow the direction of the gaze and/or gestures of others in order to share a common point of reference (Mundy & Newell, 2007). RJA can be measured in infants as young as three months of age, although there is a significant increase in correct responses up to 18 months (Mundy et al., 2007). Responding to behavior requests (RBR) can be thought of as a sub-construct of RJA. With the primary inclusion criteria that an act of RJA includes one person making a bid, another person responding, and a specific target, the requested behavior is considered the target. The attention is being directed to the desired behavior, maintaining the triadic nature of RJA.

Initiating joint attention (IJA) refers to a person's use of eye contact, gestures and/or words to direct others' attention to objects, events or him/herself (Mundy & Newell, 2007). IJA does not begin to function reliably in infants until closer to one year of age. IJA requires the child to indicate to another individual that he/she should look at something, most commonly through the use of gestures or words. In these behaviors, the infant has intentional control over his/her own bids for joint attention. It is thought that this increasing control allows the infant to explore and learn at a level that is not available through the more reflexive or passive nature of RJA (Mundy et al., 2007). Similar to the RJA/RBR consideration above, IJA and IBR are often condensed, as the behavior becomes the third point in the triad (see Figure 1).

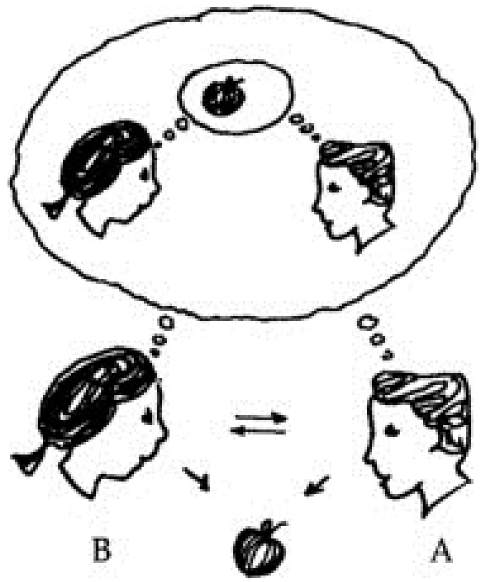

Figure 1. From Mundy & Jarrold (2010): "An illustration of integrated triadic information processing during joint attention"

Like the broad construct of attention, aspects of joint attention have been established as strong predictors of later cognitive and social abilities. In fact, joint attention is considered by many to be the first indicator of social cognition (Frischen, Bayliss, & Tipper, 2007; Mundy & Newell, 2007). Both RJA and IJA are predictive of language skills in early childhood (Delgado et al., 2002; Mundy, Sigman, & Kasari, 1990; Mundy et al., 2007), as well as social competence (Vaughan Van Hecke et al., 2007) and self- and emotion-regulatory behaviors (Morales, Mundy, Crowson, Neal, & Delgado, 2005; Vaughan Van Hecke et al., 2012). Further, IJA specifically has been linked to aspects of executive function, such as working memory and response inhibition (Bell & Fox, 1992; McEvoy, Rogers, & Pennington, 1993; Mundy, Card, & Fox, 2000; Stuss, Shallice, Alexander, & Picton, 1995).

Joint attention has historically been measured in laboratories using standardized procedures that prompt RJA and IJA behaviors. The most commonly used measure is the Early Social Communication Scales (ESCS) (Mundy et al., 2003), a structured 20-minute interaction between an experimenter and an infant that can be used with children aged 6-30 months. The ESCS utilizes a variety of presses in a standardized sequence in order to elicit either responses or bids for joint attention from the child. Other paradigms have been utilized with frameworks similar to that of the ESCS (e.g., MacDonald et al., 2006). Joint attention can also be coded during other laboratory assessments or naturalistic observations. More recently, eye tracking (Chawarska, Macari, & Shic, 2012; Fletcher-Watson, Leekam, Benson, Frank, & Findlay, 2009; Navab, Gillespie-Lynch, Johnson, Sigman, & Hutman, 2012), EEG/ERP (Henderson, Yoder, Yale, & McDuffie, 2002; Mundy et al., 2000; Striano, Reid, & Hoehl, 2006) and neuroimaging (Grossmann & Johnson, 2010; Mosconi et al., 2009) measures have been added to the literature, providing physiological and neurobiological support to behavioral claims. Further, numerous studies have documented the strong relationship between joint attention deficits in young infants and a variety of cognitive and social impairments in individuals diagnosed with ASD (Dawson et al., 2004; Leekam, López, & Moore, 2000; Mundy et al., 1990; Mundy & Crowson, 1997; Mundy, Sullivan, & Mastergeorge, 2009).

Neurobiological Bases of Attention

The constructs discussed above can be substantiated and modified based on our current understanding of the underlying neurological bases of attention. Posner and Peterson (1989) first described the attention networks of the brain. Today, there has been little change to the model, with added support from newer neuroimaging technology (Petersen & Posner, 2012; Posner & Rothbart, 2007). In this section, unless otherwise noted, information about the structures and systems involved in attentional behaviors is a summary based on a select group of relevant publications (Atkinson & Braddick, 2012; Keehn, Müller, & Townsend, 2013; Mundy, Fox, & Card, 2003; Mundy et al., 2007; Mundy & Newell, 2007; Posner & Rothbart, 2007).

The first system to develop is the *alerting network*, which is responsible for voluntary alertness and the system of internal attentional mechanisms responsible for information processing. It also controls phasic alertness or involuntary or reflexive physiological reactions to changes in the environment and is primed for novelty detection.

The brain regions involved in this network include the more primitive structures of the brain, as well as the neurotransmitter norepinephrine (NE), which is primarily involved in sleep/arousal mechanisms. The involvement of such areas and NE suggests that the attention behaviors controlled by this particular network are less voluntary.

The alerting network has also been found to control early sustained attention, a characteristic that supports the functionality of the habituation and familiarization paradigms used in early infancy. At this age, shorter looking times are considered "better", or indicative of faster information processing. Toward the latter half of the first year, sustained attention is taken over by the executive attention network and is considered more effortful. At this time, longer looking times are associated with higher levels of information processing.

The second network to develop, the *orienting network*, is responsible for selective attention that allows the brain to filter information, respond to certain stimuli and ignore others. This network controls both voluntary and involuntary attentional disengagement and shifting, overlapping in many areas with the alerting network. The orienting network has been described as "functionally mature between 3 and 6 months of age" (Cuevas & Bell, 2013). The development of this network has also been associated with the loss of "obligatory looking." The orienting network allows for more voluntary control of attention, and is thought to continue to increase in efficiency even into middle childhood.

Brain regions responsible for activity in this network include more posterior areas, as well as those known for their involvement in visual processing. The cerebellum also plays a role in both overt and covert orienting of attention. Research suggests that this network accounts for both reflexive and voluntary orienting, which is further supported by the role of acetylcholine (Ach), the primary neurotransmitter in this network. Ach has been shown to be responsible for more rapid attention shifting.

The orienting network is also related to the onset of joint attention capabilities, beginning with gaze following. Gaze following is considered to be the earliest form of social cognition and can be detected behaviorally as early as three or four months (D'Entremont, Hains, & Muir, 1997; Farroni, Johnson, Brockbank, & Simion, 2000; Hood, Willen, & Driver, 1998) and neurologically by four to six months (Farroni, Johnson, & Csibra, 2004; Reid, Striano, Kaufman, & Johnson, 2004). The ability of an infant to detect and follow the gaze of another individual reflects the development of the ability to disengage and shift attention. Gaze following is considered to be a precursor to responding to joint attention (RJA), which differs from gaze following in that it is considered to include an understanding of intent. The orienting network has been further implicated in the development of imitation or other behaviors associated with the perception of the eye and head orientation of others.

The last network to develop, the *executive attention network*, begins to emerge later in the first year with continued development throughout toddlerhood. This network is commonly associated with the higher-order cognitive skills of attentional control and executive function. As mentioned previously, this network takes over the role of sustained attention. Toddlers are able to more intentionally select and maintain focused attention on a particular stimulus. At this point in development, more focused attention and less distractibility and shifting of attention are associated with more mature cognitive processing such as executive function (EF), which includes a variety of associated higher-order cognitive processes. In early childhood, three separate but related components of EF have been identified: cognitive flexibility or set shifting, response inhibition and working memory.

Neurologically, the regions associated with this network are more anterior to the alerting and orienting networks, again supporting protracted development. The executive attention network includes areas of the prefrontal cortex, medial frontal regions such as the anterior cingulate cortex, the basal ganglia and the cerebellum. These areas interact to allow individuals to respond more effectively to increasingly complex situations.

The executive attention network has been strongly linked to the development of active emotional regulatory strategies (Graziano, Calkins, & Keane, 2011), as well as the ability to initiate joint attention (IJA). Because IJA requires more volitional control of attention, the protracted development of the frontal areas previously described supports behavioral research suggesting that IJA behaviors cannot be reliably measured until close to 10 months or later.

The development and differentiation of these three attention networks suggests that attentional behaviors during infancy can not only be observed behaviorally, but also that the individual differences in these behaviors that may be indicative of typical or atypical development may emerge long before age one. Consideration of the neurological underpinnings of attention in addition to the extensive behavioral research on attention and joint attention accounts for the first step toward validation of three new constructs from the FYI.

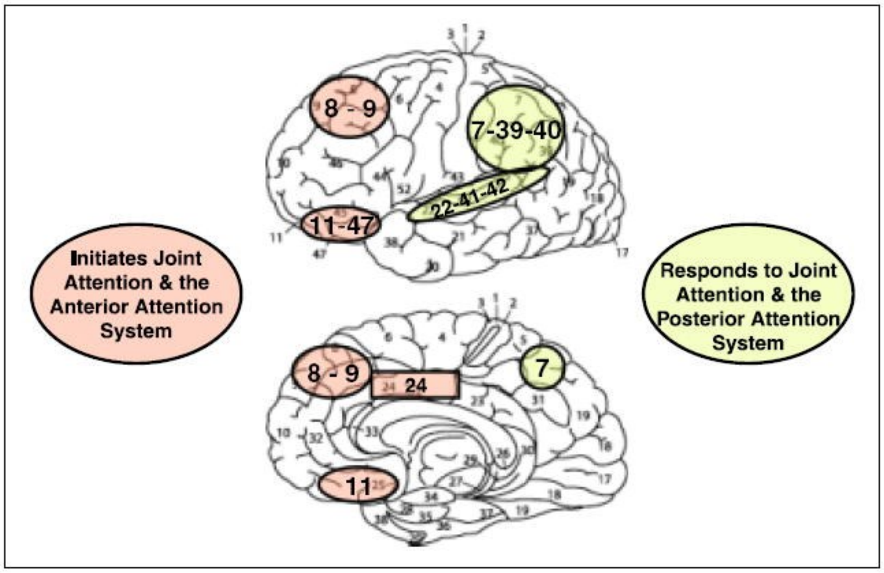

Figure 2. From Mundy & Newell (2007): Illustration of the attention networks in relation to the development of JA skills

The Current Study

My primary goal in this project was to establish a new technique for scoring the FYI, with the intent of creating domains that will allow for the dimensional evaluation of individual differences in patterns of behaviors at age one. The broad construct of attention was chosen as the focus of the new criteria for multiple reasons: its strong link to a variety of cognitive and social outcomes, its salience in the literature of both typical and atypical infant and toddler development and the research interests of the individuals involved. Constructs were established through multiple steps of validation, the first being the information gleaned from the literature on trajectories of the development of attention, with considerations of both behavioral and neurological systems, as described above. The second step was to survey other individuals knowledgeable about infant behavior. We provided operational definitions of new constructs and asked that they group FYI items based on these definitions in order to assess the "top-down" validity of constructs. The third step was to test for statistical validity. This involved first creating a new scoring algorithm for the FYI that avoids categorical outcomes of risk and allows for a more dimensional profile of typical and atypical patterns and trajectories of cognitive development. Constructs were then evaluated for internal consistency and correlated with original FYI risk domains. The fourth step was to assess the relation of the new constructs to clinical outcomes, using existing FYI follow-up data from the Social Responsiveness Scale – Preschool version (Pine, Luby, Abbacchi, & Constantino, 2006) as a dimensional measure of ASD symptom severity.

Chapter 2. Methods

Participants

The development of the three new constructs involved multiple samples of participants. For analyses of statistical validity, participants included all infants for whom parents had filled out the FYI both in the original FYI cohort (N = 1305) and as part of the Early Development Project (EDP) (N = 7823), for a total sample size of 9571. The original FYI cohort was recruited via an invitation mailed to parents of infants within 2 weeks of the infant's first birthday. Mailings were sent to families whose birth record indicated that they lived in the 6 counties closest to Chapel Hill. Longitudinal follow-up has been conducted with various subsets of this cohort at 2 years, 3 years, 5 years and 8 years. The EDP is an ongoing study in the Department of Allied Health at the University of North Carolina – Chapel Hill (UNC-CH). Using birth records, EDP sends FYIs to all parents of infants approaching their first birthdays and who reside within a nine-county radius of UNC-CH. This project utilizes the previously-described risk domains to identify infants at risk for an eventual diagnosis of ASD. If flagged as "at risk," parents are notified and invited to participate in an intervention study.

Data for predictive analyses using the Social Responsiveness Scale – Preschool version (SRS-P) (Pine et al., 2006) came from a subset of the original FYI cohort who was contacted again at age three to participate in a variety of follow-up measures, including the SRS-P and the Developmental Concerns Questionnaire (DCQ) (Reznick, 2005) for the entire follow-up sample. Those two measures and the Mullen Scales of Early Learning (MSEL) (Mullen, 1995), the

ADOS (Lord et al., 2000) and the Vineyard Adaptive Behavior Scales – Second Edition (VABS-2) (Sparrow, Cicchetti, & Balla, 2005) were obtained for a subset of children (N=38) (Turner-Brown et al., 2013). Of the families re-contacted, 735 completed the SRS-P, allowing for an initial test of the predictive value of the new constructs.

In addition to FYI participants, and as one assessment of theoretical validity, a number of colleagues (N = 22) were surveyed to assess the clarity of definitions and the grouping of items. The survey was first sent to other developmental researchers (N=15) who each left a number of comments that influenced the changes we made in our construct definitions and item groupings. The survey was later sent to undergraduate research assistants working in our research group (N=7). These students also provided feedback in the survey as well as during group discussions, resulting in final adjustments.

Construct Development

There were many steps taken and multiple iterations of the item groupings in order to maximize both theoretical and statistical validity. All questions from the FYI were initially considered individually, with a focus on ties to specific aspects of attention as defined above. Given the predictive strength of RJA and IJA in both the typical and atypical developmental literature, we wanted to represent these constructs in our new configuration of items. Although these constructs are strictly defined in the majority of the joint attention literature (MacDonald et al., 2006; Mundy et al., 2003; Mundy et al., 2007), we were interested in including RBR and IBR in our operational definitions of joint attention behaviors. Further, strict qualifications of RJA and IJA require a triadic interaction between child, adult, and a third object or person, including the self. Our constructs were further expanded to include any bid to coordinate attention, whether the response is purely attentional, behavioral or emotional. What is required is that the item is clear about whether the bid comes from the adult or the child, in order to establish whether the child is the initiator (Initiating Attention Coordination – IAC) or the responder (Responding to Attention Coordination – RAC).

Based on early behavioral and neurological theoretical support as well as the nature of skills as represented in both the typical and atypical developmental literature, we established the third construct to cover sustained attention and attention shifting. In addition to these processes, this third construct includes attention to self (including repetitive movements) and perseverative attention to objects or self. In addition, given the recent focus in ASD research on sensory abnormalities, we were interested in how certain sensory items in the FYI would fit into this domain. Previous research describes the relation of sensory characteristics with "overfocusing behaviors" (Liss et al., 2006), supporting the combination of these items into a construct called Sensory and Attentional Engagement (SAE).

After establishing our three constructs, we wrote operational definitions of each, with the intent that others would group items the same way according to these definitions. Once all items in the FYI were classified into one of the three new constructs or omitted, we adjusted the scoring patterns for each FYI item to reflect our interest in a more dimensional approach to the scoring of attention. Instead of assigning risk points, we used a categorical, Likert-type scoring (1 through 4). Original FYI scoring and the new dimensional scoring are displayed in the Appendix. Infants' scores on each construct were calculated as the average of the scores on all items included in that construct. Using SAS 9.3 (SAS Institute, Cary, NC), we calculated Cronbach's *alphas* and intercorrelations among the items in each construct, using a full database of all FYIs collected to date (N = 9128). In this first iteration, *alphas* were relatively high (between .5 and .7). We also calculated bivariate correlations between scores on new domains and scores on risk criteria from the original scoring algorithm to explore any overlap or uniqueness. These analyses resulted in closer examination of items with low intercorrelations. Adjustments were made to the groupings if existing research confirmed the exclusion of such items, and operational definitions were clarified to reflect these changes.

The next step was to survey fellow researchers who had at least a moderate understanding of infant behavior (N=15, described above). An online survey was created that included the current operational definitions on each page and a list of all items on the FYI (even those we had omitted from our groupings). Respondents were instructed to classify each FYI item into one of four groups (our three constructs and "none of the above") based on the definitions provided. They were also encouraged to provide comments about any lack of clarity, items they thought could belong in more than one construct or any other concerns or confusion about specific items (see Figure 3). Feedback from comments as well as agreement on the sorting of items provided valuable assistance in further refinement of not only the operational definitions, but also the items in each construct.

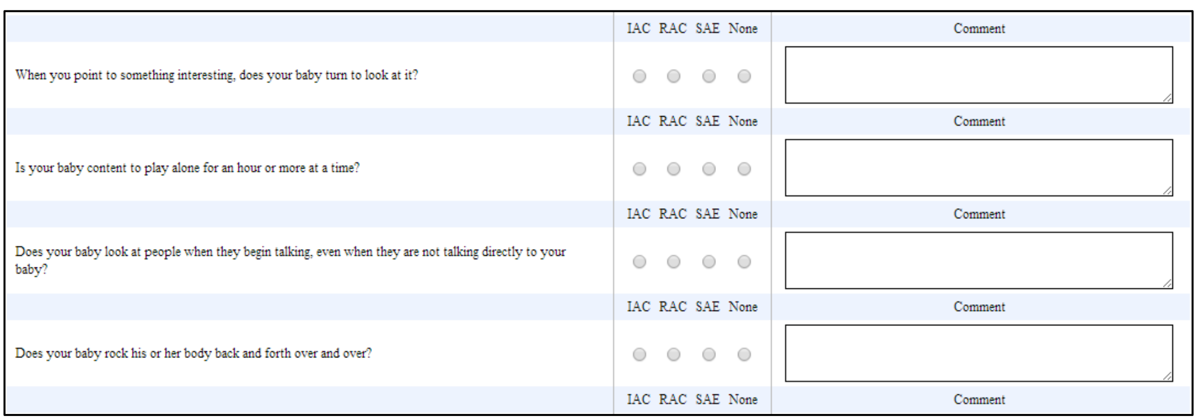

Figure 3. Screenshot from online survey, with sample items and possible responses

After adjustments were made to both the grouping of items and the operational definitions, we ran the same analyses as used previously to assess statistical validity and then surveyed a second group of researchers. This group included all of the undergraduate research assistants in our research group (N=7). For this group and with the revised definitions, agreement was generally high (90% for the items in the three constructs), but additional feedback allowed us to continue to refine operational definitions, this time with inclusion and exclusion criteria, and make additional decisions about item grouping. Analyses were again conducted to ascertain the strength of intercorrelations and internal consistency across each construct, as well as to compare new constructs to the original FYI risk domains. Although some items remained questionable, continued discussion and consideration of previous research and statistical validity confirmed their inclusion. Table 1 shows the evolution of construct definitions and indicates the different names of constructs assigned throughout the development process. Although the names of the constructs changed throughout, the main focus of each remained consistent. The bottom row indicates the final version of the operational definitions of new constructs.

Table 1. Evolution of construct definitions

Date	Construct 1:	Construct 2:	Construct 3:
Early October, 2013	Social-affective responsiveness involves dyadic interactions with a social partner. It includes motivation to engage in social interactions, showing interest in and/or taking pleasure in interactions with others, expressing agreeableness and positive affect with social partners, communicating feelings with a social partner, and integrating behaviors of self with others during social interactions.	Initiating joint attention involves the use of gaze, gestures, and/or vocalizations to direct the attention of others to a specific person or object, or to engage in a desired activity	Attentional flexibility involves the ability to transfer attentional focus between one or more objects/activities/persons in a social or non-social setting. This flexibility can include responding to bids for joint attention; disengaging from one stimulus to follow the gaze or gesture of another person. Flexibility also includes the ability to respond appropriately to a new or changing situation, and to explore new and different methods of exploratory or play behaviors with minimal prompting or enforcement by a parent, caregiver or peer. By contrast, deficits in attentional flexibility involve such perseverative actions as repetitive behaviors or the inability to disengage from a particular activity or stimulus.
Mid-October, 2013	Social-affective engagement refers to the degree to which a child shares and expresses positive affect toward and interest in a social partner (adult or other child), as well as the degree to which the child responds to, joins in and enjoys socially-directed games initiated by an adult social partner, such as imitation. This construct also includes anticipatory behaviors or affect in response to a bid for social engagement. In addition, we include the broadly defined construct of sociability – seeking and taking pleasure in interactions with others. This construct DOES NOT include passive orienting (turning to or looking) in response to an adult-initiated bid for a child's attention or engagement or a child's initial bid for attention from a social partner. Rather, it requires the child's reciprocal affect sharing or engagement in an activity (i.e. social game or affective communication) that has been initiated by an adult or peer.	Initiating joint attention is defined as a child's use of gaze, gestures, and/or vocalizations to begin a social interaction and/or to make a bid for a social partner's attention to himself or herself, to an object, toy or other desired item, or to engage in a desired activity. Initiating joint attention goes beyond social reciprocity and requires that the child more actively work to engage the attention of a social partner. This behavior requires higher-order cognitive skills, as controlled by more anterior areas of the brain (i.e. the executive attention network; Posner & Peterson, 1991; Mundy, Card & Fox, 2000). IJA has been strongly linked to later aspects of executive function, and early deficits of IJA have been noted as early markers for children at risk for a diagnosis of ASD. An example of IJA would be an infant directing an adult's attention towards a particular toy in order to indicate to the adult that the child desired to play with the object.	Attentional flexibility is defined as the child's ability to disengage from a current point of attentional focus and move his or her attentional focus (via head turn or gaze shift) toward another object, event, person, or location. When an exogenous social and/or nonsocial stimulus is presented, attentional flexibility requires that the child turn or look away from what he or she was doing, and orient to the new stimulus. This construct only includes acts of orienting to a new stimulus, disregarding any further engagement. This orienting behavior develops early and involves the posterior attention network, as defined by Posner and Peterson (1991). Impairments in attentional flexibility can be seen if the child fails to move his or her focus of attention in response to a stimulus presented either by a social partner or elicited from a nonsocial object, or when the child requires several prompts or greater stimulus input to move his or her attention away from the current point of focus and toward the new stimulus. Additionally, this construct refers to the breadth and diversity (or lack thereof) of the child's exploration during engagement with toys, objects, or activities. Deficits in attentional flexibility in this respect would thus involve a child's perseverative looking and/or limited repertoire of actions on a stimulus or object for a prolonged period of time. Thus, repetitive behaviors that only involve the body/motor system are not considered in this construct, as attention is not oriented toward an exogenous stimulus.

Mid-November, 2013	Responding to Attention Coordination (RAC) involves a child’s behavioral response to an adult’s initiation of a bid for attention and/or social interaction. The adult’s bids can include the use of vocalizations, gestures, bodily actions, or offering, showing, or acting on a toy or object. The child’s response may involve orienting to (turning to or looking at) or reciprocating with an action in response to one or more of those adult-initiated bids for attention or engagement.	Initiating Attention Coordination (IAC) involves a child’s active bid for a social partner’s attention for a variety of purposes, including drawing attention to him- or herself, acquiring a desired object, toy or other item, or engaging in a desired activity. To elicit an adult’s attention, the child can use behaviors such as gaze, gestures, and/or vocalizations. Based on Mundy and colleagues’ work, initiating joint attention and initiating behavioral requests can be considered related constructs involving slightly different levels of skill and underlying motivation. Our definition collapses across these two distinctions and broadens the scope beyond the strict definitions associated with joint attention.	Overfocused Selective Attention (OSA) refers to the degree to which a child focuses on, acts on and/or engages with objects, sensory stimuli, and/or body parts (must include a visual focus). Examples of behaviors that may represent overfocused selective attention include limited exploration, perseverative action repertoires, visual focus on objects, sensory stimuli or body parts, and/or failure to overtly orient to nonsocial salient environmental stimuli. This construct excludes items that refer to repetitive, stereotyped bodily movements that do not involve a visual focus of attention (e.g., body rocking, feet kicking, pressing body, getting body stuck in a position).
FINAL	Responding to Attention Coordination (RAC) involves an adult’s initiation of a bid for attention and/or interaction with a child and the child’s subsequent response (or lack of response or delayed response). The key to inclusion of an item in this construct is that the adult is initiating some act or communication in an attempt to elicit the attention and/or engagement of the child. The adult must clearly be initiating an interaction with the child or bidding for attention (for a variety of purposes) from the child through a behavioral, emotional or communicative act. The adult’s bids can include vocalizations, gestures, bodily actions and/or offering, showing or acting on a toy or object directed toward the child. The child’s response may involve orienting (turning to or looking at), emotionally reacting or reciprocating with an action in response to an adult-initiated bid for attention or engagement. If the wording of the item is such that the direction of the interaction is not clear (i.e., who is the initiator and who is the responder) or the child is the initiator of the interaction or bid for attention, then the item is not included.	Initiating Attention Coordination (IAC) involves a child’s active bid for a social partner’s attention for a variety of purposes, including drawing attention to him- or herself, acquiring a desired object, toy or other item or engaging in a desired activity. To elicit an adult’s attention, the child may use communicative behaviors including gaze, gestures and/or vocalizations. The child must clearly be initiating an interaction with an adult or bidding for attention (for a variety of purposes) from an adult through a behavioral, emotional or communicative act. Based on previous research, initiating joint attention and initiating behavioral requests can be considered related constructs involving slightly different levels of skill and underlying motivation. IAC collapses across these two distinctions, building on, but also broadening the scope beyond, the strict definitions associated with initiating joint attention. If the wording of the item is such that the direction of the interaction is not clear (i.e., who is the initiator and who is the responder) or the adult is the initiator of the interaction or bid for attention, the item is not included.	Sensory and Attentional Engagement (SAE) refers to the degree to and manner in which a child attends to and/or acts on objects, sensory features of objects, or his/her own body. Behaviors can include visually examining, acting on or exploring objects, body parts or sensory features. Examples that may represent SAE include visual focus on objects, sensory stimuli or body parts, focused or limited exploration or perseverative action repertoires. Items that involve automatic, reflexive orienting to sensory stimuli are not included.

Predictive Value of New Constructs

The Social Responsiveness Scale (SRS) (Constantino & Gruber, 2005) is an instrument designed to quantitatively measure the severity of ASD symptomatology in children older than age four. This scale focuses on social impairment, assessing social awareness, social information processing, social anxiety/avoidance, capacity for reciprocal social interaction and other traits relevant to ASD, and can be completed by a parent or teacher. In contrast to other commonly-used measures assessing symptoms of ASD, the SRS does not provide a categorical outcome in regards to the presence/absence of the disorder. Instead, this measure provides a quantitative overall score, as well as scores on multiple subscales covering a large range of symptom severity. These features are consistent with recent research that characterizes autism as a spectrum or continuum (as described previously), as opposed to a present-or-absent diagnostic outcome.

The Social Responsiveness Scale – Preschool Version (SRS-P) was developed for use with children between ages three and four, with items based on the original version of the SRS. This preschool version has shown high test-retest reliability (Pine et al., 2006) and has been validated by strong agreement with the social impairment scale of the Autism Diagnostic Interview – Revised (ADI-R) (Rutter, Le Couteur, & Lord, 2003). The SRS-P was used in this study to establish predictive validity of new constructs. As discussed previously, the initial FYI cohort was re-contacted when children were three years old, and the SRS-P was one of many questionnaires sent to parents. Of the original sample of 1305, 735 parents responded, allowing us to analyze SRS-P sum scores in relation to the three new constructs.

Chapter 3. Results/Discussion

Construct Development

In the final iteration of the development process, the following constructs were established: Responding to Attention Coordination (RAC), Initiating Attention Coordination (IAC) and Sensory and Attentional Engagement (SAE). Table 2 lists the items included in each construct. Not all items from the FYI were suitable for these three constructs. Some of these omitted items ask about specific developmental milestones or regulatory patterns, while others were removed based on feedback from investigators involved in the original FYI study. For more details concerning these omitted items, see the Appendix. The original FYI risk scoring also had a set of omitted items, so this should not be viewed as problematic.

Table 2. Final clustering of FYI items in new constructs.

New FYI Constructs		
Responding to Attentional Coordination (RAC)	Initiating Attentional Coordination (IAC)	Sensory and Attentional Engagement (SAE)
1. Looks when name is called	7. Looks at your face for comfort	13. Rocks body back and forth
3. Overly sensitive to your touch	19. Tries to get your attention to show things	17. Presses against things
4. Excited when knows what will happen next	20. Tries to get your attention for interactive games	30. Repeats simple activity over and over
10. Turns to look at pointed out object	21. Tries to get your attention to obtain a toy	33. Enjoys staring at bright lights
12. Looks at people when they talk	22. Tries to get your attention for physical games	37. Gets stuck on playing with a part of a toy
14. Looks up from play when shown new toy	29. Tries to get attention by sound and gaze	42. Enjoys rubbing or scratching objects
15. Upset when switching activities	34. Uses communicative gestures	44. Enjoys making objects spin over and over
24. Imitates mouth sounds	38. Uses finger to point at things	45. Enjoys kicking feet over and over
25. Imitates body movements		46. Stares at fingers while wiggling them
26. Imitates activities with objects		47. Your baby's typical play with a favorite toy
35. Responds to "Where's ____?"		48. Your baby's interest in toys on a typical day
49. When you introduce your baby to a new game, how he/she responds		59. Does baby keep a toy or object in his/her mouth
50. What you have to do to get your baby to look up from playing with a favorite toy		
52. What you have to do to get your baby to turn towards you		
53. What you have to do to get your baby to smile or laugh at you		
58. What baby typically does when you start a game by imitating		

After the rounds of revisions described previously, including rescoring of the questions, items for each construct were pooled for a variety of analyses in SAS 9.3, including correlations with initial FYI risk domains, Cronbach's *alphas* and univariate analyses in order to examine score distribution. The following results include data from all completed FYIs to date (n= 9128). All three of the new constructs were significantly correlated with all of the original FYI domains ($p < .0001$ for all correlations), as well as the original risk criteria (see Table 3 for correlations). These data suggest that the new constructs are indeed related to the original FYI risk domains; however, correlations are primarily in the low to moderate range, suggesting that the new constructs offer some unique insight into infant behavior that was not previously obtained (see Appendix for full descriptions of the original FYI variables).

Table 3. Pearson correlation coefficients between the three new constructs (IAC, RAC & SAE) with the previous FYI domains and risk scores.

FYI domain	IAC_mean	RAC_mean	SAE_mean
orientrec fyi: Orientrec raw score	0.41219	0.64274	0.20825
affeng fyi: Affeng raw score	0.65363	0.48519	0.19115
imitate fyi: Imitate raw score	0.38889	0.62756	0.15007
express fyi: Express raw score	0.57245	0.48410	0.14111
senproc fyi: Senproc raw score	0.13904	0.30202	0.46180
regpat fyi: Regpat raw score	0.09134	0.15499	0.14107
react fyi: React raw score	0.07931	0.21684	0.13388
repplay fyi: Repplay raw score	0.07111	0.18362	0.72226
soc_com_risk fyi: soc com risk summary score	0.68248	0.75358	0.24072
sen_reg_risk fyi: sen reg risk summary score	0.14056	0.32627	0.50537
risk fyi: overall risk summary score	0.53247	0.68537	0.44741
risk_pctile fyi: risk percentile	0.49889	0.61786	0.44541

Responding to Attentional Coordination

Definition:

RAC involves an adult's initiation of a bid for attention and/or interaction with a child and the child's subsequent response (or lack of response or delayed response). The key to inclusion of an item in this construct is that the adult is initiating some act or communication in an attempt to elicit the attention and/or engagement of the child. The adult must clearly be initiating an interaction with the child or bidding for attention (for a variety of purposes) from the child through a behavioral, emotional or communicative act. The adult's bids can include vocalizations, gestures, bodily actions and/or offering, showing or acting on a toy or object directed toward the child. The child's response may involve orienting (turning to or looking at), emotionally reacting or reciprocating with an action in response to an adult-initiated bid for attention or engagement. If the wording of the item is such that the direction of the interaction is not clear (i.e., who is the initiator and who is the responder) or the child is the initiator of the interaction or bid for attention, then the item is not included.

The RAC construct consists of 16 items and shows good internal consistency ($\alpha = .716$). The range of RAC scores for the entire sample is from 1.0 to 3.34 ($M = 1.44$; $SD = 0.25$), with lower mean scores indicating better parent-reported RAC behaviors. See Figure 3 for a graphical representation of the distribution of mean RAC scores.

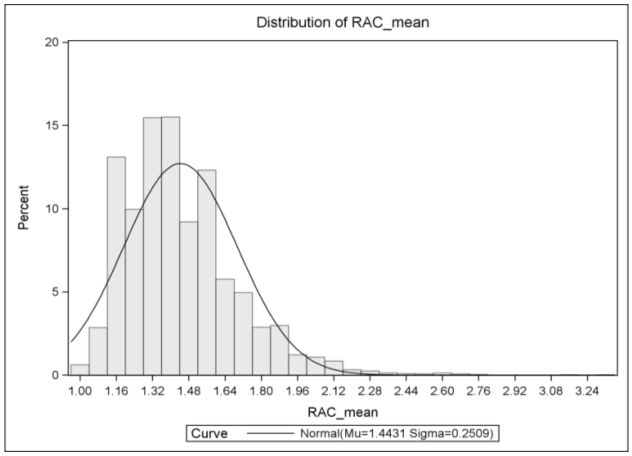

Figure 3. Distribution of mean RAC scores using the new scoring algorithm.

Initiating Attentional Coordination

IAC involves a child's active bid for a social partner's attention for a variety of purposes, including drawing attention to him- or herself, acquiring a desired object, toy or other item or engaging in a desired activity. To elicit an adult's attention, the child may use communicative behaviors including gaze, gestures and/or vocalizations. The child must clearly be initiating an interaction with an adult or bidding for attention (for a variety of purposes) from an adult through a behavioral, emotional or communicative act. Based on previous research, initiating joint attention and initiating behavioral requests can be considered related constructs involving slightly different levels of skill and underlying motivation. IAC collapses across these two distinctions, building on, but also broadening the scope beyond, the strict definitions associated with initiating joint attention. If the wording of the item is such that the direction of the interaction is not clear (i.e., who is the initiator and who is the responder) or the adult is the initiator of the interaction or bid for attention, the item is not included.

The IAC construct consists of 8 items and shows good internal consistency (α = .746). The range of IAC scores for the entire sample is from 1.0 to 4.0 (M = 1.62; SD = 0.46), with lower mean scores indicating better parent-reported IAC behaviors. See Figure 4 for a graphical representation of the distribution of mean IAC scores.

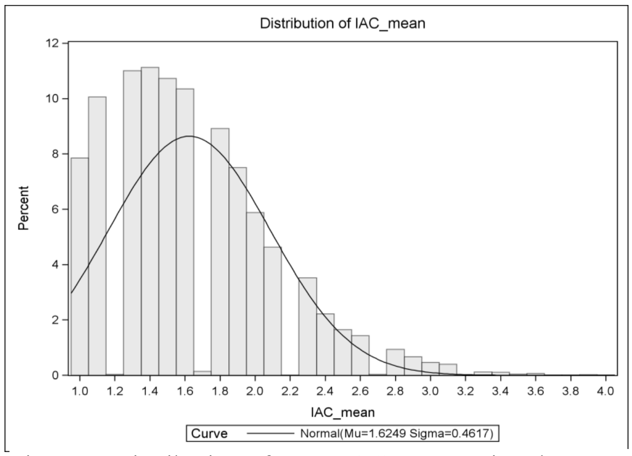

Figure 4. Distribution of mean IAC scores using the new scoring algorithm.

Sensory and Attentional Engagement

SAE refers to the degree to and manner in which a child attends to and/or acts on objects, sensory features of objects, or his/her own body. Behaviors can include visually examining, acting on or exploring objects, body parts or sensory features. Examples that may represent SAE include visual focus on objects, sensory stimuli or body parts, focused or limited exploration or perseverative action repertoires. Items that involve automatic, reflexive orienting to sensory stimuli are not included.

The SAE construct consists of 12 items and shows good internal consistency (α = .787). The range of SAE scores for the entire sample is from 1.0 to 3.83 (M = 1.81; SD = 0.47), with lower mean scores indicating better parent-reported SAE behaviors. See Figure 5 for a graphical representation of the distribution of mean SAE scores.

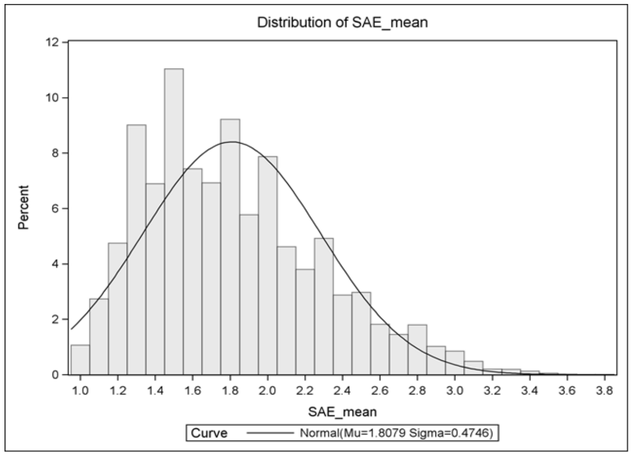

Figure 5. Distribution of mean SAE scores using the new scoring algorithm.

Constructs as Predictors of Social Responsiveness

The first FYI cohort was re-contacted at age three, and a subset of this group (N=735) completed the Social Responsiveness Scale – Preschool version (SRS-P; Pine et al., 2006). The SRS-P produces a total score, with higher scores indicating increased severity of ASD symptomatology. All three constructs (RAC, IAC and SAE) at age one were significantly correlated with SRS-P scores at age three: $r = 0.35$ ($p < .001$), $r = 0.26$ ($p < .001$) and $r = 0.24$ ($p < .001$) for RAC, IAC and SAE, respectively.

Using SAS 9.3, stepwise multiple regression analysis was conducted to evaluate whether all three new attention constructs (RAC, IAC & SAE) were predictive of age-three SRS-P scores. Step one of the analysis entered RAC into the regression equation and this was significantly related to SRS-P score, $F(1,733)=101.94$, $p <.0001$). The squared multiple correlation coefficient (R^2) indicated that 12.2% of the variance in SRS-P score at age three can be accounted for by RAC score at age one. SAE was entered into the equation at step two and was, in addition to RAC, significantly related to SRS-P score, $F(2,732)=65.77$, $p <.0001$. There was a significant increment in R^2, with 15.2% of the variance in SRS-P score accounted for by both RAC and SAE. Step three added IAC into the equation, and all three variables remained significantly related to SRS-P score, $F(3,731)=48.28$, $p <.0001$. There was another significant increment in R^2, with 16.5% of the variance in SRS-P score accounted for by all three constructs: RAC, SAE and IAC. Further, simultaneous regression analyses indicate that each construct has a unique contribution to the variance in SRS-P scores.

For comparison, original FYI risk variables were also entered into a multiple linear regression model. Although both the sensory-regulatory and social-communicative risk constructs significantly predicted SRS-P scores at age three, $F(2,732) = 54.14$, $p < .001$, these two variables could only account for 12.9% of the variance in SRS-P scores.

Chapter 4. General Discussion

Table 1 describes the various iterations of the new construct definitions. Modifications were driven by both theoretical and statistical tests of validity, and this cyclical feedback allowed us to establish operational definitions that most clearly differentiate between the constructs and delineate which items are included in each. Once the items in each construct were finalized, analyses were conducted to explore both internal consistency within constructs and relations to previous risk domains. All three constructs showed good internal consistency. When compared to the original risk domains, there were, as expected, high correlations between the new constructs and certain previous domains. However, correlations were not so high as to raise concern that the new constructs were not offering any unique information. This distinction is also reflected in the relation to SRS-P scores, discussed next.

Regression analyses revealed that the three new constructs are predictive of social responsiveness scores at age three. The goal of this fourth step of validity was not to make theoretical claims about the relation of new constructs to the SRS-P as a clinical tool for diagnostic outcomes, but this analysis was explored in order to establish whether or not the new constructs could do as well as, or better than, the original risk domains at predicting ASD symptomatology. Although the percentage of variance explained by the new constructs was fairly small ($R^2 = .165$), all three (RAC, IAC and SAE) provided significant and unique contributions. Compared to the original FYI domains, the three attention constructs explain a higher percentage of variance in SRS-P scores (16.5% vs. 12.9%, respectively). Although this difference is not large, it supports the decision to explore different avenues of scoring the FYI. Further, the new attention constructs represent a quantitative approach to the data and which fall in line with new initiatives by the NIH to study psychopathology through dimensional, as opposed to categorical, approaches.

Based on the vast body of research on the links between infant attention and a variety of later cognitive and social skills, it is important to establish measures that can accurately represent attentional behaviors effectively by age one. Much can be debated concerning the validity of parent-report measures, but they remain the most cost-effective and efficient means of obtaining data about infant behaviors. In considering the value of early identification of risk for ASD, this need is even more salient.

Limitations and Future Directions

The primary limitation of the development of these constructs from the FYI is that it is a measure designed to detect risk for ASD, so some of the FYI items may not be appropriate for a measure attempting to assess attention behaviors across the range of typical and atypical development. In addition, although significant, the percentage of variance in SRS-P score explained by the three new constructs is relatively low. Additional longitudinal data will need to be collected to support the predictive value of the constructs, and there is a need for validation against well-established attentional measures.

In contrast, by altering the scoring of the FYI items and aiming for a more quantitative assessment of infant behaviors, it is possible that the new constructs are only appropriate for looking across typically developing attention skills and may not have any implications for psychopathology. Exploratory analyses in relation to the SRS-P suggest that there may be some predictive value in terms of clinical outcomes, but further research needs to be conducted to delineate such relations.

Another limitation is the relatively low, although significant, R^2 value associated with the three constructs in predicting SRS-P scores. The SRS-P primarily measures social aspects of behavior, with a sub-category for repetitive behaviors. With constructs that were developed with an emphasis on attention, it may be more beneficial to use a quantitative assessment that takes into account more cognitive skills and features that may be impaired in clinical populations. The SRS-P data were all that was available for the analysis of predictive validity, and although informative, further research should be conducted to explore more cognitive outcomes.

Planned future directions include using the established constructs to create profiles of attentional behaviors and to use these profiles to predict a variety of attentional, regulatory and executive control behaviors at 30 months. Different patterns of attentional behaviors as determined by the FYI will allow for the prediction of typical and atypical developmental trajectories of multiple different social and cognitive constructs measured by parent-report surveys and laboratory assessments. The relation of these profiles of attention as well as individual construct scores to later behaviors will be another step toward validating new constructs.

Conclusions

This study defined three new constructs from the items of the FYI, based on the well-established value of measuring attention in infancy. These constructs were refined and validated through 1) an extensive literature review on behavioral and neurological correlates of infant attention, 2) theoretical validity as further determined by the input of other individuals concerning the operational definitions of, and the items included in, each construct, 3) statistical validity determined by internal consistency and relation to the original FYI risk domains and 4) an analysis of the new constructs as predictors of clinical outcomes (SRS-P scores). The final constructs are responding to attention coordination (RAC), initiating attention coordination (IAC) and sensory and attentional engagement (SAE). Each of these constructs has strong internal consistency, with Cronbach's *alphas* greater than .70, and each construct significantly and uniquely predicted ASD symptomatology at age three. Results support the reconsideration of existing measures to establish novel ways of measuring infant behavior.

APPENDIX

Table 1. FYI scoring – old (top row) & new (bottom row)

FYI Item	Never	Seldom	Sometimes	Often
1. Does your baby turn to look at you when you call your baby's name?	<1[b]	1[b]	8[a]	91
	4	**3**	**2**	**1**
2. Does your baby seem bothered by loud sounds?	8[a]	39	46	7[a]
	+			
3. Does your baby seem overly sensitive to your touch (for example, fuss or pull away when you touch him or her)?	64	31	5[a]	<1[b]
	+			
4. During familiar games like "I'm gonna get you," does your baby get excited because he or she knows what will happen next?	<1[b]	<1[b]	8[a]	92
	4	**3**	**2**	**1**
5. Does your baby seem to have trouble hearing?	94	5[a]	1[b]	<1[b]
	++			
6. When you and your baby are facing each other, does your baby turn his or her eyes to avoid looking at you?	53	30	15[a]	2[b]
	+			
7. In new or strange situations, does your baby look at your face for comfort?	1[b]	6[a]	40	53
	4	**3**	**2**	**1**
8. Does your baby ignore loud or startling sounds?	34	42	21	3[b]
	+			
9. Does your baby spit out certain textures of foods, such as lumpy or chunky pieces?	11	25	48	16[a]
	++			
10. When you point to something interesting, does your baby turn to look at it?	1[b]	4[b]	39	56
	4	**3**	**2**	**1**
11. Is your baby content to play alone for an hour or more at a time?	27	29	31	13[a]
	++			
12. Does your baby look at people when they begin talking, even when they are not talking directly to your baby?	<1[b]	3[b]	44	53
	4	**3**	**2**	**1**
13. Does your baby rock his or her body back and forth over and over?	54	24	15	7[a]
	1	**2**	**3**	**4**
14. Does your baby look up from playing with a favorite toy if you show him or her a different toy?	<1[b]	2[b]	39	59
	4	**3**	**2**	**1**
15. Does your baby get upset when you need to switch your baby from one activity to another one?	7	35	53	5[a]
	+			
16. Is it easy to understand your baby's facial expressions?	<1[b]	1[b]	14[a]	85
	*			
17. Does your baby forcefully press his or her face, head, or body against people or furniture?	38	27	24	11[a]
	1	**2**	**3**	**4**
18. Does your baby smile while looking at you?	<1[b]	<1[b]	9[a]	91
	*			
19. Does your baby try to get your attention to show you something interesting?	7[a]	16	40	37
	4	**3**	**2**	**1**
20. Does your baby try to get your attention to play games like peek-a-boo?	5[a]	15	41	39
	4	**3**	**2**	**1**
21. Does your baby try to get your attention to obtain a favorite toy or food?	2[b]	9[a]	32	57
	4	**3**	**2**	**1**
22. Does your baby try to get your attention to play physical games, like swinging, tickling, or being tossed in the air?	10[a]	23	40	26
	4	**3**	**2**	**1**
23. When your baby is awake and you pick him or her up, does your baby's body feel loose or floppy?	81	14[a]	4[b]	1[b]
	**			

24. Does your baby copy or imitate you when you make sounds or noises with your mouth?	1[b]	4[b]	32	63
	4	**3**	**2**	**1**
25. Does your baby copy or imitate your actions, like sticking out your tongue, clapping your hands, or shaking your head?	<1[b]	2[b]	23	75
	4	**3**	**2**	**1**
26. Does your baby copy or imitate you when you do something with a toy or object, like shaking a rattle or banging a spoon on the table?	<1[b]	1[b]	22	77
	4	**3**	**2**	**1**
27. Is it difficult to calm your baby once he or she becomes upset?	20	62	17	1[b]
	+			
28. Are your baby's sleeping and waking patterns regular from day to day?	1[b]	4[b]	20	75
	**			
29. Does your baby try to get your attention by making sounds and looking at you at the same time?	1[b]	4[b]	30	65
	4	**3**	**2**	**1**
30. Does your baby get stuck doing a simple activity over and over?	36	45	16	3[b]
	1	**2**	**3**	**4**
31. Does your baby seem interested in other babies his or her age?	<1[b]	5[a]	28	67
	**			
32. Does your baby babble by putting sounds together, such as 'ba-ba', 'ga-ga-ga', or 'ba-dee'?	<1[b]	1[b]	8[a]	91
	**			
33. Does your baby enjoy staring at a bright light for long periods of time?	49	32	15[a]	4[b]
	1	**2**	**3**	**4**
34. Does your baby use gestures such as raising arms to be picked up, shaking head, or waving bye-bye?	<1[b]	3[b]	12[a]	85
	4	**3**	**2**	**1**
35. When you say "Where's (a familiar person or object)?" without pointing or showing, will your baby look at the person or object named?	4[b]	10[a]	35	51
	4	**3**	**2**	**1**
36. Does your baby use the first finger and tip of the thumb to pick up a very small object like a raisin or a Cheerio?	<1[b]	1[b]	5[a]	94
	**			
37. Does your baby seem to get stuck on playing with a part of a toy (such as an eyeball, label, wheel or tag), instead of the whole toy?	14	32	39	15[a]
	1	**2**	**3**	**4**
38. Does your baby communicate with you by using his or her finger to point at objects or pictures?	12[a]	18	24	46
	4	**3**	**2**	**1**
39. Do you get the feeling that your baby plays or communicates with you less now than in the past?	80	14	5[a]	1[b]
	**			
40. Do your baby's eyes line up together when looking at an object?	1[b]	1[b]	3[b]	95
	**			
41. Are your baby's feeding patterns regular from day to day?	1[b]	2[b]	19	78
	**			
42. Does your baby enjoy rubbing or scratching toys or objects for long periods of time?	49	34	13[a]	4[b]
	1	**2**	**3**	**4**
43. Does your baby seem to get his or her body stuck in a position or posture that is hard to move out of?	70	23	6[a]	1[b]
	**			
44. Does your baby enjoy making objects spin over and over in the same way?	32	33	27	8[a]
	1	**2**	**3**	**4**
45. While lying down, does your baby enjoy kicking his or her feet over and over for long periods of time?	42	33	19	6[a]
	1	**2**	**3**	**4**
46. Does your baby stare at his or her fingers while wiggling them in front of his or her eyes?	32	35	27	6[a]
	1	**2**	**3**	**4**

FYI Item	Response choices	Previous scoring	New scoring
47. Which of the following best describes your baby's typical play with a favorite toy?	a. Uses the toy in more or less the same way all the time.	12[a]	**4**
	b. Occasionally finds a new way to play with the toy.	55	**2.5**
	c. Often explores new ways to play with the toy	33	**1**
48. Which of the following describes your baby's interest in toys on a typical day?	a. Plays with one or two special toys most of the time.	3[b]	**4**
	b. Plays with a small number of toys (3–5).	27	**2.5**
	c. Plays with a large number of toys (6 or more).	70	**1**
49. When you introduce your baby to a new game (peek-a-boo, so-big, patty-cake, etc.) how does your baby respond?	a. Almost always joins in immediately without any help.	29	**1**
	b. Usually joins in, with a little help.	63	**2**
	c. Joins in only with a lot of help	6[a]	**3**
	d. Doesn't seem very interested in new baby games.	2[b]	**4**
50. What do you typically have to do to get your baby to look up from playing with a favorite toy?	a. Just show him or her different toy	43	**1**
	b. Move, shake or make a noise with the different toy	54	**2.5**
	c. Take the favorite toy away and give your baby the different toy	3[b]	**4**
51. What is your baby's usual reaction to somewhat painful experiences, like bumping his or her head?	a. Doesn't seem to notice	4[b]	+
	b. Reacts a little but gets over it quickly	93	
	c. Seems very sensitive or cries for a long time	3[b]	
52. What do you typically have to do to get your baby to turn towards you?	a. Simply say your baby's name	71	**1**
	b. Say your baby's name several times	25	**2**
	c. Say your baby's name loudly or use other means, such as clapping	4[b]	**3**
	d. Your baby doesn't do this yet	<1[b]	**4**
53. What do you typically have to do to get your baby to smile or laugh at you?	a. Smiling and laughing is enough	92	**1**
	b. Usually need to touch and tickle	8[a]	**2**
	c. Usually need to swing and bounce	<1[b]	**3**
	d. Your baby doesn't do this yet	<1[b]	**4**
54. On a typical night, how many hours does your baby sleep?	a. 12 or more	13	**
	b. 10-11	71	
	c. 8-9	14	
	d. 7 or fewer	2[b]	
55. On a typical night, how many times does your baby wake up?	a. 0 times	51	**
	b. 1-2 times	43	
	c. 3 or more times	6[a]	
56. Which of the following best describes your baby's skill level?	a. Walks independently	48	**
	b. Walks with hand(s) held, holding a push-toy, or holding onto furniture.	44	
	c. Pulls to stand but doesn't walk yet	6[a]	
	d. Does not pull up to stand yet	2[b]	
57. Which of the following	a. Almost never gets upset	28	**

best describes your baby's typical day?	b. Gets upset and needs to be calmed 1–3 times.	59	
	c. Gets upset and needs to be calmed 4-6 times.	11[a]	
	d. Gets upset and needs to be calmed 6 or more times.	2[b]	
58. If you start a game by copying or imitating a sound your baby makes, what does your baby typically do?	a. Doesn't seem to notice the sound	<1[b]	
	b. Looks at you, but doesn't make the sound.	11[a]	**3**
	c. Looks at you and makes the sound.	35	**2**
	d. Plays the game, making the sound several times.	54	**1**
59. When your baby is awake and not eating, does your baby keep a toy or object in his or her mouth?	a. Almost never	29	**1**
	b. Sometimes	50	**2**
	c. Often	17	**3**
	d. Almost always	4[b]	**4**
60. Which of the following best describes the way your baby coordinates his or her eyes and hands while playing with a toy?	a. Almost always looks at the toy that he or she is physically handling.	81	**
	b. Sometimes looks at the toy that he or she is physically handling.	19	
	c. Rarely looks at the toy that he or she is physically handling.	<1[b]	
	d. Almost never looks at the toy that he or she is physically handling.	<1[b]	

Notes:
In the original FYI scoring, responses to items were classified as not indicating risk. In the above table, responses labeled *a* were given one risk point, and responses labeled *b* were given two risk points

Questions listed above without new scores were omitted for the following reasons:
* Unclear who initiator/responder is
** More indicative of general developmental level
+ Emotional reactivity
++ Advice from research team members

Table 2. Original FYI domains and sub-domains

Variable	FYI Domain	FYI Sub-Domain
orientrec fyi: Orientrec raw score	Social-communication	Social orienting and receptive communication
affeng fyi: Affeng raw score		Social-affective engagement
imitate fyi: Imitate raw score		Imitation
express fyi: Express raw score		Expressive communication
senproc fyi: Senproc raw score	Sensory-regulatory functions	Sensory processing
regpat fyi: Regpat raw score		Repetitive behavior
react fyi: React raw score		Reactivity
repplay fyi: Repplay raw score		Repetitive play
soc_com_risk fyi: soc com risk summary score	Total social-communication risk score (flagged if ≥ 20.5)	
sen_reg_risk fyi: sen reg risk summary score	Total sensory-regulatory functions risk score (flagged if ≥ 12.0)	
risk fyi: overall risk summary score	Average score of the 8 sub-domains	
risk_pctile fyi: risk percentile	Risk percentile	

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