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Separable Attentional Predictors of Language Outcome

Brenda Salley, Robin K. Panneton, and
Department of Psychology, Virginia Tech

John Colombo
Schiefelbusch Life Span Institute, University of Kansas

Abstract

The aim of this study was to examine the combined influences of infants' attention and use of social cues in the prediction of their language outcomes. This longitudinal study measured infants' visual attention on a distractibility task (11 months), joint attention (14 months), and language outcomes (word–object association, 14 months; MBCDI vocabulary size and multi-word productions at 18 months of age). Path analyses were conducted for two different language outcomes. The analysis for vocabulary revealed unique direct prediction from infants' visual attention on a distractibility task (i.e., maintaining attention to a target event in the presence of competing events) and joint attention (i.e., more frequent response to tester's bids for attention) for larger vocabulary size at outcome; this model accounted for 48% of variance in vocabulary, after controlling for baseline communication status (assessed at 11 months). The analysis for multi-word productions yielded direct effects for infants' distractibility, but not joint attention; this model accounted for 45% of variance in multi-word productions, again after controlling for baseline communication status. Indirect effects were not significant in either model. Results are discussed in light of the unique predictive role of attentional factors and social/attention cues for emerging language.

Meaningful linguistic communication is a pivotal milestone that emerges as infants begin to understand and then produce the sounds of their language. The wide variability in early language outcomes, reflected both within the broad parameters of typical development and among language impaired populations (Fenson et al., 1994, 2000), makes the identification of language delay or impairment a challenge (Rescorla, 1989). As such, understanding the complex developmental pathway of language bears relevance for both typical and atypical populations (see Colombo, McCardle & Freund, 2009). In their day-to-day world, infant learners are exposed to the linguistic stream by way of visual and auditory information from many speakers in the context of multiple competing events. Recent efforts have characterized infants' use of computational strategies in support of their linguistic development (Kuhl, 2004; Maye, Werker & Gerken, 2002; Saffran, Aslin & Newport, 1996), as well as various components of language skill that demonstrate associations with later outcomes, such as early speech perception, word segmentation, and word–object

association learning (Bernhardt, Kemp & Werker, 2007; Newman, Ratner, Jusczyk, Jusczyk & Dow, 2006; Tsao, Liu & Kuhl, 2004). However, these learning strategies are likely facilitated by infants' emerging use of attentional/social cues (Bruner, 1983; Mundy, 2003; Tomasello, Carpenter, Call, Behne & Moll, 2005). Although it has been established that individual differences in infants' attention and use of social cues predict language outcomes, these contributions have been examined separately, from the vantage point of either early visual attention (i.e., visual habituation, distractibility) or social cognition (i.e., gaze following, joint attention). This study sought to examine the combined contributions of infants' regulation of visual attention and joint attention behaviors on their later language outcomes.

Individual differences in infant visual attention have been related to later language development and cognitive performance. Shorter duration of looking on habituation tasks in infancy (thought to reflect memory and speed of processing) is associated with larger vocabulary and higher cognitive ability in childhood (Bornstein & Sigman, 1986; Colombo, Shaddy, Richman, Maikranz & Blaga, 2004; Colombo et al., 2008). In contrast, during object exploration tasks, longer duration of attention (thought to reflect sustained attention and persistence) has been associated with better language and cognitive abilities (Kannass & Oakes, 2008; Kopp & Vaughn, 1982). These differences reflect the developmental course of attention, from exogenous control of attention during the first 3 months of life (Colombo, 2001; Ruff & Rothbart, 1996) to endogenous attentional control as infants approach their first birthday, that is concurrent with changes in cortical development (e.g., frontal eye fields, parietal cortex, and prefrontal cortex; Colombo & Cheatham, 2006; Richards, 2001). By 9 months of age, most infants are skilled at initiating, shifting, and disengaging attention, and are also learning to direct the attention of others. Around 12 months of age, novelty becomes less salient (as infants begin to habituate much more quickly), while sustained, focused attention becomes increasingly influential.

Alongside these changes in attention regulation skills, infants display increased capacity to maintain attention in the context of competing events (i.e., distractibility; Kannass, Oakes & Shaddy, 2006; Oakes, Kannass & Shaddy, 2002; Ruff & Capozzoli, 2003). This developmental progression allows longer duration of looking to dynamic, interactive, and complex stimuli (Courage, Reynolds & Richards, 2006) and increased ability for self-regulation of attention in the face of multiple streams of information, which together pave the way for the emergence of coordinated attention between objects and other people near the end of the first year of life. This emerging ability to sustain attention to a source in the face of simultaneous distractors (e.g., peripheral events) appears to be an important indicator of resource allocation with respect to information processing/encoding. For example, Lansink and Richards (1997) found that in the presence of an interesting toy, latencies to shift attention toward a peripheral distractor were much longer when infants' heart rate activity and visual focus indicated sustained attention. These authors and others (e.g., Oakes & Tellinghuisen, 1994) have interpreted such patterns as indicative of the relationship between attention engagement and optimal information processing in infancy.

When considered from a theoretical perspective, the impact of socially guided attention on language development is thought to reflect the development of processes including social

cognition, emotion and motivation, and early social attention regulation (Bruner, 1983; Mundy, 2003; Tomasello et al., 2005). A well-established literature has demonstrated that joint attention behaviors mediate later language outcomes in typically and atypically developing children (Baldwin, 1995; Bruner, 1983; Carpenter, Nagell & Tomasello, 1998; Mundy, Sigman & Kasari, 1994; Mundy et al., 2007). Composite measures of joint attention (i.e., multi-modal attention bids involving a look, point, and vocalization) between 6 and 18 months predict vocabulary size at 24 and 30 months (Carpenter et al., 1998; Hollich, Hirsh-Pasek & Golinkoff, 2000; Morales et al., 2000a; Mundy et al., 2007). Compared with other components of joint attention, gaze following has been most often theoretically and empirically related to language development. Gaze following is considered an important foundational experience that allows an infant to correctly pair an object with its spoken name and thus learn word-object associations (Baldwin, 1995). However, true gaze following appears to emerge between 10 and 11 months of age, when infants reliably follow a head turn only when an adults' eyes are open (not when they are closed); in contrast, younger infants follow a head turn regardless of whether the adults' eyes are open or closed (Brooks & Meltzoff, 2005). The ability to participate in coordinated attention sharing between a person and an object/event (i.e., triadic joint attention) develops between 12 and 18 months. Consequently, the components of joint attention (i.e., eye contact, gaze following) appear long before social-cognitive processes are considered operational (Brooks & Meltzoff, 2005; Morales et al., 2000a). Nonetheless, the role of attention regulation in the development of joint attention processes is unknown.

Prominent theoretical explanations of language development account for the role of global attention factors, cognitive constraints, and social-pragmatic processes, acknowledging that these processes are accessed simultaneously, but perhaps differentially over development (Hollich et al., 2000; Kuhl et al., 2008). It has been suggested that younger infants are guided primarily by perceptual cues, whereas older infants capitalize upon social cues in word-learning opportunities (Hollich et al., 2000). Early word learning (before awareness of social intent) may progress via perceptual salience and general associative mechanisms and has been characterized as “word-object” association. For example, 14-month-olds have been shown to learn word-object pairings (i.e., the ‘switch’ task) in the absence of social information (Werker, Cohen, Lloyd, Cassiola & Stager, 1998). This developmental shift is further supported by evidence that when perceptual salience is placed in conflict with social cues, 10- and 12-month-old infants map words onto objects that are perceptually more “interesting” (over “boring” objects) while 19- and 24-month-old infants are guided by the speaker's social intent regardless of perceptual salience, and especially as object-label ambiguity increases (Hollich et al., 2000; Pruden, Hirsh-Pasek, Golinkoff & Hennon, 2006; Vaish, Demir & Baldwin, 2011). Infants' word-object learning has been shown to be associated with later language outcomes in some (but not all) studies. In a small longitudinal study, word-object association learning (at 17 or 20 months of age) was not significantly predictive of parent-reported vocabulary size (when infants were between 22 and 29 months of age). However, a longer-term follow-up (when infants were between 37 and 50 months of age) found significant associations with Preschool Language Scale (PLS-3) Total Language scores and Peabody Picture Vocabulary Test (PPVT-R) scores (Bernhardt et al., 2007).

In sum, although the contributions of components of general attention and responsiveness to social attention cueing (i.e., joint attention) on linguistic development are well identified, what remains unclear is the nature of their combined associations. Language outcome studies examining the combined predictive utility of infants' visual attention and joint attention behaviors are noticeably lacking. This study measured infants' ability to maintain attention to a dynamic female speaker in the context of a competing event, using a distractibility paradigm (e.g., Lansink & Richards, 1997; Oakes & Tellinghuisen, 1994; Oakes et al., 2002) that has been modified to include a dynamic, infant-directed female speaker reciting a children's nursery rhyme as the "target" (rather than an object). This modification was made to examine whether the degree to which infants' attention to a social interlocutor could be interrupted by a peripheral distractor might be significantly related to later emerging language skills. This task was completed at 11-month of age, when infants display increased ability to engage in sustained attention and also demonstrate reliable gaze following behaviors. Joint attention behaviors were assessed when infants were 14 months, during the period in which variability in nonverbal social communication behaviors have been related to language outcomes. Drawing on infants' ability to associate highly frequent words with familiar objects, word (associative) learning was assessed at 14 months, as a behavioral measure of emerging language skill. Relevant for this study, success on this task requires attention to both phonetic and visual information in the absence of social cues. A screening instrument was completed at 11 months of age to provide an opportunity to characterize and control for initial communication differences. Productive vocabulary and multi-word productions were assessed when infants were 18 months of age, using a parent-report measure of language development.

We anticipated that, in accordance with previously established relationships, individual differences in infants' visual attention regulation and joint attention would each be predictive of productive vocabulary size and multi-word productions. That is, maintaining attention to a target event in the presence of competing events (i.e., less distractibility) and more frequent response to the tester's bids for joint attention were expected to predict larger vocabulary size and more frequent multi-word productions (i.e., combining words). It was predicted that when considered in terms of combined contributions, infants' visual attention and joint attention would uniquely account for variability in language outcome after accounting for initial communication level. Infants demonstrating word-object association learning were expected to have larger productive vocabulary size at outcome. In addition, infants with lower levels of distractibility were expected to have better word-object association learning. Hypothesized relationships are presented in Figure 1.

Method

Participants

Fifty-three families were recruited to participate via letter and follow-up telephone calls. Prenatal and postnatal health of the infant was confirmed with their parents. Of these mother-infant dyads, 52 completed 11- and 14-month laboratory assessments, and 47 families completed the 18-month questionnaire measures. Demographics of the longitudinal cohort ($n = 52$) were obtained directly from parent report and were representative of the

geographic region. The sample was predominantly Caucasian (85%; 9% African American; 6% bi-racial/other) and female (33; 19 male). Median annual household income was US \$50–65,000 and median maternal level of education was a college degree.

Procedure

Laboratory visits took place when infants were 11 and 14 months of age. For all tasks, when the infant was calm and alert, he or she was brought into the testing room by the caregiver, who remained with the infant during the entire session. For tasks presented audio-visually (distractibility; word–object association), infants were seated on their caregiver's lap, facing a 32-inch color LCD monitor, surrounded by black material (making the screen prominent in the infant's visual field). Two small loud speakers were located directly adjacent to the right and left of the screen, with a remotely controlled dome camera (Panasonic WV-CS574) positioned directly above. The infant and caregiver were seated in line with the remote camera so that head/eye position of the infant was clearly distinguishable to the observer. The observer watched and recorded the infant on a colored television monitor, in an adjacent, sound-attenuated control room (this observer was blind/deaf to the events presented to the infant). When infants were 18 months of age, questionnaire packets were mailed to parents.

Measures

Distractibility task (11 months old)—A distractibility paradigm was used to measure infants' ability to engage attention to a central target event and their distractibility to an event presented in the visual periphery. The distractibility paradigm has been used to measure endogenous attention under a variety of conditions (e.g., Kannass et al., 2006; Lansink & Richards, 1997; Oakes & Tellinghuisen, 1994; Richards & Turner, 2001; Ruff, Capozzoli & Saltarelli, 1996). For this study, the aim was to quantify infants' allocation of visual attention to a dynamic speaker in the presence of competing (distracting) events. The rationale for this task was based on the assumption that a dynamic female speaker would most likely be an event that can quickly and effectively engage attention in many (but perhaps not all) infants and that even after initial engagement, infants would differ in their degree of engagement with the dynamic speaker as reflected in their likelihood of shifting attention away (i.e., disengagement). Given the previous results showing that sustained attention in infants is positively related to latency to shift attention to a peripheral distractor (e.g., Kannass et al., 2006; Richards, 1989; Ruff & Capozzoli, 2003), it was reasoned that longer latencies in this distractibility task would be a good metric of social attention (a term that has been used to refer to the preference for viewing social sources of information; Frank, Vul & Saxe, 2012) and potentially related to other measures such as joint attention ability and vocabulary size. Our goal was to maintain the standard design and construct validity of the distractibility paradigm, while also including events that were relevant to the day-to-day language experiences of the infant (e.g., language emerges in a social context and infants encounter speakers in the context of competing events). Thus, our “target” consisted of a dynamic female speaker and the distractor consisted of a flashing black and white checkerboard.

Once the infant was judged to be looking at a pretrial attention getter, the target event began. The central visual event consisted of a dynamic adult female telling an engaging story in an infant-directed style. After the target event had been playing for 5 consecutive seconds, the distracter (a flashing black and white checkerboard in silence) was presented in the upper right-hand sector of the viewing area (26° from midline). After the end of a trial (10 sec in length), the attention-getter reappeared on the screen until the infant fixated, and then the next trial ensued. Each infant received a total of 8 trials, and the latency of the infant's first fixation to the distracter (or 10 sec, whichever occurred first) was recorded for each trial. The timing of the target presentation and distracter onset (i.e., 5 sec after target initiation) allowed for a period of stimulus orienting (Richards, 2004). Infants' looking times were coded offline by trained observers (interobserver reliability across individual trials was 0.96). After examining individual latencies across trials, it became clear that a number of infants received the maximum trial length as their latency because they did not disengage from the target and look toward the distracter (i.e., 10 sec). As a result, the outcome measure of distractibility was the number of trials on which infants did not orient to the distracter event (i.e., higher score reflected less distraction across trials).

Emerging communication (11 months old)—Infants' communication skill at the age of entry into the study was characterized using the Ages and Stages Questionnaire (ASQ; Bricker & Squires, 1999), as means of screening for potential language delays in the sample. This measure is a widely used developmental screening measure that is completed by parents. Items describe specific behaviors that are either observed or easily elicited by parents in the home. For the purposes of this study, only the communication domain was of interest (e.g., Does your baby follow a simple command such as “Come here” without your using gestures? When you ask, “Where is the ball (hat, shoe, etc.)?” does your baby look at the object?). Further evaluation for areas of concern is indicated if the child falls two standard deviations or more below the mean in these domains. As this measure represents an index of infants' communicative status prior to the influences measured in this longitudinal study, we refer to this measure later in the paper as baseline language status.

Word-object association task (14 months old)—Infants' emerging language skill was measured using a word-object association (“switch”) task, which involved presenting sound-image pairings and then testing infants' ability to learn the word-object pairing (Cohen, 1998; Stager & Werker, 1997; Werker et al., 1998). Each infant was habituated to repeated pairings between moving Object A + Word A and moving Object B + Word B. After habituation, the infant was presented with one “same” trial, consisting of a familiar object/word pairing (e.g., Object A + Word A), followed by a “switch” trial, which had a novel object/word pairing (e.g., Object A + Word B). If the infant learned to associate specific objects with their accompanying labels, attention on “switch” trials would be higher compared with attention on “same” trials.

As soon as the infant fixated the attention-getter, the moving object+-word events were presented (two object+word events alternating) for as long as the infant fixated the screen. When the infant looked away for at least 1 sec, the event terminated, and the attention-getter came on again. The two object+word events were presented across habituation trials until

the mean looking time on two consecutive trials fell below 50% of the mean from the first two trials of the session. Each soundtrack that accompanied a given moving object consisted of multiple exemplars of one of the two nonsense consonant–vowel–consonant (CVC) words: *neem* and *boog*. These nonsense words were constructed because they are from different vowel categories and have different consonant dimensions of nasality, voicing, and place dimensions (making the words maximally different, yet unfamiliar). The words were recorded by a female speaker, instructed to imagine that she was talking to an infant (to ensure infant-directed speech and prosodic contours). Visual stimuli were two colorful moving objects that the infant had never seen before (one object consisted of a triangular base with a sphere on top with protruding spikes; a second object was a stylized origami figure with several protrusions); the movement was relatively constant, but the direction of movement differed for the two objects, with one moving toward and then away from the viewer and the other moving up and then downward.

Immediately following the habituation phase, the two test trials began. During test trials, infants were presented with a “same” pairing (same word–object pairing used in habituation, e.g., Object A/*neem*) and a “switch” pairing (familiar word and object in a new combination, e.g., Object B/*neem*). The order of test trials was counterbalanced across participants. The dependent variable on this task was duration of looking time during “switch” and “same,” both compared to criterion (last two habituation) trials. Longer duration of looking during “switch” trials indicates the infant has learned the word–object association. Infants' duration of looking time was coded online by trained observers from the onset of each trial until the infant's first visual fixation away from the image.

Joint attention task (14 months old)—Infants' joint attention behaviors were assessed using the Early Social Communication Scales (ESCS; Mundy et al., 2003), a widely used structured method of coding individual differences in nonverbal social communication behaviors. The ESCS was presented immediately following the word–object association task. In this study, infants' attention to the bids of a social partner or responding to joint attention (RJA) was of interest, given the well-established associations between RJA in the second year of life and later receptive language development in typical and atypical populations after controlling for cognitive development (Morales, Mundy & Rojas, 1998; Morales et al., 2000a,b; Mundy & Gomes, 1998; Mundy, Kasari, Sigman & Ruskin, 1995). For this task, infants were seated on their caregiver's lap (or in a high chair, with their caregiver seated adjacently), at a small table, facing the tester (all procedures following Mundy et al., 2003). The tester called the infant's name to gain attention, then turned and visually fixated on a poster in the room, while pointing and saying the infant's name. A constant order of left, left-behind, right and right-behind was presented (two trials each for a total of eight trials). All sessions were videotaped, with a digital camcorder placed so that infant behavior was recorded face-on. Infants' gaze following behavior was coded from taped sessions as the percentage of trials in which they successfully oriented to look into the direction of the tester's attention. Joint attention behaviors were coded offline by trained observers with interobserver reliability of 0.98.

Language (18 months old)

Measures of language productivity were obtained when infants were 18 months old using the MacArthur–Bates Communicative Development Inventory (MBCDI), short-form version (Fenson et al., 2003). The MBCDI is a parent report questionnaire designed to provide a measure of productive vocabulary. From a series of word lists (“Words Children Use”), including nouns, action lists, and animal sounds, parents choose words their child says. Parents also indicate whether their child is using multi-word productions (i.e., combining more than one word). This instrument has been widely used in clinical and research settings to assess language production and has demonstrated high internal consistency and test–retest reliability (Fenson et al., 1994).

Analytic strategy

To describe the predictive contributions of infants' attention (i.e., distractibility) and responsivity to social cueing (i.e., joint attention) for language outcomes, a path model was tested using Mplus 6 (Muthén & Muthén, 1998–2011). Path coefficients and indirect effects were tested using a bootstrap analysis (based on 1,000 replications), a procedure that is advocated for small sample sizes because it does not impose the assumption of multivariate normality on the sampling distribution (Preacher & Hayes, 2008). Bootstrapping involves repeatedly sampling from the original data set to estimate the direct and indirect effects in each resampled data set and then constructing a confidence interval (CI) for each population-specific effect. Bootstrapping procedures are particularly recommended for multiple indirect effects (Preacher & Hayes, 2008) and perform better than parametric procedures in small to moderate samples in terms of statistical power and type 1 error rates (Fritz & Mackinnon, 2007).

Results

Available data for all 52 sample members are included. Descriptive statistics for all tasks and measures are presented in Table 1. All measures and tasks were examined for potential gender and order effects, with no significant effects (p 's > .05).

Zero-order correlations

Zero-order correlations among study variables appear in Table 2; partial correlations with effects of initial communication development controlled are shown in parentheses. These correlations supported several of the expected relationships. Infants' distractibility demonstrated a strong positive relationship with vocabulary size and multi-word productions. Responding to joint attention evidenced a moderate positive relationship with vocabulary size, but was not correlated with multi-word productions. In addition, infants' baseline language status (ASQ communication) was strongly correlated with their later language outcomes (vocabulary and multi-word productions). In an unexpected finding, word–object association learning was not significantly correlated with 18-month language outcomes (see Table 2), nor was it a significant predictor of initial communication development at 11 months.

ASQ communication

The strong correlation that emerged between 11-month ASQ and language outcomes supported the decision to consider this measure as an index of infants' communication status prior to the influences measured in this longitudinal study. It should be noted that the ASQ identified six infants whose scores fell below the clinical cutoff at 11 months of age. However, when these infants were excluded from the analyses, no change in the observed pattern or strength of relationships was observed (e.g., after removing these infants from the sample, the correlation between ASQ and vocabulary was $r = +.436, p < .01$; for the entire sample $r = +.438, p < .01$). As a result, we included the full sample of infants in the final analyses.

Switch task performance

Although infant performance on the switch task is typically taken as an index of word +object referential learning, we used performance on this task as a graded metric of emerging language skill with respect to other measures of social attention (i.e., distractibility and joint attention). In other words, the primary interest here was not at the group level (i.e., was average looking on switch trials significantly greater than on nonswitch trials), but rather on switch performance as an individual index of language skill.

As expected, examination of infants' posthabituation looking times on "same" and "switch" trials revealed a substantial level of variability in looking times. As a result, we analyzed infants' duration of looking on "switch" trials compared with their looking times on habituation criterion trials (last two habituation trials), while simultaneously covarying their individual looking times on "same" trials; the order of posthabituation trials was also entered as a factor. This yielded a measure of whether infants learned the word-object association (i.e., longer duration of looking during "switch" trials), while simultaneously removing the influence of both spontaneous recovery and dishabituation from infants' responses on switch trials. This analysis yielded a significant effect for infants' response to switch trials, $F(1,38) = 4.324, p = .04$, with no significant interaction with the order of the habituation sequence, indicating word-object association at the group level (i.e., demonstrated the expected pattern of increased looking time on switch trials compared with habituation trials). More important for this study, however, are the multivariate analyses in which infants' responses to switch trials were entered as standardized residual scores. Standardized residuals for response to switch trials were calculated for each infant using the difference between their actual and predicted switch trial looking time; this approach was chosen over more traditional difference scores because of the high variability in infants' looking times and the large error term contained in these values.

Path analyses for language outcomes

The next sections describe path analyses conducted using the three predictor variables (distractibility, performance on the switch task, and responding to joint attention) to two different language outcomes: vocabulary and multi-word productions (both assessed through the MBCDI). In each analysis, models were tested in a two-step process; in the first step, without any covariates (e.g., Figure 1), and in the second step, controlling for a baseline measure of the status of infants' communication (see description of the ASQ above).

Although the conduct of the second step allowed us to draw conclusions about measures taken during the longitudinal window of the study while controlling for infants' extant communication proficiency at the time of entry into the study, we found the presentation of both steps to be instructive, as many longitudinal studies of social/environmental contributors to language development do not account for this baseline variability. As the results will show, the contrast of these two models speaks to the advisability of such a control for future studies.

Predictors of productive vocabulary

Figure 2 represents the tested models with estimated standardized parameters for vocabulary both before (a) and after (b) controlling for baseline language status. As can be seen in Figure 2a, infants' distractibility and response to joint attention significantly predicted vocabulary size, but word–object association learning did not evidence a significant direct effect on vocabulary. In addition, direct links between distractibility and both RJA and word–object association learning were nonsignificant. Infants' lower levels of distractibility (i.e., higher number of trials on which the infant did not orient away from the dynamic speaker in the presence of distraction) at 11 months of age and more frequent response to the tester's bids for joint attention (RJA) at 14 months of age were predictive of larger vocabulary size at outcome. This model accounted for 38% of variance in vocabulary development at 18 months of age. In terms of magnitude of effects, distractibility emerged as the strongest predictor ($\beta = 0.488$) when compared to responding to joint attention ($\beta = 0.278$).

The model including baseline language (i.e., ASQ communication scores) as a control variable is presented in Figure 2b. After controlling for the significant contribution of infants' initial communication level (on both responding to joint attention and vocabulary), distractibility continued to significantly predict vocabulary size. Surprisingly, in this second-step analysis, responding to joint attention was no longer significant in the model, indicating that infants' responsiveness to social cueing did not contribute to variability in vocabulary scores after accounting for variance in initial communication level. This model accounted for 48% of variance in vocabulary size at 18 months of age. Distractibility again demonstrated the strongest predictive utility ($\beta = 0.466$), over and above initial communication level (ASQ communication; $\beta = 0.367$).

Because the model tested was saturated (all coefficients were estimated, yielding no degrees of freedom), standard model fit indices were not useful (statistics equal zero), and thus, goodness of model fit was evaluated using confidence intervals. If zero falls outside of the lower and upper 95% CI limits, then the parameter being estimated is deemed statistically different from zero at the 0.05 level. For the model predicting vocabulary, the point estimates and 95% CIs with bias-corrected (BC) standard errors are presented in Table 3. Before controlling for ASQ communication, the CIs for the direct effects of distractibility and responding to joint attention do not include zero. In contrast, the CI for word–object association does include zero. After controlling for ASQ communication, the direct effect of infants' distractibility is maintained, but the direct effect of responding to joint attention is not. The point estimates and 95% BC CIs for the bootstrapped indirect effects of

distractibility through responding to joint attention and word–object association are presented in Table 4. As can be seen from the CIs, none of the total or specific indirect effects were significant, because the confidence intervals all included zero. Overall, in the prediction of vocabulary outcomes, the best fit for the observed data was provided by the model including the direct effects of distractibility while controlling for initial communication development (ASQ communication).

Predictors of multi-word productions

Estimated standardized parameters for the models testing multi-word productions are presented in Figure 3. As can be seen in Figure 3a (before controlling for initial communication level), infants' distractibility significantly predicted multi-word productions, but responding to joint attention and word–object association learning did not demonstrate significant direct effects. As in the previous analyses, direct links between distractibility and both RJA and word–object association learning were nonsignificant. Infants' lower levels of distractibility (i.e., higher number of trials on which the infant did not orient away from the dynamic speaker in the presence of distraction) at 11 months of age was predictive of more frequent multi-word productions at outcome. This model accounted for 23% of variance in multi-word productions at 18 months of age.

The model including initial communication (i.e., ASQ scores) as a control variable is presented in Figure 3b. After controlling for the significant contribution of infants' initial communication level (on responding to joint attention and multi-word productions), distractibility continued to significantly predict multi-word productions. This model accounted for 45% of variance in multi-word productions at 18-month-old.

The point estimates and 95% CIs with bias-corrected (BC) standard errors are presented in Table 5. Before controlling for ASQ communication, the CI for the direct effects of distractibility does not include zero. In contrast, the CIs for responding to joint attention and word–object association learning do include zero. After controlling for ASQ communication, the direct effect of distractibility is maintained. The point estimates and 95% BC CIs for the bootstrapped indirect effects of distractibility through responding to joint attention and word–object association are presented in Table 6. As can be seen from the CIs, none of the total or specific indirect effects were significant, because the confidence intervals all included zero. Overall, in the prediction of multi-word productions at 18 months old, the best fit for the observed data was provided by the model including the direct effect of distractibility while controlling for initial communication development.

Habituation measures and study outcomes

While conducting analyses for this study, a number of correlations emerged that were secondary to the aim of the project but that are relevant to our understanding of the structure of attention in infancy as related to emerging language skills. Even though infants' performance on the word–object association task displayed limited associations with study outcomes, other task variables related to habituation showed some interesting patterns. Infants' decrement in looking time during habituation, defined as

$$\frac{(\text{habit trial}_1 + \text{habit trial}_2 / 2) - (\text{criterion trial}_1 + \text{criterion trial}_2 / 2)}{\text{number of fixation trials}},$$

was negatively correlated with responsiveness to joint attention ($r = -0.310, p = 0.048$), such that faster habituators exhibited frequent RJA. Likewise, infants' number of fixation trials during habituation was negatively correlated with multi-word productions at outcome ($r = -0.313, p = 0.044$); that is, combining more words was related to fewer trials during habituation. However, these correlations were no longer significant after correction for multiple comparisons, and as such, should be interpreted with caution.

Discussion

The aim of this study was to examine the combined contributions of infants' attention and responsiveness to social cueing for language outcomes, developmental components that have to date been examined from separate vantage points of early visual attention or social cognition. To our knowledge, this is the first attempt to examine the *unique* contributions of both basic cognitive and social–cognitive indices to variability in language outcome.

We initially hypothesized that distractibility, word–object association and response to joint attention would make unique contributions to multiword productions and vocabulary outcomes at 18 months of age, even after controlling for communication status prior to enrollment in the study. The final picture supports the contribution of distractibility, along with a more nuanced role for responding to joint attention, but does not support the role of word–object association for language outcomes. The actual findings are summarized in the following sections.

Contribution of distractibility

Distractibility measured at 11 months emerged as a strong predictor of language outcomes (vocabulary size and multi-word productions) at 18 months. This contribution was unique relative to the contribution of other predictors in models for both language outcomes, but particularly strong for vocabulary. Distractibility reflects the capacity for endogenous attention, or the volitional direction/engagement of attention to objects or events (Colombo, 2001, 2002), while at the same time inhibiting attention to peripheral distractors (overriding dorsal and ventral pathways that bias attention shifting to peripheral visual targets) to maintain attention to a focal event (Colombo & Cheatham, 2006). Importantly, infants are less distractible during periods of focused or sustained attention (Kannass et al., 2006; Lansink & Richards, 1997; Richards, 1989; Ruff & Capozzoli, 2003; Tellinghuisen & Oakes, 1997). The ability to engage in longer bouts of sustained attention to focal events supports linguistic development, an observation that is consistent with previous work (Bornstein & Sigman, 1986; Colombo et al., 2004, 2008; Kopp & Vaughn, 1982). Less distractibility in the context of learning words and their referents provides a clear advantage for building a vocabulary. Infants who display more optimal endogenous attention may be more likely to attend to and process language relevant information that they encounter. In addition, infants who have greater regulation of attention may be more likely to experience

more frequent and/or higher quality of language-learning opportunities as they attend to adults providing word labels. Our results are also in line with research demonstrating a relationship between attention and word learning (Dixon & Shore, 1997; Dixon & Smith, 2000). During word-learning tasks, children exposed to novel words in the absence of environmental distractions were better able to generalize those words (Dixon & Salley, 2007). During distracting conditions, toddlers with high attention focus were less affected in their word learning compared with children low in attentional focus (Dixon, Salley & Clements, 2006). Together, these findings provide convincing support for the role of attention regulation skill in linguistic development.

It is worth noting that in this study, the target for the distractibility task was social in nature (i.e., a dynamic female speaker); the nature of this target (i.e., whether a social or nonsocial target is used) may or may not have impacted infants' proclivity for attentional engagement and may provide the basis for other studies to clarify this finding. Although the role of social context has long been considered relevant for linguistic outcomes, the separable influence of social versus nonsocial information for visual attention regulation in the support of language development is unknown.

Contribution of RJA

In keeping with a considerable literature on the relationship between infants' following of others' social cues with vocabulary (Baldwin, 1995; Bruner, 1983; Carpenter et al., 1998; Mundy et al., 1994, 2007), we observed that RJA yielded a unique predictive contribution to 18-month vocabulary size. However, of particular interest here was the finding that, when baseline language status was controlled for, RJA no longer accounted for statistically significant amounts of variance in the model for vocabulary. One potential explanation for this pattern of results is that the contribution of RJA to vocabulary in the uncontrolled (first) step of the model is attributable to the contribution of RJA to language that occurs earlier than 11 months of age; the positive correlation between RJA and baseline language status ($r = +.28$) supports this, even though the correlation itself is not significant with the statistical power of this study. This potential scenario would need to be addressed in future research. The presence of the baseline language status measure (which typically has not been included in past work) plays a large part in elucidating this possibility.

Finally, it should be noted that RJA did not account for any statistically significant amounts of variance with respect to multi-word productions, irrespective of whether baseline language status was controlled or not. This is consistent with the consensus in the literature that RJA primarily contributes to the development of the lexicon.

Word-object association

In contrast to our predictions, performance on the word-object association task did not contribute significant variance to the prediction of vocabulary or multi-word productions. In previous research, word-object association learning (at 17 and 20 months old) has predicted language outcome 1–2 years later, but was not significantly related to earlier measures of vocabulary (between 22 and 29 months of age; Bernhardt et al., 2007). Age of the child may be a consideration in the failure of the switch measure to predict language outcomes, as this

study assessed word–object association learning at 14 months of age; although 14-month-olds demonstrate word–object association learning (Werker et al., 1998), their performance at this age has not been examined in relationship to language outcomes. One further possibility is that infants' emerging, focused attention on objects in a social context (i.e., in interaction with a partner) more directly links to language growth than their attention to objects and labels per se. Thus, optimal word-learning skills rely on infants' sustained, focused attention on speakers, not just what is being spoken about. Some support for this interpretation is derived from a recent study exploring 14-month-old word–object learning in the switch task when the auditory labels were delivered by a live female speaker seated near the infant (Fais et al., 2012). In this situation, infants who engaged in higher amounts of mutual gaze with the live speaker during habituation showed superior word–object learning (increased attention during switch trials). Such results are enticing with respect to future studies that could systematically incorporate varying degrees of social cueing into referential learning tasks.

Relations between habituation indices, predictors and outcomes

Adding to the empirical contributions of this paper are findings which suggest that more efficient processing from the habituation phase of the word–object association task were related to other positive aspects of the child's language-related behaviors and outcomes. Higher habituation decrements at 14 months were related to RJA at the same age, and fewer trials to meet the habituation criterion at 14 months predicted multi-word productions at 18 months. These findings are generally in keeping with a known literature relating early efficiency in habituation to concurrent and lagged prediction of other cognitive measures and outcomes (Bornstein & Sigman, 1986; Colombo et al., 2004, 2008). While these correlations were no longer significant after controlling for multiple comparisons, they nonetheless raise interesting questions for future research.

Contributions of the baseline ASQ measure

The inclusion of the ASQ as an indicator of baseline language status proved instructive, as controlling for language proficiency prior to entry into the study clarified the relative contributions of the predictors used here with language outcomes. As such, the inclusion of such baseline variables may be desirable in future studies of language prediction and outcomes.

As noted above in detail, controlling for 11-month communication status erased both the significant contribution of RJA to 18-month vocabulary and the contribution of word–object association to multi-word productions. More importantly, the contribution of distractibility to both language outcome measures remained strong and statistically significant, even after entry language status was controlled for, thus providing more confidence in the role of this attention variable (measured at 11 months) to language at 18 months. The 11-month-old ASQ communication scores themselves yielded a large direct effect on both vocabulary size and multiword productions at 18 months old, in fact conveying the largest predictive utility for multi-word productions. The ASQ communication domain queries behaviors that collectively involve readiness for language (i.e., recognizing simple words; looking for familiar objects; social reciprocity; use of gesture). These findings suggest the validity of

measuring developmental behaviors relevant for linguistic outcome by parent report as early as 11 months of age and suggest that linguistically relevant skills may be established before the infants' first birthday. However, given that the ASQ communication yields a general measure of risk for language delay, future studies would benefit from employing a more specific measure of linguistic development.

Summary

Current theory holds that global attention factors, cognitive constraints, and social–pragmatic processes are accessed simultaneously and differentially across development (Hollich et al., 2000; Kuhl et al., 2008). Evidence from this study provides support for the notion that several cognitive and social–cognitive factors make unique and dissociable contributions to language outcomes. A measure of attention regulation was observed to contribute strongly to language outcomes in the second year. The contributions of joint attention behaviors to vocabulary were also supported, but these data suggest that such contributions may be more relevant during the first year. The role of word–object association in these outcomes was unclear and should be a topic for further inquiry. Finally, indices of processing efficiency from habituation, although not hypothesized to contribute and thus not included in formal path models tested here, also were observed to contribute to the language-learning array in the second year.

This study represents one step toward a better understanding of the cognitive and social–cognitive inputs that contribute to language outcomes. Future work will require comprehensive measurement strategies and developmental designs in the context of studying individual differences. Ultimately, this work will have considerable relevance for understanding language outcomes in both typically and atypically developing children.

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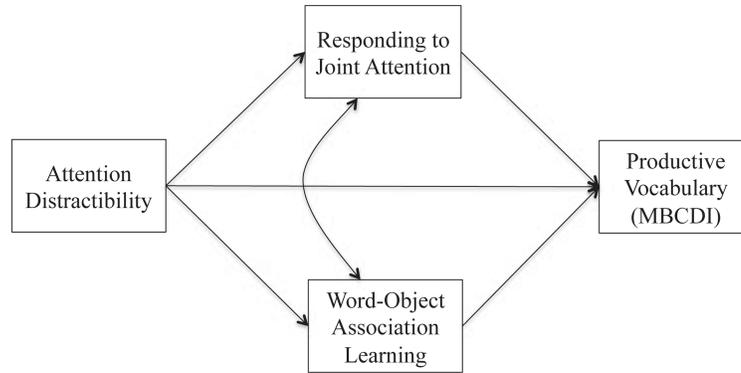
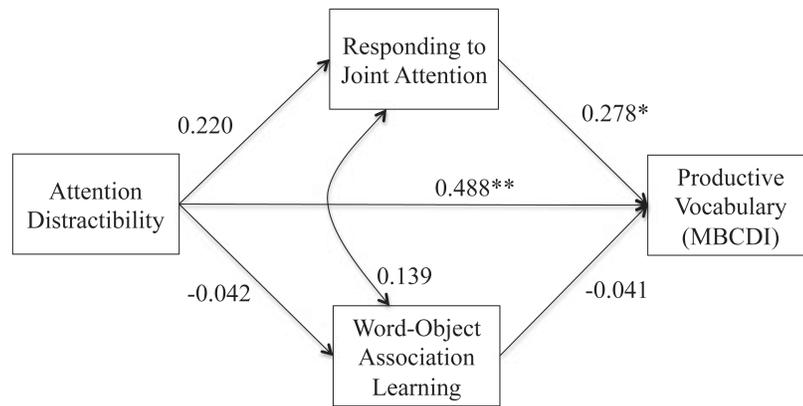


Figure 1. Proposed model predicting language outcome (tested separately for vocabulary; multi-word productions).

(a) Before controlling for initial communication level:



(b) After controlling for initial communication level:

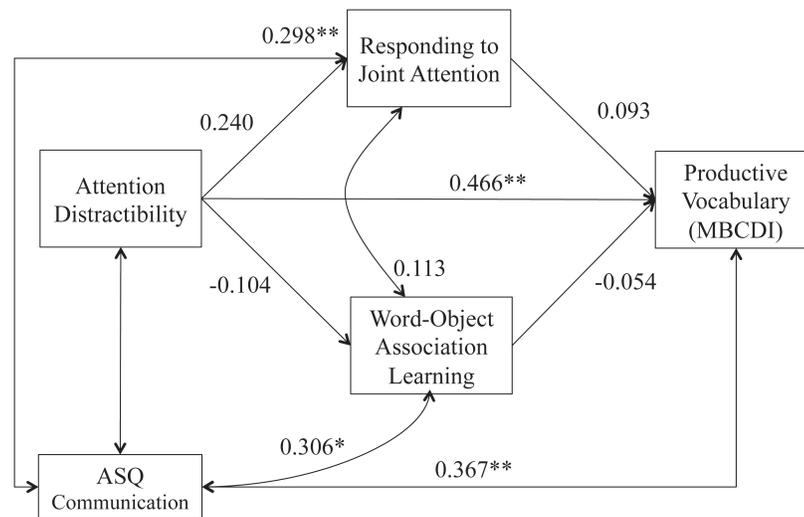
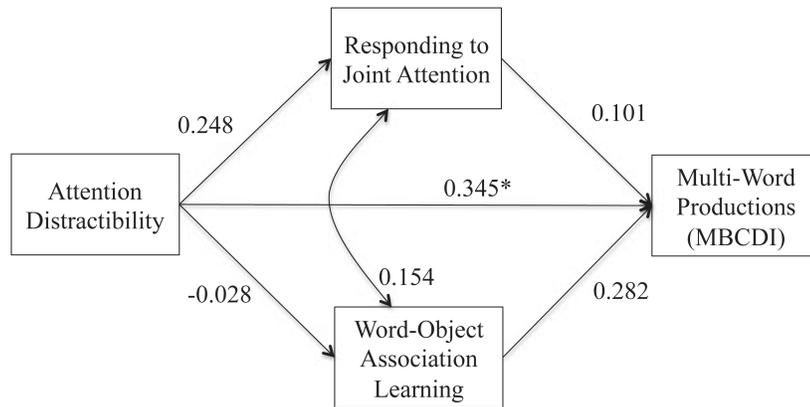


Figure 2. Path coefficients for the proposed model predicting MBCDI productive vocabulary. Note * $p < .05$, ** $p < .01$, *** $p < .001$

(a) Before controlling for initial communication level:



(b) After controlling for initial communication level:

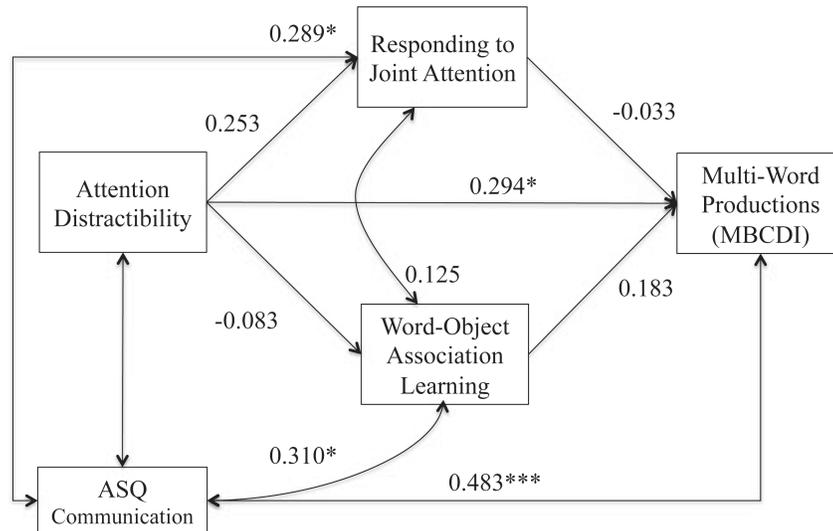


Figure 3. Path coefficients for the proposed model predicting MBCDI multi-word productions. Note * $p < .05$, ** $p < .01$, *** $p < .001$

Table 1
Descriptive Statistics

	Range	Mean (SD)
Ages and Stages Questionnaire (<i>n</i> = 46)		
Communication (Cutoff < 15; <i>n</i> = 6 below clinical cutoff)	0.0–95.0	37.93 (16.92)
Distractibility Task (<i>n</i> = 51)		
Number of Trials Infant Did Not Orient to Distractor	0–8	3.73 (2.28)
Early Social Communication Scales (<i>n</i> = 51)		
Proportion of Responding to Joint Attention (RJA)	0.07–0.94	0.53 (0.18)
Word–object Association Learning (<i>n</i> = 44)		
Switch Score (Residual)	–7.76 to 17.56	0.00 (6.37)
Peak Look Duration	21.20–169.85	66.56 (35.17)
Decrement in Looking	8.20–114.84	45.90 (25.63)
Number of Fixation Trials	4–27	10.19 (4.73)
MacArthur–Bates Communicative Development Inventory (<i>n</i> = 47)		
Productive Vocabulary Size	0.0–69.0	37.93 (16.92)
Multi-word Productions(Combining words: 1 – not yet; 2 – sometimes; 3 – often)	1–3	2.0 (0.72)

Table 2
Correlations Among Study Variables (Correlations with ASQ Communication Partialled)

	1	2	3	4	5	6
1. ASQ Communication	–					
2. Distractibility	0.17	–				
3. Responding to Joint Attention	0.28	0.19 (0.16)	–			
4. Word-object Association	0.30	-0.04 (-0.20)	0.19 (0.20)	–		
5. Productive Vocabulary	0.44**	0.53*** (0.61**)	0.35* (0.16)	-0.05 (-0.11)	–	
6. Multi-word Productions	0.59***	0.33* (0.24)	0.26 (0.03)	0.30(0.16)	0.67***	–
						(0.58**)

Note.

* $p < .05$,

** $p < .01$,

*** $p < .001$.

Table 3
Bootstrapped Direct Effects of Distractibility, Responding to Joint Attention, and Word-object Association on MBCDI Productive Vocabulary

	Point Estimate ^a	SE	Z	P	Bias-Corrected 95% CI	
					Lower	Upper
Before controlling for initial communication level						
Word-object Association	-0.120	0.411	-0.291	0.771	-0.837	0.792
Responding to Joint Attention	25.995	10.621	2.448	0.014	1.709	43.453
Distractibility	3.84	1.046	3.671	0.000	1.792	6.427
After controlling for initial communication level						
Word-object Association	-0.159	0.461	-0.345	0.730	-1.005	0.801
Responding to Joint Attention	8.963	11.830	0.758	0.449	-14.176	31.568
Distractibility	3.721	1.231	3.022	0.003	1.173	5.974
ASQ Communication	0.399	0.151	2.635	0.008	0.084	0.679

^aUnstandardized point estimates for the model are reported here to include corresponding SE values; standardized values are reported in Figure 2; 1,000 bootstrap samples.

Table 4
Bootstrapped Specific Indirect Effects of Distractibility on MBCDI Productive Vocabulary through Word-object Association and Responding to Joint Attention

	Point Estimate	SE	Z	p	Bias-Corrected 95% CI	
					Lower	Upper
Before controlling for initial communication level						
Word-object Association	0.002	0.025	0.068	0.946	-0.047	0.066
Responding to Joint Attention	0.061	0.055	1.101	0.271	-0.048	0.204
Total	0.063	0.062	1.018	0.308	-0.058	0.221
After controlling for initial communication level						
Word-object Association	0.006	0.038	0.151	0.880	-0.068	0.079
Responding to Joint Attention	0.022	0.037	0.600	0.549	-0.050	0.095
Total	0.028	0.054	0.515	0.607	-0.078	0.134

Note. 1,000 bootstrap samples.

Table 5
Bootstrapped Direct Effects of Distractibility, Responding to Joint Attention, and Word-object Association on MBCDI Multi-word Productions

	Point Estimate ^a	SE	Z	p	Bias-Corrected 95% CI	
					Lower	Upper
Before controlling for initial communication level						
Word-object Association	0.033	0.019	1.700	0.089	-0.003	0.069
Responding to Joint Attention	0.376	0.426	0.882	0.378	-0.591	1.181
Distractibility	0.108	0.045	2.410	0.010	0.028	0.202
After controlling for initial communication level						
Word-object Association	0.022	0.021	1.055	0.292	-0.020	0.063
Responding to Joint Attention	-0.131	0.534	-0.245	0.806	-1.126	0.922
Distractibility	0.097	0.049	1.975	0.048	0.008	0.204
ASQ Communication	0.022	0.006	3.556	0.000	0.008	0.032

^aUnstandardized point estimates for the model are reported here to include corresponding SE values; standardized values are reported in Figure 2; 1,000 bootstrap samples.

Table 6
Bootstrapped Specific Indirect Effects of Distractibility on MBCDI Multi-word Productions through Word-object Association and Responding to Joint Attention

	Point Estimate	SE	Z	p	Bias-Corrected 95% CI	
					Lower	Upper
Before controlling for initial communication level						
Word-object Association	-0.008	0.048	-0.164	0.869	-0.103	0.087
Responding to Joint Attention	0.025	0.038	0.658	0.510	-0.050	0.100
Total	0.017	0.066	0.260	0.795	-0.113	0.147
After controlling for initial communication level:						
Word-object Association	-0.015	0.042	-0.363	0.716	-0.097	0.067
Responding to Joint Attention	-0.008	0.039	-0.215	0.830	-0.085	0.068
TOTAL	-0.024	0.061	-0.388	0.698	-0.143	0.095

Note. 1,000 bootstrap samples.