Multisensory Integration in Early Toddlerhood: Interrelationships with Context, SES and Expressive Vocabulary

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ABSTRACT

In the everyday environment, we receive information from various sensory inputs, and yet, we perceive and integrate the incoming information in a way that is meaningful. Remarkably, infants and toddlers are capable of sensory integration early in life. By integrating information, particularly speech, infants ultimately learn to reproduce language by late toddlerhood. These language skills form a foundation for learning and achievement later in life, and there is documented evidence that language skills vary by experiences related to socioeconomic status (SES). Language disparities can be measured early in development, and continue to divide throughout childhood. Although there is clear evidence that language learning trajectories are influenced by SES, less is known about multisensory integration (MSI) as they are measured here and how these skills may differ as a function of SES. Here, MSI was investigated to gain insight into the potential changes that occur in MSI and expressive vocabulary for 68 toddlers between 18 months and 24-months. Finally, this relationship was investigated in the context of SES. At 18-months, toddlers demonstrated significant matching for nonsocial conditions, and at 24-months toddlers also matched for low competition social trials, thus demonstrating an improvement in matching from 18 to 24-months. There were no significant relationships between MSI and expressive vocabulary, and only one unexpected relationship between MSI and SES. These findings extend the research from Bahrick and colleagues (2018) by supplementing the previously studied 12-month-olds and 2-5-year-olds

with an earlier age (e.g., 18-months), and open new doors for studying toddlers' emerging social MSI.

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GENERAL AUDIENCE ABSTRACT

In the everyday environment, we experience various sights and sounds from multiple sources, and yet, we perceive the incoming information in a way that is meaningful. Infants and toddlers are also capable of combining multiple sources of information together in a way that is beneficial for language learning. Merging sensory information (e.g., correctly matching their mother's voice to their mother) creates a foundation for language learning. There is evidence that suggests language abilities differ as a result of socioeconomic status (SES), and can be found early in development and continue to progress into childhood. Although research indicates differences in language arise as a result of SES, it is unclear whether the ability to merge multiple sources of information (also known as multisensory integration), particularly while experiencing competing information (e.g., noise, multiple speakers) also differs as a result of SES.

Here, the ability to integrate multiple sources of information and vocabulary in young toddlers ages 18-months and 24-months was studied to understand whether these skills progress with age and also whether they differ as a result of SES. 18-month-olds demonstrated better integration of sensory information when blocks were falling (e.g., nonsocial event) than when women were shown on the screen speaking in child-directed speech (e.g., social event). At 24-months, toddlers also correctly matched the information of the social event when there was no competing information on the screen, thus improving social integration from 18-months. There were no significant relationships between MSI and vocabulary, and only one relationship

between MSI and SES. More research will need to be conducted to understand the improvement of social integration from 18 to 24-months, and more questions will need to be addressed on how SES may play a role in integrating information.

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The everyday environment provides an abundance of information from multiple sensory modalities, and yet adults are able to successfully perceive and integrate information in this complex array. Remarkably, so do human infants. That is, early in postnatal life, infants are able to successfully integrate information that they can simultaneously hear, see, smell, and feel (Bahrick & Lickliter, 2000). With increasing experience, infants improve their responsivity to changes in sensory information, and display more advanced perceptual recognition of dynamic events.

The ability to simultaneously process information occurring visually, auditorily, haptically, etc. is called 'multisensory integration'. More specific to this study, multisensory integration involves the ability to perceive information from two or more sensory systems based on their shared, amodal properties such as temporal synchrony, rhythm, intensity, duration and/or location (Bahrick & Lickliter, 2000; Stein, Stanford & Rowland, 2014). A rich example of this form of multisensory integration is when we are watching a percussionist perform a piece of music whose tempo we can see, hear, and feel all at the same time. For most infants and toddlers, this integration primarily involves information that they simultaneously hear and see. However, for the hearing- and/or visually-impaired child, integration across other systems (e.g., vestibular) is equally important.

Perceptual systems develop in contexts that may actually promote or demote integration abilities across sensory modalities, leading to inter-individual variability in the presentation of

these skills. There is evidence that such contexts as prenatal factors, parental care, and/or cognitive stimulation affect intersensory integration (Hackman, Farah, & Meaney, 2010). One ecological niche known to impact early perceptual and cognitive development is socioeconomic status (SES). However, little is known about the relationship between SES and emerging multisensory integration. SES is complex; it comprises numerous factors that are difficult to disentangle. Living in lower SES contexts can not only be disadvantageous for the development of children, but experiences related to lower SES can foster adverse effects on psychological well-being into adulthood. For example, research indicates a disproportionate representation of depression, anxiety, and stress in lower SES populations (Heflin & Iceland, 2009). These effects on parental well-being may cascade into parent-infant interactions, and negatively influence developmental outcomes. Research indicates disparities between higher and lower SES infants in various domains, including communicative initiation behaviors, lexical processing, and attentional abilities, which deem useful for later language acquisition (Clearfield & Niman, 2012; Fernald, Marchman, & Weisleder, 2013; Landry, Smith, Miller-Loncar, & Swank, 1997; Rowe & Goldin-Meadow, 2009). Such variability may result from differences in cognitive stimulation, and/or material resources related to socioeconomic adversity (Huttenlocker et al., 2010; McLoyd, 1998).

The goals of the current study were threefold: to assess multisensory integration in 18-month-olds as a potential transition point between multisensory processing of objects (12-month-olds) and multisensory processing of people (24-month-olds), to examine the relationship between multisensory integration and expressive vocabulary, and to examine whether multisensory integration is related to the SES of the infant's household. In order to understand the possibility that multisensory integration skills are differentially related to language ability as

a function of SES context, the sections below describe (1) the developmental emergence of multisensory attention skills, and (2) how SES relates to perceptual/cognitive development in infancy and early toddlerhood.

Developmental Emergence of Multisensory Integration

Early in postnatal life, infants are sensitive to amodal (e.g., synchrony, rhythm) information, and can perceive and integrate this information from naturally occurring events. For example, 4-month-olds infants were shown two dynamic events on a screen. On one side of the screen a game of peekaboo was being played and on the other side a toy percussion was shown playing a musical sequence (Spelke, 1976). Importantly, there was only one audiovisual match that was synchronous to the soundtrack being played, and the 4-month-old infants looked more towards the event synchronous to the soundtrack. Although these capabilities are evident early in development, research indicates that with experience, infants become more proficient in their perceptual abilities. In fact, early in development infants may not detect a change in unimodal stimuli (visual only) but will detect a change in stimuli if they were first habituated to bimodal (audiovisual) stimuli. As an illustration, Bahrick and Lickliter (2004) tested perceptual development in 5 and 8-month-old infants by investigating whether infants could detect subtle changes in the rhythm and tempo of a hammer tapping in unimodal or bimodal conditions. In the unimodal condition, infants were habituated to a clip of a hammer silently tapping to a specific rhythm and tempo (e.g., the rhythm was x x o xx where x represents a whole-beat impact, xx two half-beat impacts, and o a whole-beat rest). The rhythm was presented at a tempo of 110 beats per minute (1.8 Hz). During test trials for the unimodal condition, the hammer was shown silently tapping the same rhythm but at a new tempo (i.e., 240 beats per minute). For the bimodal change, infants were habituated to the same stimuli as the unimodal condition, although they

were shown the clip of the hammer tapping with a synchronized audio track. The 5-month-olds detected the change only in the bimodal condition (audiovisual) whereas the 8-month-olds detected changes in both unimodal and bimodal conditions.

Taken together, young infants are more likely to attend to, process, and remember patterns of amodal stimulation that are available through bimodal relations. In this sense, the detection of amodal properties serves as an early foundational guide to infant information processing, at least for inanimate objects and their associated sounds. But do infants show this same propensity to process amodal information in a more social domain (e.g., for speakers and their voices)? When presented with two identical faces visually articulating a different vowel, 8-week-old infants looked more to the face in synchrony with the soundtrack (Patterson & Werker, 2003). Additionally, infants 18- to 20-weeks-old detected the match between auditory and visual speech when presented synchronously (Kuhl & Meltzoff, 1982). When infants viewed two speakers articulating different vowel sounds (/a/ v. /i/), infants fixated longer on the visual vowel production that was matched and synchronous with the auditory production. This early sensitivity to amodal information that is bound by shared temporal space is called the *intersensory redundancy hypothesis* (IRH) (Bahrick & Lickliter, 2000). IRH contends that information presented redundantly across sensory modalities selectively recruits attention that promotes infant perceptual learning. For example, there is naturally-occurring synchronous auditory and visual information available in the mouth and head movements of speakers and the temporal (rhythmic) properties of their speech. Infants are guided to facial features that elicit redundant information. Lewkowicz and Hansen-Tift (2012) found infants between the ages of 4-8 months shift their attention from the eyes of a speaker to the mouth regardless of language, thus processing redundant information they can both hear and see. When viewing audiovisual

videos of a woman speaking, infants attended more to the mouth at 9 and 12-months (Tenenbaum et al., 2013). Importantly, this pattern of increased attention to the mouth of a speaker has recently been found in children up to five years of age (Morin-Lessard et al., 2019). When the mouth is not providing redundant information with speech (e.g., the face is static), increased attention to the mouth is no longer found. Conversely, while hearing a woman's speech but the woman is smiling, infants spend more time gazing at her eyes. Together, these findings underscore the ways in which attention to social partners can be selectively guided by multimodal information.

The development of selective attention occurs concurrently with the development of inhibition of attention. That is, in order to actively process information relevant to tasks or events, infants must also disregard extraneous information (e.g., noise, visual distractors) which can be attentionally demanding. Infants who display delayed attentional control are at higher risk for later deficits or delay in language development. For example, Dixon, Salley, and Clements (2006) found toddlers with low levels of attentional focus or ability to allocate attention have greater difficulty learning words when faced with distractions. The toddlers who demonstrated greater attention maintenance skills were less influenced by environmental distractors, particularly those of a social nature (i.e., woman reading a story in the child's nonnative language in the background during the task). Moreover, infants at-risk for autism have shown patterns that indicate impaired multisensory processing (Bahrick & Todd, 2012). This may be partially responsible for the prevalence of impaired language processing in children on the autism spectrum (Kjelgaard & Tager-Flusberg, 2001).

Socioeconomic Status and Related Attention and Cognitive Ability

Such studies as those mentioned above suggest that multisensory integration is present in the complex developmental network, continuously being augmented and refined by the environment in which infants develop. However, not all ecological niches provide the same benefits or augment developmental processes by the same means. Living in lower SES households, for example, can create challenges for families and for children to develop by the same means as their more affluent peers. There is abundant evidence regarding the negative influences for infants and children developing in lower socioeconomic circumstances (Masarik & Conger, 2017; Schwab & Lew-Williams, 2016; Tomalski et al., 2013; this relationship between lower SES and developmental risk is discussed in more detail below). As a result, there are differences in language learning trajectories between toddlers from lower v. higher SES families (Fernald, Marchman, & Weisleder, 2013). Currently, it is unclear if multisensory integration skills appear to be affected by SES for toddlers at 18 or 24-months-of-age. However, there is evidence indicating multisensory integration is related to language learning in toddlers, though more research needs to be done to more fully understand when multisensory integration as measured here can be used predictively for language - particularly for 18-month-olds (Bahrick, Todd, & Soska, 2018). The following section presents evidence for differences in attention abilities found in toddlers and older children as a result of socioeconomic status.

Lower SES environments create unique risks (e.g., excessive stress and anxiety for parents) that can be disadvantageous for families, and create negative cascades in early development for children. One important component within the context of SES is access to resources, with disproportionate access occurring in higher SES families (Phelan, Link, & Tehranifar, 2010). For parents, these resources can include income, but also include facets such as social support, child care, and/or access to health services. Families in lower SES homes face

greater hardships and barriers than families from higher SES homes, and when examining the role of SES hardships on development, maternal distress (e.g., depression, anxiety, and stress) often limits the capacity to actively attend to the needs of children (Evans, Boxhill, & Pinkava, 2008). Research has found that maternal sensitivity, warmth, and positive mother-infant interactions lead to better outcomes in language abilities and development (Schwab & Lew-Williams, 2016). Recently, maternal attention facilitation skills have been shown to positively relate to multisensory integration of social information in 2-year-olds (Bruce, Panneton, & Taylor, 2021). This raises the possibility that aspects of parenting that are associated with differing SES status may selectively impact emerging multisensory integration in young children.

As these effects cascade into parent-child interactions, there are measurable differences in outcomes across the socioeconomic continuum found in infants and toddlers. Researchers have sought to measure just how early these differences or delays emerge, and have found differences at various levels of development. Clearfield and Jedd (2013) followed infants longitudinally at 6, 9, and 12 months to determine if differences in attention could be detected between higher and lower SES infants. Attention was measured during a free play task that included high and low complex conditions (one toy vs. six toys). It was expected that lower SES infants would be more inattentive across conditions regardless of complexity. Differences in visual attention were detected as early as 6 months with infants from higher SES families attended longer to the single toy and better distributed their attention when presented with more complex stimuli (more toys). In contrast, infants from lower SES families were more easily distracted, and did not modify attention upon an increase in complexity. As the higher SES children aged, their look durations decreased in seconds to the simpler stimuli and increased focused attention for complex stimuli.

Comparatively, lower SES infants showed significantly higher levels of inattention at each time point for both the one-toy and six-toy condition when compared to higher SES infants, who showed less inattention overall at each time point.

Using a cumulative risk index, two measures were recently used to evaluate sustained attention in infancy as a mediator of socioeconomic risk and self-regulation prior to school entry (Brandes-Aitken et al., 2019). Both task-related sustained attention and global sustained attention were measured at 7-months and 15-months during home visits. Task-related attention involved observing and rating infant attention on a 5-point scale (e.g., gaze aversion when the child's eyes were distracted from the task, looking at the coder or camera). Global attention was rated using the Infant Behavior Record (Bayley, 1969) by completion of the research assistant that attended the home visit. Using this scale, global attention was rated on a 9-point scale related to overall attention to activities, objects, or people in the room during the home visit. Results showed a negative correlation between higher scores of cumulative risk and sustained attention. At school entry, a positive correlation was found between sustained attention and executive function. Wray et al. (2017) found that higher SES children demonstrated better selective attention in a dichotic listening task at age 4 whereas lower SES children did not exhibit similar scores until they were tested at age 5. Moreover, the lower SES children showed increased attention to a concurrent distracter than the higher SES children, indicating differences in inhibiting attention skills between these two groups that persist into early childhood.

In sum, SES effects on attention are persistently detected. Given the discrepancies between lower and higher SES toddlers in attentional skills, the interrelationship between language development and multisensory integration in the context of SES is an important avenue of research.

Socioeconomic Status and Language Development

Language skills set the foundation for subsequent learning and academic achievement later in life, and there is recent evidence that language skills vary by familial SES (Noble et al., 2015). Fernald, Marchman, and Weisleder (2013) detected SES-related differences in language processing and vocabulary outcomes in 18-month-olds. By 24-months, children from lower SES homes were showing a 6-month delay in typical language levels. Using the looking-while-listening procedure, Fernald and colleagues presented two groups of children (lower SES and higher SES) two pictures presented on a screen (e.g., car, juice, book). While viewing these two pictures, one of the two target objects was labeled by an English-speaking actress. The higher SES children showed faster and greater levels of attention to the named object compared to lower SES children. Also, higher SES children had larger expressive vocabularies by 24-months even though the lower SES children eventually attained comparable levels (similar to the delay in selective attention mentioned above). By the time the children that performed lower on this task entered preschool, their expressive vocabularies were slightly below their more advantaged peers, thus creating a gap in opportunity from the onset of their formal education. These findings provide evidence of cumulative negative effects on language learning in lower SES samples. It would be highly beneficial to try and connect specific skills (e.g., multisensory integration) to emerging language competence and how this relationship may be challenged by SES.

Aims of the Current Study

Recently, Bahrick, Todd, and Soska (2018) found that 12-month-old infants and toddlers from 24-months to 5 years of age show differential multisensory integration as a function of whether they were matching social v. nonsocial events and whether there was low or high competition for their attention. The protocol utilized in their study, the Multisensory Attention

Assessment Protocol (MAAP) presents two lateral dynamic events (speakers or objects) with one concordant soundtrack. High multisensory integration is operationalized as more attention to the matching visual+auditory event. Half of the test trials also had a visual distractor between the lateral events to see if attention maintenance to the match continued when competition was challenged.

In Bahrick et al.'s (2018) findings, important developmental differences emerged between the age groups (12-month-olds v. 24-month-olds to five year old children). The 12-month-olds demonstrated significant matching but only for nonsocial trials under low competition. They showed no other patterns of significant multisensory integration. In contrast, 24-month-olds demonstrated proficient matching across both social and non-social trials when competition for attention was low, and again on social trials when competition for attention was high. Thus, a developmental improvement in MSI was seen from 12- to 24-months of age, especially for social events.

In the current study, we had three main goals: (1) examine MSI skills in an intervening age (18-month-olds) to track the trajectory of MSI; (2) replicate the findings of Bahrick et al. (2018) for 24-month-olds, and (3) examine whether differences in SES were related to MSI or expressive vocabulary at either age. To complete these goals, this study first investigated whether there were significant differences in the multisensory integration skills on a task testing their abilities to match visual and auditory sound tracks in both social and nonsocial conditions. Next, the relationship between performance on this task and indices of language learning were tested between social and nonsocial conditions. Finally, analyses were conducted to determine potential differences in MSI or expressive vocabulary as a function of SES. For the first aim, we investigated whether 18-month-olds demonstrated MSI that was more similar to the 12-month-

olds (better matching in nonsocial conditions) or the 24-month-olds (better matching in the social conditions); thus, we had no specific prediction for this age group. For the second aim, we predicted that 24-month-olds would demonstrate matching on social trials irrespective of the competition for attention, but would only demonstrate matching on nonsocial trials when competition was low. Also, we predicted that MSI for low competition social trials would be positively correlated with expressive language, and that MSI and expressive vocabulary would be positively related to SES for both 18 and 24-month-olds.

Method

Participants

The current study used a secondary dataset that included 68 participants at two age points, first at 18-months and again at 24-months. The final sample included 68 18-month olds (M = 18.05 months, SD = .42; range: 17.00 months to 19.36 months) and 68 24-month-olds (M = 24.15 months, SD = .31; range: 23.70 months to 25.15 months) collected in Miami, Florida.

The demographic form was used to collect information regarding race, ethnicity, maternal income and maternal education (see Appendix A). Socioeconomic status (SES) was calculated using this form (measurement described below). Participants were recruited using county birth records, public phone records, posting in social media groups, and flyers in local businesses. Families received either a $10 gift card for participating. There were 35 females and 33 males; 42 participants were Hispanic or Latino, 24 were non-Hispanic, and two did not report. Twelve participants were African-American, one was Asian, 44 were Caucasian, one participant reported other, five participants reported more than one ethnicity, and five did not respond. In total, 26 toddlers were reported as being bilingual (e.g., English, Spanish) and 29 were

monolingual English; 13 parents did not return MCDI forms and therefore the toddlers remained uncategorized (see Table 1 for a summary of demographic variables).

Table 1.

Participant Demographics

	n	*%*
Age		
18-month-olds	68	
24-month-olds	68	
Gender		
Female	35	51.5
Male	33	48.5
Race		
Hispanic	42	61.8
Non-Hispanic	24	35.3
Did not report	2	2.9
Ethnicity		
African-American	12	17.6
Asian	1	1.5
Caucasian	44	64.7
More than one	5	7.4
Other	1	1.5
N/A	5	7.4
Language		
English	29	42.6
Bilingual	26	38.2
Missing	13	19.1

Experimental Tasks and Multisensory Integration Measures

Multisensory Attention Assessment Task (MAAP)

The MAAP measures multisensory integration and attention maintenance skills (Bahrick, Todd, & Soska, 2018). For this task, dynamic video clips were shown to the toddlers, with two condition types: 1) social, and 2) nonsocial, and two trial types: 1) with distractor (high

competition), and 2) no distractor (low competition). On every trial, two lateral, dynamic events were shown with only one lateral event being synchronous with the soundtrack being played. The social condition involved women reciting a story using typical child-directed speech. The nonsocial condition involved small objects (e.g., blocks, bolts) striking a surface and their associated sounds (see Figure 1 for an example of each condition). Prior to each trial, a visual, dynamic attention getter appeared in the center of the screen that remained on the screen for 3s until the trial began. During the session, there were 8 trials for each condition (social, nonsocial) for a total of 32, 10-second events (the duration of the MAAP lasted approximately 6.5 minutes). On half of the trials, the visual attention getter remained on the screen between each lateral event for the duration of the trial (i.e., high competition trial); for the other half, the attention getter terminated at the start of the trial and the middle of the screen was blank (i.e., low competition trial).

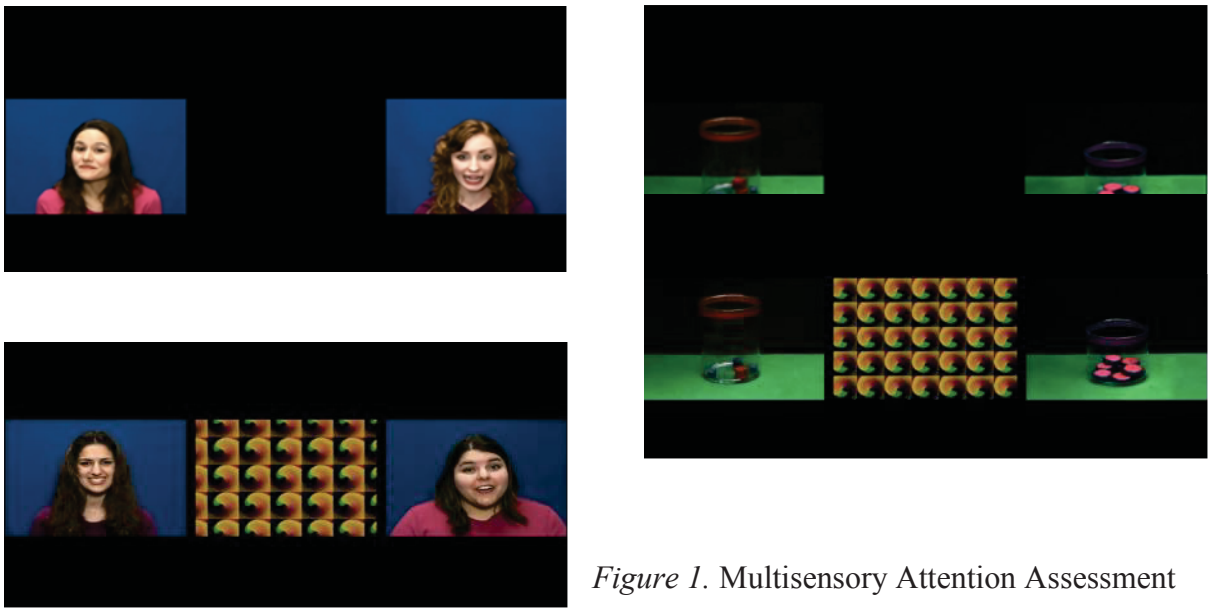

Figure 1. Multisensory Attention Assessment Protocol (MAAP): Social trials (left) and nonsocial trials (right); low competition (top row) and high competition (bottom row). Soundtrack matched

only one of the two lateral events within each trial. The match was counterbalanced on the left and right across trials.

From the MAAP, multisensory integration (MSI) was operationalized as toddlers' ability to (1) maintain attention to the match more than to the non-match (*match:non-match* ratio calculated as (match/(match+non-match)). This ratio ranged from 0 to 1.0, with values above .50 indicating more attention to the matched event.

Language and Socioeconomic Status Measures

To maintain consistency for 18 and 24-month-olds, expressive vocabulary was quantified using the MacArthur-Bates Communicative Development Inventory (MBCDI; Fenson et al., 1994). The MCDI consists of two forms: Words and Gestures (MBCDI-W&G) normed for toddlers ages 8 to 18 months, and Words and Sentences (MBCDI-W&S) normed for toddlers ages 16 months to 30 months. Words and Gestures was administered at 18-months and Words and Sentences was administered at 24-months. Scores were standardized, and each form served to measure expressive language at the corresponding age level.

At 18-months, caregivers completed the Words and Gestures form by responding to 396 items to indicate if the toddler understood or produced each individual item. At 24-months, caregivers completed the Words and Sentences form and responded to 680 items to indicate if the toddler produced each word. This form demonstrates high levels of internal consistency and test-retest reliability (Fenson et al., 1994; Heilmann et al., 2005).

Socioeconomic status (SES) was calculated by compositing the standardized scores of reported income and maternal education level. Income ranged from 1 (< $11,270) to 12 ($100,000+), and maternal education ranged from 1 (some high school) to 6 (Master degree/higher).

Procedure

The session began by bringing the parent and toddler into the waiting room/play area to allow the toddler to become comfortable in the space. The child was given toys to play with while the experimenter explained the overall procedure to the parent. During this time, the parent completed the demographic questionnaire and any remaining questions were answered during this time. The experimenter also discussed voluntary participation in Databrary to allow the parent to make an informed decision on whether or not they would like their recorded sessions to be uploaded to the secure database. After the procedure was thoroughly explained and the caretaker consented to participate, the experimenter and participants relocated into the test room.

The toddler was placed in front of the screen, either on their parent's lap or with the parent behind them. The toddler was seated approximately 100 cm away from the 102 in monitor. The viewing area subtended a visual angle of approximately 52°. The loudspeaker was placed behind the monitor and the soundtrack was presented at a level of 62 dB.

Trained observers who were blind to the condition and were unable to see the videos recorded visual fixations by depressing a button while children viewed the videos to calculate duration of looking. The total time the observer pressed the button indicated the total looking time the toddler was looking to either lateral event. To assess reliability for calculating duration of looking for each trial, a second observer recorded looking for 31% of the sample, which indicated high reliability between observers (Pearson product moment correlations were .91 for MSI).

Results

18-Month-Olds Multisensory Integration, Expressive Vocabulary, and SES

One primary interest was whether 18-month-old's multisensory integration in each condition (social, nonsocial) and trial type (low, high-competition) resembled that of 12-month-olds or 24-month-olds (Bahrick, Todd & Soska, 2018). One sample t-tests were calculated on match:non-match ratios against a test value of 0.50 (no preference). Scores significantly above .50 indicate the toddlers were looking more to the match.

For the nonsocial condition, 18-month-olds looked significantly more to the match than to the non-match during low competition trials (match:non-match ratio = .54; $t(67) = 4.41$, $p = .001$) and during high competition trials (match:non-match ratio = .55; $t(67) = 4.08$, $p = .001$).

For the social condition, 18-month-olds did not look significantly more to the match than to the non-match during low competition trials (match:non-match ratio = .51; $t(67) = .92$, $p = .35$) or high competition trials (match:non-match ratio = .48; $t(67) = -1.34$, $p = .18$). This partially replicates the pattern of findings of Bahrick, Todd and Soska (2018) for 12-month-olds. In that study, 12-month-olds only attended longer to the match on nonsocial, low competition trials. In contrast, we found 18-month-olds attended more to the match on both kinds of competition trials in the non-social condition. However, neither 12-month-olds nor 18-month-olds have shown more attention to the match on social trials, regardless of the level of competition.

A second interest was in the correlation between matching during the MAAP and expressive vocabulary. It was hypothesized MSI on low competition social trials would be correlated with expressive vocabulary. Using the Words and Gestures form (MBCDI; Fenson et al., 1994) a bivariate correlation was calculated between the social match:non-match ratio for low competition trials.[1] This hypothesis was not supported; MSI on social low competition trials

[1] The attrition for the MCDI (i.e., Words and Gestures, Words and Sentences) was high, reducing the sample size to n=39 for each age group (18-month-olds, 24-month-olds). Although

was not significantly correlated to expressive vocabulary (r = +.031, p = .852). Additionally, there were no significant correlations between additional match ratios and expressive vocabulary, regardless of condition (social, nonsocial) or competition (low, high) (see Table 2).

A third interest was in evaluating correlations between MSI and socioeconomic status. It was hypothesized that MSI in both conditions (nonsocial and social) would be positively correlated with SES. Bivariate correlations between MSI match:non-match ratios for each condition (social, nonsocial) and trial type (low, high competition) and SES were conducted using the composite SES score (i.e., maternal education and income). No significant correlations between MSI and SES were found (all p's > .05). Additionally, we wanted to investigate SES and expressive vocabulary; we expected a positive correlation between SES and expressive vocabulary. This hypothesis was not supported (r = +.038, p = .817; (see Table 2).

24-Month-Olds Multisensory Integration, Expressive Vocabulary, and SES

For the 24-month-olds, analyses focused on the pattern of toddlers' multisensory integration in each condition (social, nonsocial) and competition level (low, high). It was hypothesized that (1) 24-month-olds would exhibit higher levels of matching in the social condition at both levels of competition, and (2) that 24-month-olds would show significant matching on nonsocial trials that were low in competition, but not on high competition trials. As with the 18-month-olds, one sample t-tests were calculated on match:non-match ratios against a test value of 0.50 (no preference). Scores significantly above .50 indicated significantly higher looking times more to the matched event.

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there were toddlers with language scores at each age, several toddlers had reported language scores only at one time point. The final sample size (n = 39) were not all the same toddlers at each age.

For the nonsocial condition, 24-month-olds looked significantly more to the match on low competition trials (match:non-match ratio = .52; $t(67) = 2.24$, $p = .02$), as well as during high competition trials (match:non-match ratio = .55; $t(67) = 4.46$, $p = .001$).

For the social condition, 24-month-olds looked significantly more to the match on low competition trials (match:non-match ratio = .52; $t(67) = 2.4$, $p = .016$) but not on high competition trials (match:non-match ratio = .50; $t(67) = .56$, $p = .57$).

As with the 18-month-olds, bivariate correlations were calculated between MSI ratios and expressive vocabulary using the Words and Sentences form (MBCDI; Fenson et al., 1994). We expected MSI on social low competition trials would be significantly correlated with expressive vocabulary. However, this hypothesis was not supported. There was no significant relationship between MSI on social low competition trials and expressive vocabulary ($r = +.11$, $p = .51$). There were no significant correlations between any of the match ratios regardless of condition (social, nonsocial) or competition (low, high) (see Table 2).

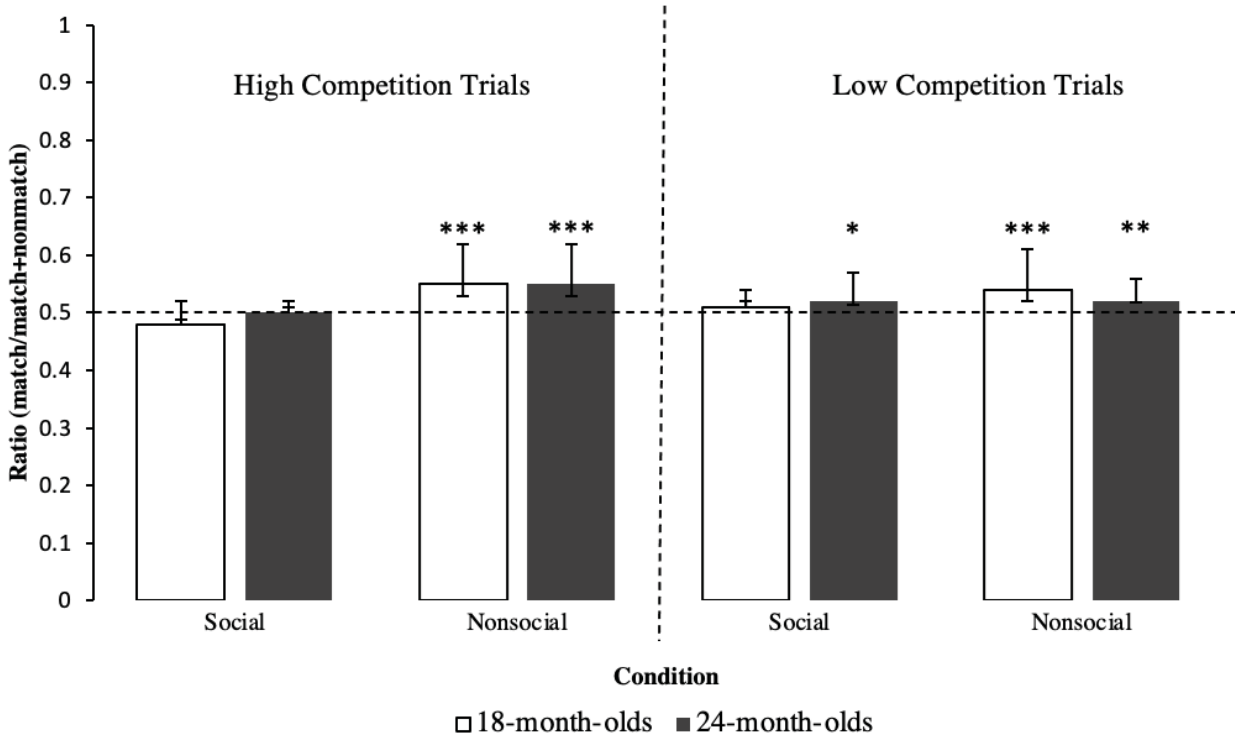
Two separate bivariate correlations were conducted, first between SES and MSI, second between SES and expressive vocabulary; we expected to see that both MSI and expressive vocabulary were positively correlated with SES. No significant correlations were found between the composite SES score and expressive vocabulary (all p's > .05; see Table 2). Only one significant (albeit unexpected) relationship emerged between MSI and SES. Nonsocial low competition trials were negatively related to SES ($r = -.25$, $p = .03$).

Table 2. Bivariate Correlations Between Multisensory Integration Ratios, Expressive Vocabulary, and Socioeconomic Status for 18 and 24-month-olds.

	18-Month-Olds	24-Month-Olds

	Expressive Vocabulary	SES	Expressive Vocabulary	SES
Social Trials				
Match:non-match Ratio (Low)	.031	-.017	.108	.214
Match:non-match Ratio (High)	-.041	.140	.247	-.053
Nonsocial Trials				
Match:non-match Ratio (Low)	.038	-.216	-.089	-.249*
Match:non-match Ratio (High)	-.197	.001	-.254	.117

Note. n = 39 for expressive vocabulary, n = 68 for SES; * p < .05



*p<.05, **p<.01, ***p<.001

Figure 2. Relative attention to the match compared to the non-match (match: non-match ratio) as a function of condition (social and nonsocial) for high competition trials (left) and low

competition trials (right). Ratios were compared to .50 (no preference), scores above .50 indicate more attention to the match or to the non-match. The standard error bars represent the confidence interval range for each event.

Discussion

The current study had three aims: 1) assess MSI in 18-month-olds, 2a) replicate the MSI findings of Bahrick et al. (2018) for 24-month-olds, and 2b) to analyze the relationship between their MSI of social events and their emerging expressive vocabulary; and 3) examine whether differences in SES were related to MSI in either of the 18 and 24-month-olds. Toddlers viewed two conditions (nonsocial, social) and two trial types (low competition, high competition). MSI was calculated by taking the ratio of total looking time to the match vs. the non-match (match/(match+non-match)) in low and high competition trials. Expressive language was measured by Words and Gestures for 18-month-olds and Words and Sentences for 24-month-olds (Fenson et al., 1994) and SES was evaluated using a composite measure of income and maternal education.

AIM 1: What is the nature of MSI in 18-month-olds?

Bahrick, Todd and Soska (2018) investigated MSI for 12-month-olds, and toddlers ages 24-months up to five-year-olds. Based on the previous findings, there is a developmental shift in MSI from 12-months to 24-months; 12-month-olds demonstrate matching only for nonsocial trials with low competition, whereas the 24-month-olds demonstrate an improvement in matching, particularly for social trials. The results of the current study found 18-month-olds attended significantly more to the matched event in both nonsocial conditions (low competition, high competition) but not in either of the social conditions. Thus, the 18-month-olds were still in a nonsocial phase that is more closely aligned with 12-month-olds. From 12 to 18-months,

toddlers in the current sample improved attention control to bimodally-specified nonsocial events by attending more to the matched events not only when competition for attention was low, but also when competition was high. However, the lack of evidence for their multisensory integration of a dynamic face+voice is notable.

First, social information is more variable, complex, and more unpredictable than nonsocial information when considering the natural environments of infants and toddlers. Nonetheless, research shows infants are faster to orient to social stimuli than nonsocial stimuli and social processing improves with age (Bahrick et al., 2016; Courage, Reynolds & Richards, 2006). However, 18-month-olds in this study did not demonstrate better matching in social conditions than for nonsocial conditions. Thus, from 12 to 18-months infants gain the ability to selectively attend to the synchronous event significantly above chance for high competition trials, at least for nonsocial conditions.

Given the salience of social stimuli in early development and the lack of matching for social conditions, one question remained: were toddlers attending more to the nonsocial conditions? That is, were the toddlers showing greater attention to the nonsocial conditions, thereby providing more opportunities to find the match? Looking duration for the entirety of each trial (i.e., 12 seconds) to both nonsocial conditions (low, high, collapsed across competition) and social conditions (low, high, collapsed across competition) was explored. There were no significant differences in looking duration for social vs. nonsocial conditions when collapsed across competition levels (low, high), or between high competition social and nonsocial conditions. However, the toddlers' total duration of looking time in low competition social conditions was significantly higher than in low competition nonsocial conditions.

With this in mind, it is unclear exactly where the toddlers were attending on screen if they were not matching above chance during the social conditions. One possibility is that the toddlers were showing a "social preference" by looking back and forth between the match and the non-match. In a previous study, this question was addressed via a new ratio (non-match/(non-match + distractor)) for 24-month-olds; if there was no significant difference between looking to the match or to the non-match, this would indicate a social preference rather than a preference for multimodal matching (Bruce et al., 2021). However, 18-month-olds were looking significantly above chance to the match, indicating the findings were not just a "social preference" but toddlers were more interested in the social event that was coordinated to the soundtrack. Thus, at 18-months, the toddlers find the match, but may also switch between both speakers. The non-match ratio will be essential to understand more deeply whether the lack of social matching for 18-month-olds was due to a social preference.[2]

AIM 2a: What is the nature of MSI in 24-month-olds?

Similar to the findings of Bahrick, Todd and Soska (2018), the current study found that 24-month-olds showed significant matching in both nonsocial and social conditions when competition was low, as well as the nonsocial condition when competition was high. However, unlike Bahrick et al., the current study did not corroborate toddlers' significant matching on social trials with high competition.

One potential explanation for this discrepancy may be due to Bahrick et al.'s aggregation of performance across a wide age range (i.e., MSI was collapsed across children from 2- to 5-years of age). If both the skill of perceiving bimodally-specified events and the motivation to process faces+voices is increasing with age, the successful matching in the social condition on

[2] This ratio would have been calculated in the current study, however this information was unavailable to the researchers during data analysis.

high competition trials may be due to the inclusion of older children. In fact, Bahrick, Todd and Soska (2018) analyzed the parameter estimates of age as a covariate in their model and found that matching significantly increased with age, especially on high competition trials in their social condition.

The current study involved only 24-month-olds and this may be just the beginning of a trajectory of improvement for processing face+voice information. It will be important for future studies to investigate MSI individually at each intervening age. In this vein, a recent new study from our own laboratory conducted with 24-month-olds found significant matching on low and high competition trials, and within both social and non-social conditions (Bruce, Panneton & Taylor, 2021). At best, it appears that the ability of 24-month-olds' to sustain their attention on a sound-synchronous face+voice event when competition is high is an emerging but unstable skill that improves over the months to come.

Aim 2b: Is 24-month-olds' multisensory integration of social events correlated with their expressive vocabulary?

Another inconsistency across the current study and that of Bahrick, Todd and Soska (2018) was in the relationship between social MSI and expressive vocabulary. No significant correlation was found between these variables in the current data, either for social low or social high competition trials. In this study, as the children age, they likely demonstrate more advanced MSI, attention control, and expressive vocabularies. This finding was surprising as expressive vocabulary has been shown to positively correlate with low competition social MSI not only in Bahrick et al.'s findings, but also in a recent study from our own laboratory (using the same stimuli utilized in the current study) whereby 24-month-olds' social matching on both low and high competition trials was significantly and positively correlated with expressive vocabulary

(Bruce, Panneton, & Taylor, 2021). The discrepancies may be related to 1) sample age, and/or 2) language exposure. In the current sample, at least 38% of the 24-month-olds were bilingual.[3] Currently, it is unknown if bilingual toddlers at this age show varying MSI as a function of their language exposure. However, an important component of Bruce et al.'s (2021) significant findings between social MSI and expressive vocabulary may be related to the fully monolingual English sample.

Research indicates bilingual toddlers show varying developmental trajectories and experiences compared to monolingual toddlers. For example, audiovisual speech integration varied as a function of language exposure in a sample of 4- to 8-month-old infants (Mercure et al., 2019). Monolingual and bilingual infants were shown to increase attention to the mouth of talking faces between the ages of 4 to 8 months, whereas bimodal bilingual toddlers (i.e., hearing infants with Deaf mothers) did not increase attention to the mouth. Thus, the authors conclude that experience with audiovisual speech influences sensitivity to integration of audio and visual cues.

A study conducted on young adults found significant differences in MSI between monolinguals and bilinguals (Bidelman & Heath, 2018). While using the double-flash illusion task, bilingual individuals were less susceptible to the illusion of the double-flash, and had a more narrow temporal binding window compared to the monolinguals. Thus, older bilingual individuals showed enhanced MSI and audiovisual binding as a result of a second language experience. In the current findings, it is unclear if bilinguals are showing a cognitive or

[3] A total of 13 toddlers had no reported language score, and therefore could have potentially been bilingual. These toddlers were not included in any language analyses, though may show varying MSI for social events as these were presented in English.

perceptual advantage, thus warranting an investigation of MSI between bilingual and monolinguals earlier in development.

To account for potential gaps in expressive vocabulary, aggregated scores from the English and Spanish MCDI forms were investigated in relation to expressive vocabulary. The relationship between social MSI and expressive vocabulary remained insignificant.

In this sample, we found 1) toddlers did not significantly match in the high competition social condition, and 2) social MSI (during low competition trials) was not related to expressive vocabulary. It will be important for future studies to disentangle language experience from MSI, particularly for social conditions.

AIM 3: Is multisensory integration differentially related to SES?

It was hypothesized social MSI and expressive vocabulary would be positively related to SES for 18 and 24-month-olds. This hypothesis was not supported for either age group. SES effects related to cognitive, perceptual, and language development can be found across various studies using diverse methodology (behavioral, psychophysiological) and yet we found only one relationship between SES and MSI (albeit unexpected), and no relationships between SES and expressive vocabulary. One negative correlation emerged between nonsocial low competition and SES, and this relationship was only seen in the 24-month-olds.

One important limitation of the current study was the lack of variability in SES in this sample. That is, there was substantial range restriction in both maternal education and maternal income. The mean for maternal education was 4.48 (SD=1.34) with a median of 5 on a scale from 1 to 6. The mean for maternal income was 9.44 (SD=3.41) with a median of 11 on a scale from 1 to 12. Out of the 67 mothers who indicated their level of education, 49 (73%) had an associates degree or higher. Income was presented to the mothers categorically on the family

demographic survey so the actual family income is unknown. However, of the 64 mothers who indicated their family income bracket, 46 mothers reported an income level higher than the mean, and of these 46, 21 mothers reported an income higher than $100,000. As such, both maternal education and maternal income were both negatively skewed.

Nonetheless, previous studies show significant differences across the SES continuum, and future studies should aim to 1) diversify sample demographics, and 2) expand SES conceptualization. Although many studies have utilized maternal education and income when measuring SES, recent work suggests this conceptualization is too narrow, leading to difficulties comparing SES across studies (Pollak & Wolf, 2020). These authors suggest that by disentangling socioeconomic status, income, and poverty, more fine-grained comparisons can be made. Future studies should aim to include a more comprehensive measure (i.e., Pollak & Wolfe, 2020) to calculate SES in an effort to maximize potential gains in SES related research.

We found only one, unexpected negative relationship between nonsocial low competition matching and SES. One possibility is that all toddlers across the SES continuum demonstrated matching, however, more fine-grained individual differences related to SES would likely be detected in indices related to attention control (e.g., total duration of looking at the match across trials, proportion of time spent looking at the match than to the distractor (match:distractor ratio)). Similarly, faster disengagement from the central distractor (for high competition trials) would also glean important differences related to attention control. Previous findings indicate robust differences related to attention and attention control across the SES continuum, so these indices will be important to include in future studies, particularly when measuring SES related effects (Brandes-Aitken et al., 2019; Clearfield & Jedd, 2013; Wray et al., 2017).

From 18-months to 24-months, toddlers transitioned from more of a "nonsocial phase" whereby the infants matched only for nonsocial conditions, to more of a "social phase" at 24-months in which they matched for social low competition trials, and both nonsocial conditions (low, high competition). The significant and negative correlation between nonsocial low competition and SES may indicate 24-months-olds are becoming more advanced in their MSI, particularly for social stimuli. Given the findings that show higher SES toddlers are more advanced in their attentional skills earlier in development than lower SES toddlers, this finding may reflect this advanced trajectory (Brandes-Aitken et al., 2019; Wray et al., 2017). Particularly given the lack of the distractor during low competition trials, this condition (i.e., nonsocial) may be too simple and does not challenge attentional systems, leading to fewer looks and less attention to the match.

Additionally, we hypothesized expressive language and SES would be significantly correlated. This hypothesis was not supported for either age group. However, research indicates maternal responsiveness, or attention facilitating behaviors are positively related to expressive vocabulary, which may be beneficial for language learners in lower SES environments (Bruce et al., 2021; Tamis-LeMonda et al., 2014). However, recent work found the relationship between parental linguistic input (i.e., syntactic complexity, vocabulary diversity) and child language was unrelated to SES or maternal education (Anderson et al., 2021). In a similar vein, Sperry et al., (2019) found significant variation in the language environments of toddlers in communities across the SES continuum that was not a byproduct of SES. That is, the authors suggest future studies should investigate variance in language input from caregivers in communities (e.g., demographic location) both within and across SES brackets.

In sum, this study investigated MSI, language, and SES across 18 and 24-month-old toddlers, with the intention of replicating Bahrick, Todd, & Soska (2018) and extending their findings to an additional age group (18-months). The current study also investigated these relationships in the context of SES, to explore potential differences in MSI or language. Results indicated an improvement in 18-month-olds' MSI for nonsocial trials with high competition from 12-months, and an improvement in social trials with low competition at 24-months. Accordingly, it stands to reason that attention to face+voice stimuli is an emerging skill that gains improvement with experience. However, no significant relationships were found for either age group between MSI and expressive language, and only one between MSI and SES. Nonetheless, it is evident that MSI is transforming in early development, and the current findings create new, exciting pathways for questions to be addressed in future studies.

References

Anderson, N. J., Graham, S. A., Prime, H., Jenkins, J. M., & Madigan, S. (2021). Linking quality and quantity of parental linguistic input to child language skills: A meta-analysis. *Child Development*, *92*(2), 484-501. https://doi.org/10.1111/cdev.13508

Bahrick, L. E., & Lickliter, R. (2000). Intersensory redundancy guides attentional selectivity and perceptual learning in infancy. *Developmental Psychology, 36*(2), 190-201. https://psyc-net.apa.org/doi/10.1037/0012-1649.36.2.190

Bahrick, L. E., & Lickliter, R. (2004). Infants' perception of rhythm and tempo in unimodal and multimodal stimulation: A developmental test of the intersensory redundancy hypothesis. *Cognitive, Affective, & Behavioral Neuroscience, 4*, 137-147. https://doi.org/10.3758/CABN.4.2.137

Bahrick, L. E., & Todd, J. T. (2012). Multisensory processing in autism spectrum disorders: Intersensory processing disturbance as a basis for atypical development. *The New Handbook of Multisensory Processes*, 657-674. Retrieved from http://www.academia.edu/

Bahrick, L. E., Todd, J. T., & Soska, K. C. (2018). The Multisensory Attention Assessment Protocol (MAAP): Characterizing individual differences in multisensory attention skills in infants and children and relations with language and cognition. *Developmental Psychology, 54*(12), 2207-2225. https://doi.org/10.1037/dev0000594

Bayley, N. (1969). Manual for the Bayley scales of infant development. Psychological Corporation.

Betancourt, L. M., Brodsky, N. L., & Hurt, H. (2015). Socioeconomic (SES) differences in language are evident in female infants at 7 months of age. *Early Human Development, 91*(12), 719-724. https://doi.org/10.1016/j.earlhumdev.2015.08.002

Bidelman, G. M., & Heath, S. T. (2019). Enhanced temporal binding of audiovisual information in the bilingual brain. *Bilingualism, 22*(4), 752-762. https://doi.org/10.1017/S1366728918000408

Brandes-Aitken, A., Braren, S., Swingler, M., Voegtline, K., & Blair, C. (2019). Sustained attention in infancy: A foundation for the development of multiple aspects of self-regulation for children in poverty. *Journal of Experimental Child Psychology*, 184, 192-209. https://doi.org/10.1016/j.jecp.2019.04.006

Bruce, M. Panneton, R. & Taylor, C. (2021). Social multisensory integration and maternal sensitivity are related to each other and predictive of expressive vocabulary in 24-month-olds (in progress).

Clearfield, M. W., & Jedd, K. E. (2013). The effects of socio-economic status on infant attention. *Infant and Child Development, 22*(1), 53-67. https://doi.org/10.1002/icd.1770

Clearfield, M. W., & Niman, L. C. (2012). SES affects infant cognitive flexibility. *Infant Behavior & Development*, *35*(1), 29–35. https://doi.org/10.1016/j.infbeh.2011.09.007

Courage, M. L., Reynolds, G. D., & Richards, J. E. (2006). Infants' attention to patterned stimuli: Developmental change from 3 to 12 months of age. *Child Development, 77*(3), 680-695. https://doi.org/10.1111/j.1467-8624.2006.00897.x.

Dixon Jr, W. E., Salley, B. J., & Clements, A. D. (2006). Temperament, distraction, and learning in toddlerhood. *Infant Behavior and Development, 29*(3), 342-357. https://doi.org/10.1016/j.infbeh.2006.01.002

Evans, G. W., Boxhill, L., & Pinkava, M. (2008). Poverty and maternal responsiveness: The role of maternal stress and social resources. *International Journal of Behavioral Development, 32*(3), 232-237. https://doi.org/10.1177/0165025408089272

Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., Pethick, S. J., & Stiles, J. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development, 59*(5),1–173. https://doi.org/10.2307/1166093

Fernald, A., Marchman, V. A., & Weisleder, A. (2013). SES differences in language processing skill and vocabulary are evident at 18 months. *Developmental Science, 16*(2), 234-248. https://doi.org/10.1111/desc.12019

Hackman, D. A., Farah, M. J., & Meaney, M. J. (2010). Socioeconomic status and the brain: Mechanistic insights from human and animal research. *Nature Reviews Neuroscience, 11*(9), 651-659. https://doi.org/10.1038/nrn2897

Heflin, C. M., & Iceland, J. (2009). Poverty, material hardship, and depression. *Social Science Quarterly, 90*(5), 1051-1071. https://doi.org/10.1111/j.1540-6237.2009.00645.x

Huttenlocher, J., Waterfall, H., Vasilyeva, M., Vevea, J., & Hedges, L. V. (2010). Sources of variability in children's language growth. *Cognitive Psychology, 61*(4), 343-365. https://doi.org/10.1016/j.cogpsych.2010.08.002

Kjelgaard, M. M., & Tager-Flusberg, H. (2001). An investigation of language impairment in autism: Implications for genetic subgroups. *Language and Cognitive Processes, 16*(2–3), 287–308. https://doi.org/10.1080/01690960042000058

Kuhl, P. K., & Meltzoff, A. N. (1982). The bimodal perception of speech in infancy. *Science, 218(*4577), 1138-1141. https://doi.org/10.1126/science.7146899

Landry, S. H., Smith, K. E., Miller-Loncar, C. L., & Swank, P. R. (1997). Predicting cognitive-language and social growth curves from early maternal behaviors in children at varying degrees of biological risk. *Developmental Psychology*, *33*(6), 1040–1053. https://doi.org/10.1037/0012-1649.33.6.1040

Lewkowicz, D. J., & Hansen-Tift, A. M. (2012). Infants deploy selective attention to the mouth of a talking face when learning speech. *Proceedings of the National Academy of Sciences, 109*(5), 1431-1436. https://doi.org/10.1073/pnas.1114783109

Masarik, A. S., & Conger, R. D. (2017). Stress and child development: A review of the family stress model. *Current Opinion in Psychology*, 13, 85-90. https://doi.org/10.1016/j.copsyc.2016.05.008

McLoyd, V. C. (1998). Socioeconomic disadvantage and child development. *American Psychologist*, 53(2), 185–204. Retrieved from https://academia.edu/

Morin-Lessard, E., Poulin-Dubois, D., Segalowitz, N., & Byers-Heinlein, K. (2019). Selective attention to the mouth of talking faces in monolinguals and bilinguals aged 5 months to 5 years. *Developmental Psychology, 55*(8), 1640-1655. https://doi.org/10.1037/dev0000750

Mercure, E., Kushnerenko, E., Goldberg, L., Bowden-Howl, H., Coulson, K., Johnson, M. H., & MacSweeney, M. (2019). Language experience influences audiovisual speech integration in unimodal and bimodal bilingual infants. *Developmental Science, 22*(1), e12701. https://doi.org/10.1111/desc.12701

Noble, K. G., Engelhardt, L. E., N. H., Mack, L. J., Nail, E. J., Angal, J., Barr, R., Fifer, W. P., Elliot, A. J., & PASS Network. (2015). Socioeconomic disparities in neurocognitive development in the first two years of life. *Developmental Psychobiology, 57*(5), 535-551. https://doi.org/10.1002/dev.21303

Patterson, M. L., & Werker, J. F. (2003). Two-month-old infants match phonetic information in lips and voice. *Developmental Science, 6*(2), 191-196. https://doi.org/10.1111/1467-7687.00271

Phelan, J. C., Link, B. G., & Tehranifar, P. (2010). Social conditions as fundamental causes of health inequalities: Theory, evidence, and policy implications. *Journal of Health and Social Behavior*, *51*(1), S28-S40. https://doi.org/10.1177/0022146510383498

Pollak, S. D., & Wolfe, B. L. (2020). Maximizing research on the adverse effects of child poverty through consensus measures. *Developmental Science, 23*(6), e12946. https://doi.org/10.1111/desc.12946

Rowe, M. L., & Goldin-Meadow, S. (2009). Differences in early gesture explain SES disparities in child vocabulary size at school entry. *Science*, *323*(5916), 951–953. https://doi.org/10.1126/science.1167025

Schwab, J. F., & Lew-Williams, C. (2016). Language learning, socioeconomic status, and child-directed speech. Wiley Interdisciplinary Reviews: *Cognitive Science*, *7*(4), 264-275. https://doi.org/10.1002/wcs.1393

Spelke, E. (1976). Infants' intermodal perception of events. *Cognitive Psychology, 8*(4), 553-560. https://doi.org/10.1016/0010-0285(76)90018-9

Sperry, D. E., Sperry, L. L., & Miller, P. J. (2019). Reexamining the verbal environments of children from different socioeconomic backgrounds. *Child Development, 90*(4), 1303-1318. https://doi.org/10.1111/cdev.13072

Stein, B. E., Stanford, T. R., & Rowland, B. A. (2014). Development of multisensory integration from the perspective of the individual neuron. *Nature Reviews Neuroscience, 15*(8), 520-535. https://doi.org/10.1038/nrn3742

Tamis-LeMonda, C. S., Kuchirko, Y., & Song, L. (2014). Why is infant language learning facilitated by parental responsiveness?. *Current Directions in Psychological Science, 23*(2), 121-126. https://doi.org/10.1177/0963721414522813

Tenenbaum, E. J., Shah, R. J., Sobel, D. M., Malle, B. F., & Morgan, J. L. (2013). Increased focus on the mouth among infants in the first year of life: A longitudinal eye-tracking study. *Infancy, 18*(4), 534-553. https://doi.org/10.1111/j.1532-7078.2012.00135.x

Tomalski, P., Moore, D. G., Ribeiro, H., Axelsson, E. L., Murphy, E., Karmiloff-Smith, A., Johnson, M. H., & Kushnerenko, E. (2013). Socioeconomic status and functional brain development–associations in early infancy. *Developmental Science, 16(*5), 676-687. https://doi.org/10.1111/desc.12079

Wray, A. H., Stevens, C., Pakulak, E., Isbell, E., Bell, T., & Neville, H. (2017). Development of selective attention in preschool-age children from lower socioeconomic status backgrounds. *Developmental Cognitive Neuroscience,* 26, 101-111. https://doi.org/10.1016/j.dcn.2017.06.006

Appendix A: Multinet Background Questionnaire

MULTINET BACKGROUND QUESTIONNAIRE

FOR OFFICE USE ONLY
Participant ID: _____ Age: mos_____, days_____ Test Date: _____
Study: _____ Subject #_____ Visit #_____ Session: _____
Site PI and Location: _____
Other Prior Studies: _____

Section A: Basic information about you and your child.

1. What is your relationship to your child?
____ Mother
____ Father
____ Other, please specify _____

2. Are you the child's primary caregiver? _____ Yes ____ No
If you answered No, who is the child's primary caregiver? _____

3. Sex of your child: ____ Male ____ Female

4. What is your child's date of birth? _____

Section B: Race, Ethnicity, Nationality. Please check one in each category for each person. We are required to report these data to the National Institutes of Health (NIH) in this format.

Category 1 (please check one)	Child	Mother	Father
Hispanic or Latino			
Not Hispanic or Latino			
Category 2 (please check one)			
American Indian/Alaska Native			
Asian			
Native Hawaiian or Other Pacific Islander			
Black or African American			
White			
More than one race			

5. What is your country of origin? _____

6. What is your spouse/partner's country of origin? _____

Section C: Parent education, employment, and income.

The following questions are about you and your partner. Your "partner" refers to any significant figure in your household that plays a major role in helping you raise your child (e.g., spouse, parent, grandparent, other).

7. What is your relationship to your child?
____ Mother
____ Father
____ Other, please specify _____

Age: _____

8. What is your partner's relationship to your child?
____ Mother
____ Father
____ Other, please specify _____

Age: _____

9. What is the highest level of education that you and your spouse/partner have achieved to date?

Please check one category for each person: You Your spouse/partner
8th grade or less
Some high school (or equivalent)
High school graduate
Some vocational/technical training (after high school)
Completed vocational/technical training (after high school)
Some college
Completed college (bachelor's degree)
Some graduate school
Completed a master's degree
Some graduate training beyond a master's degree
Completed a doctoral degree (e.g., Ph.D., J.D., M.D., PsyD)

10. Please indicate your current employment status for you and your spouse/partner:

Please check one category for each person: You Your spouse/partner
Full-time
Part-time
Retired
Unemployed

11. If employed, please indicate your occupation/job title: _____

12. If employed, please indicate your spouse/partner's occupation/job title:

_____

13. Thinking about your income and the income of everyone who lives in your household and contributes to the household budget, what was the total household income before taxes and deductions in the last tax year? Include all sources of income, including non-legal sources.

___ less than $5,000
___ $5,000 to $9,999
___ $10,000 to $14,999
___ $15,000 to $19,999
___ $20,000 to $24,999
___ $25,000 to $29,999
___ $30,000 to $39,999
___ $40,000 to $49,999
___ $50,000 to $74,999
___ $75,000 to $99,999
___ $100,000 to $149,999
___ $150,000 to $199,999
___ $200,000 or more

Section D: Languages.

14. What is your and your spouse/partner's preferred language?

Please check only one category for each person:	You	Your spouse/partner
English		
Spanish		
Other (Specify):		
Other (Specify):		

15. What is your and your spouse/partner's native language? Please check only one:

Please check only one category for each person:	You	Your spouse/partner
English		
Spanish		
Other (Specify):		
Other (Specify):		

16. What language do you and your spouse/partner usually speak when talking with your child?

Please check only one category for each person:	You	Your spouse/partner
Only English		
More English than Spanish/other language		
Both equally		

More Spanish/other language than English
Only Spanish/other language

17. Considering all the people who speak to your child in a typical day, please circle the percentage of time your child hears English (vs. Spanish, or another language, please specify_____)

100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 0%

Always or almost always
English Usually
English Half the time
English/half other language(s) Sometimes
English Almost never or never
English

Section E: Pregnancy history.

18. When the child's mother was pregnant, about how many prenatal-care visits did she have with a doctor or nurse/mid wife?
____ 0
____ 1-2
____ 3-5
____ 4-6
____ 7-10
____ 11-15
____ More than 15

19. During this pregnancy, how often did she drink alcoholic beverages?
____ Never
____ Less than once a month
____ Several times a month
____ Several times a week
____ Almost every day

20. During this pregnancy, about how many cigarettes did she smoke? (choose the option that comes closest to how much she smoked)
____ None
____ One pack a day or less
____ More than 1 pack a day, but less than 2 packs a day
____ 2 or more packs a day

21. Did she take any antidepressant medication during any portion of your pregnancy? ____ Yes ____ No
If yes, please indicate which medication(s) she took:

Selective serotonin reuptake inhibitors (SSRIs):
____ Zoloft (sertraline)
____ Celexa (citalopram)
____ Lexapro (escitalopram)
____ Prozac, Sarafem (fluoxetine)
____ Luvox (fluvoxamine)
____ Paxil (paroxetine)

Serotonin-norepinephrine reuptake inhibitors (SNRIs):
____ Effexor (venlafaxine)
____ Effexor XR (venlafaxine XR)
____ Pristiq (desvenlafaxine)
____ Cymbalta (duloxetine)
____ Fetzima (levomilnacipran)
____ Savella (milnacipran)

Atypical antidepressants:
____ Bupropion (wellbutrin, forfivo XL, aplenzin, zyban)
____ Mirtazapine (remeron)
____ Nefazodone (serzone)
____ Desyrel (trazodone)
____ Vortioxetine (trintellix)

22. What was the child's due date? _____

23. Was your child born full term? (within a few days of the due date) ____ Yes ____No

24. Was your child born pre-term? (week or more before the due date) ____ Yes ____No
If yes, how many weeks early (before the due date)?
____ 1
____ 2
____ 3
____ 4
____ 5
____ 6
____ 7 or more

25. Was your child born late? (a few days or more after the due date) ____ Yes ____No

26. How many days did your child stay in the hospital after birth? _____

27. Were any of those days spent in the NICU? ____ Yes ____No

If yes, then how many? _____

Section F: Child health.

28. Has your child had any health problems requiring surgery? Yes____ No____
If so, please describe_____

29. Has your child had any hearing and/or vision impairments? Yes____ No____
If so, please describe_____

30. Does your child currently have any hearing or vision impairments? Yes____ No____
If so, please describe_____

31. Has your child been identified with any of the following?
____ Autism or autism spectrum disorder
____ Language delay
____ Cognitive delay
____ Reading delay
____ Motor impairment
____ ADHD
____ Other (please describe) _____

32. In your opinion, does your child exhibit developmental delays? ____ Yes ____No
If yes, when did you first notice difficulties in development or behavior?_____
If yes, what difficulties do you notice?
_____

33. Have any of your child's siblings been diagnosed with a developmental delay including autism spectrum disorder (ASD), Asperger Syndrome (AS), or a Specific Language Impairment (SLI)? ____ Yes ____ No
If yes, please describe the age of the sibling and the nature of the delay/diagnosis.
_____
_____

Section G: Family structure.

34. Please indicate the total number of adults in the child's household: ____. Please check all that apply:
____ Mother
____ Father
____ Grandparent
____ Aunt/uncle
____ Other (please specify)

35. Does your child have siblings? ____ Yes ____ No

36. Does your child live with his/her siblings? ____ Yes ____ No
If yes, how many? ____

37. For siblings who your child lives with, please indicate the number of:
____ Older siblings
____ Younger siblings
____ Same age siblings (e.g., twin, triplet)

38. How often does your child have frequent interaction/contact with children who are not his/her siblings?
____ Very frequently (e.g., daily)
____ Frequently (e.g., several times a week)
____ Occasionally
____ Rarely
____ Never
Please describe:
_____

Section H: Child activities.

39. In the past 3 months, during a typical week, about how many days per week was your child in daycare/preschool?
Enter the number here (write zero if none): ____

40. In total, about how months has your child been in daycare/preschool?
Enter the number here (write zero if none): ____

41. Was the daycare/preschool part-time (half a day or less) or full time (almost the entire day)? _____

42. During daycare/preschool, does your child hear predominantly
____ English
____ Spanish
____ Other language, please specify _____

43. How many hours per day does your child spend using screens in each of the following categories?

	Less than 30 min	30 min to 1 hr	1 hr to 2 hrs	2 hrs to 3 hrs	3 hrs to 4 hrs	More than 4 hrs
Educational TV shows or movies						
Non-educational TV shows or movies						

Watching videos on Youtube or similar services
Browsing the internet
Playing games on tables, phones, or computers

44. How did you hear about the study? (please check all that apply)
____ A friend
____ We phoned you
____ An advertisement
____ We mailed you a letter
____ Social media (Facebook, Instagram, Twitter, etc.)
____ Information provided at a hospital
____ Information provided at a pediatrician or other doctor's office
____ Other (please specify):_____

45. Additional comments about your child or your visit:
_____
_____
_____
_____

Thank you for your help.

____ Check here if you do not wish to provide some or all of the above information.

The purpose of the above questions is to help us to better understand the results of our studies and to account for differences in responses between participants. Your answers will not affect your child's participation in the study for which you have come today. All answers will be kept confidential.

1. How did you hear about the study?
(A). A friend_____ (B). We phoned you_____ (C). Our Ad_____ (D). We mailed a letter____
(E). Information provided at hospital_____ (F). Other: (specify) _____

2. When your child was an infant:
a. Did s/he get upset? _____ easily _____ moderately _____not easily
b. Was s/he easy to soothe when upset? _____easy _____moderate _____difficult
c. What was most effective for soothing him/her?
_____holding _____your voice _____rhythmic movement
_____food (bottle/nursing) _____other sounds (please describe)_____
_____other (please describe) _____

Please answer the following questions if your child is less than 1.5 years old.

The next series of questions will ask you to compare your child's behavior as an infant to other children.

3. What other children can you compare your child's behavior to?
_____siblings of your child _____ Is the sibling older? _____ Younger?
_____close relatives (i.e., your child's cousins)
_____play group
_____other (please describe) _____

4. Did you notice differences in your child's behavior as an infant compared to other children of the same age group in any of the following? Please circle yes or no for each question. If "Yes", please circle a rating.

a) Yes / No Interactive games, such as peek-a-boo? Much less Less More Much more
If so, please describe_____
b) Yes / No Eye contact? Much less Less More Much more
If so, please describe_____
c) Yes / No Attention to moving objects? Much less Less More Much more
If so, please describe_____
d) Yes / No Attention to people when talking? Much less Less More Much more
If so, please describe_____
e) Yes / No Attention to people when silent? Much less Less More Much more
If so, please describe_____
f) Yes / No Ability to visually follow an object? Much less Less More Much more
If so, please describe_____
g) Yes / No Ability to disengage attention from one object to focus on something else? Much less Less More Much more
If so, please describe_____
h) Yes / No Other attentional differences? Much less Less More Much more
If so, please describe_____

Appendix B. MacArthur-Bates Communicative Development Inventories (MCDI)

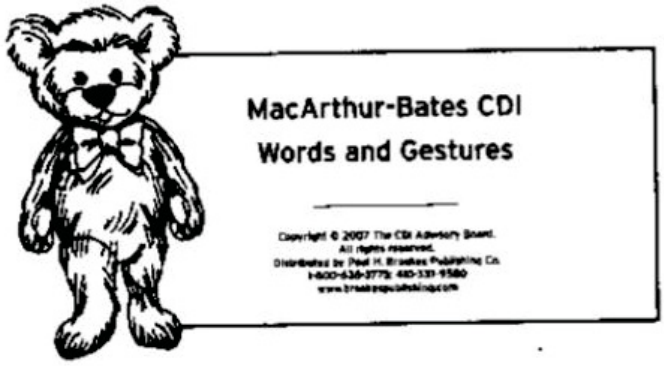
MacArthur-Bates Communicative Development Inventories
Trajectories Longitudinal

For Office Use Only

ParticipantID_____ **S#**_____ **Visit#**_____ **Sess**_____

Date Sent____/____/____ **Administrator**_____

Relationship to child_____ **Date Completed**____/____/____



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Part I: Early Words

A. First Signs of Understanding

Before children begin to speak, they show signs of understanding language by responding to familiar words and phrases. Below are some common examples. Does your child do any of these?

		yes	no
1.	Respond when name is called (e.g., by turning and looking at source).	○	○
2.	Respond to "no no" (by stopping what he/she is doing, at least for a moment).	○	○
3.	React to "there's mommy/daddy" by looking around for them.	○	○

B. Phrases (28)

In the list below, please mark the phrases that your child seems to understand.

	understands		understands		understands		understands
Are you hungry?	○	Daddy's/mommy's home.	○	Give me a kiss.	○	Sit down.	○
Are you tired/sleepy?	○	Do you want more?	○	Go get ___.	○	Spit it out.	○
Be careful.	○	Don't do that.	○	Good girl/boy.	○	Stop it.	○
Be quiet.	○	Don't touch.	○	Hold still.	○	Time to go night night.	○
Clap your hands.	○	Get up.	○	Let's go bye bye.	○	Throw the ball.	○
Change diaper.	○	Give it to mommy.	○	Look/look here.	○	This little piggy.	○
Come here/come on.	○	Give me a hug.	○	Open your mouth.	○	Want to go for a ride?	○

C. Starting to Talk

		Never	Sometimes	Often
1.	Some children like to "parrot" or imitate things that they've just heard (including new words that they are just learning, and/or parts of sentences, for example, repeating "work now" after mother says "Mommy's going to work now.") How often does your child imitate words?	○	○	○
2.	Some children like to go around naming or labeling things, as though proud of knowing the names and wanting to show this. How often does your child do this?	○	○	○

D. Vocabulary Checklist

The following is a list of typical words in young children's vocabularies. For words your child understands but does not yet say, place a mark in the first column (understands). For words that your child not only understands but also uses, place a mark in the second column (understands and says). If your child uses a different pronunciation of a word (for example, "raffe" for "giraffe" or "sketti" for "spaghetti"), mark the word anyway. Remember, this is a "catalogue" of words that are used by many different children. Don't worry if your child knows only a few right now.

1. *Sound Effects and Animal Sounds* (12)

	under-stands	under-stands and says		under-stands	under-stands and says		under-stands	under-stands and says		under-stands	under-stands and says
baa baa	○	○	grrr	○	○	ouch	○	○	vroom	○	○
choo choo	○	○	meow	○	○	quack quack	○	○	woof woof	○	○
cockadoodledoo	○	○	moo	○	○	uh oh	○	○	yum yum	○	○

2. *Animal Names (Real or Toy)* (36)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
animal	○	○	cow	○	○	goose	○	○	pig	○	○
bear	○	○	deer	○	○	horse	○	○	pony	○	○
bee	○	○	dog	○	○	kitty	○	○	puppy	○	○
bird	○	○	donkey	○	○	lamb	○	○	sheep	○	○
bug	○	○	duck	○	○	lion	○	○	squirrel	○	○
bunny	○	○	elephant	○	○	monkey	○	○	teddy bear	○	○
butterfly	○	○	fish	○	○	mouse	○	○	tiger	○	○
cat	○	○	frog	○	○	owl	○	○	turkey	○	○
chicken	○	○	giraffe	○	○	penguin	○	○	turtle	○	○

3. *Vehicles (Real or Toy)* (9)

	understands	understands and says		understands	understands and says		understands	understands and says
airplane	○	○	car	○	○	stroller	○	○
bicycle	○	○	firetruck	○	○	train	○	○
bus	○	○	motorcycle	○	○	truck	○	○

4. *Toys* (8)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
ball	○	○	block	○	○	bubbles	○	○	pen	○	○
balloon	○	○	book	○	○	doll	○	○	toy	○	○

5. *Food and Drink* (30)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
apple	○	○	cheerios	○	○	fish	○	○	peas	○	○
banana	○	○	cheese	○	○	food	○	○	pizza	○	○
bread	○	○	chicken	○	○	ice cream	○	○	raisin	○	○
butter	○	○	coffee	○	○	juice	○	○	spaghetti	○	○
cake	○	○	cookie	○	○	meat	○	○	toast	○	○
candy	○	○	cracker	○	○	milk	○	○	water	○	○
carrots	○	○	drink	○	○	noodles	○	○			
cereal	○	○	egg	○	○	orange	○	○			

6. *Clothing* (19)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
beads	○	○	diaper	○	○	necklace	○	○	shorts	○	○
bib	○	○	dress	○	○	pajamas	○	○	sock	○	○
boots	○	○	hat	○	○	pants	○	○	sweater	○	○
button	○	○	jacket	○	○	shirt	○	○	zipper	○	○
coat	○	○	jeans	○	○	shoe	○	○			

7. *Body Parts* (20)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
arm	○	○	face	○	○	head	○	○	owie/boo boo	○	○
belly button	○	○	foot	○	○	knee	○	○	tooth	○	○
cheek	○	○	finger	○	○	leg	○	○	toe	○	○
ear	○	○	hair	○	○	mouth	○	○	tongue	○	○
eye	○	○	hand	○	○	nose	○	○	tummy	○	○

8. *Furniture and Rooms* (24)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
bathroom	○	○	crib	○	○	living room	○	○	sink	○	○
bathtub	○	○	door	○	○	oven	○	○	stairs	○	○
bed	○	○	drawer	○	○	play pen	○	○	stove	○	○
bedroom	○	○	garage	○	○	potty	○	○	table	○	○
chair	○	○	high chair	○	○	refrigerator	○	○	TV	○	○
couch	○	○	kitchen	○	○	rocking chair	○	○	window	○	○

9. *Small Household Items* (36)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
blanket	○	○	dish	○	○	money	○	○	scissors	○	○
bottle	○	○	fork	○	○	paper	○	○	soap	○	○
bowl	○	○	glass	○	○	penny	○	○	spoon	○	○
box	○	○	glasses	○	○	picture	○	○	telephone	○	○
broom	○	○	hammer	○	○	pillow	○	○	toothbrush	○	○
brush	○	○	keys	○	○	plant	○	○	towel	○	○
clock	○	○	lamp	○	○	plate	○	○	trash	○	○
comb	○	○	light	○	○	purse	○	○	vacuum	○	○
cup	○	○	medicine	○	○	radio	○	○	watch	○	○

10. *Outside Things and Places to Go* (27)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
backyard	○	○	moon	○	○	school	○	○	sun	○	○
beach	○	○	outside	○	○	shovel	○	○	swing	○	○
church*	○	○	park	○	○	sky	○	○	tree	○	○
flower	○	○	party	○	○	slide	○	○	water	○	○
garden	○	○	pool	○	○	snow	○	○	work	○	○
home	○	○	rain	○	○	star	○	○	zoo	○	○
house	○	○	rock	○	○	store	○	○			

*or word used in your family

11. *People* (20)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
aunt	○	○	brother	○	○	grandpa*	○	○	people	○	○
baby	○	○	child	○	○	lady	○	○	person	○	○
babysitter	○	○	daddy*	○	○	man	○	○	sister	○	○
babysitter's name	○	○	girl	○	○	mommy*	○	○	teacher	○	○
boy	○	○	grandma*	○	○	child's own name	○	○	uncle	○	○

*or word used in your family

12. *Games and Routines* (19)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
bath	○	○	hello	○	○	no	○	○	thank you	○	○
breakfast	○	○	hi	○	○	patty cake	○	○	wait	○	○
bye or bye bye	○	○	lunch	○	○	peekaboo	○	○	wanna/want to	○	○
dinner	○	○	nap	○	○	please	○	○	yes	○	○
don't	○	○	night night	○	○	shh/shush/hush	○	○			

13. *Action Words* (55)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
bite	○	○	bump	○	○	dance	○	○	eat	○	○
blow	○	○	clean	○	○	draw	○	○	fall	○	○
break	○	○	close	○	○	drink	○	○	feed	○	○
bring	○	○	cry	○	○	drive	○	○	finish	○	○

(continued)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
get	○	○	look	○	○	say	○	○	take	○	○
give	○	○	love	○	○	see	○	○	throw	○	○
go	○	○	open	○	○	show	○	○	tickle	○	○
help	○	○	play	○	○	sing	○	○	touch	○	○
hit	○	○	pull	○	○	sleep	○	○	watch	○	○
hug	○	○	push	○	○	smile	○	○	walk	○	○
hurry	○	○	put	○	○	splash	○	○	wash	○	○
jump	○	○	read	○	○	stop	○	○	wipe	○	○
kick	○	○	ride	○	○	swim	○	○	write	○	○
kiss	○	○	run	○	○	swing	○	○			

14. *Words About Time* (8)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
day	○	○	morning	○	○	now	○	○	tomorrow	○	○
later	○	○	night	○	○	today	○	○	tonight	○	○

15. *Descriptive Words* (37)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
all gone	○	○	dark	○	○	hot	○	○	sick	○	○
asleep	○	○	dirty	○	○	hungry	○	○	sleepy	○	○
bad	○	○	dry	○	○	hurt	○	○	soft	○	○
big	○	○	empty	○	○	little	○	○	thirsty	○	○
blue	○	○	fast	○	○	naughty	○	○	tired	○	○
broken	○	○	fine	○	○	nice	○	○	wet	○	○
careful	○	○	gentle	○	○	old	○	○	yucky	○	○
clean	○	○	good	○	○	pretty	○	○			
cold	○	○	happy	○	○	red	○	○			
cute	○	○	hard	○	○	scared	○	○			

16. *Pronouns* (11)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
his	○	○	it	○	○	my	○	○	you	○	○
her	○	○	me	○	○	that	○	○	your	○	○
I	○	○	mine	○	○	this	○	○		○	○

17. *Question Words* (6)

	understands	understands and says		understands	understands and says		understands	understands and says
how	○	○	when	○	○	who	○	○
what	○	○	where	○	○	why	○	○

18. *Prepositions and Locations* (11)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
away	○	○	in	○	○	on	○	○	under	○	○
back	○	○	inside	○	○	out	○	○	up	○	○
down	○	○	off	○	○	there	○	○			

19. *Quantifiers* (8)

	understands	understands and says		understands	understands and says		understands	understands and says		understands	understands and says
all	○	○	more	○	○	not	○	○	same	○	○
another	○	○	none	○	○	other	○	○	some	○	○

Part II: Actions and Gestures

A. First Communicative Gestures

When infants are first learning to communicate, they often use gestures to make their wishes known. For each item below, mark the line that describes your child's actions right now.

		Not Yet	Sometimes	Often
1.	Extends arm to show you something he/she is holding.	○	○	○
2.	Reaches out and gives you a toy or some object that he/she is holding.	○	○	○
3.	Points (with arm and index finger extended) at some interesting object or event.	○	○	○
4.	Waves bye-bye on his/her own when someone leaves.	○	○	○
5.	Extends his/her arm upward to signal a wish to be picked up.	○	○	○
6.	Shakes head "no".	○	○	○
7.	Nods head "yes".	○	○	○
8.	Gestures "hush" by placing finger to lips.	○	○	○
9.	Requests something by extending arm and opening and closing hand.	○	○	○
10.	Blows kisses from a distance.	○	○	○
11.	Smacks lips in a "yum yum" gesture to indicate that something tastes good.	○	○	○
12.	Shrugs to indicate "all gone" or "where'd it go".	○	○	○

B. Games and Routines

Does your child do any of the following?

		Yes	No
1.	Play peekaboo.	○	○
2.	Play patty cake.	○	○
3.	Play "so big".	○	○
4.	Play chasing games.	○	○
5.	Sing.	○	○
6.	Dance.	○	○

C. Actions with Objects

Does your child do or try to do any of the following?

		Yes	No
1.	Eat with a spoon or fork.	○	○
2.	Drink from a cup containing liquid.	○	○
3.	Comb or brush own hair.	○	○
4.	Brush teeth.	○	○
5.	Wipe face or hands with a towel or cloth.	○	○
6.	Put on hat.	○	○
7.	Put on a shoe or sock.	○	○
8.	Put on a necklace, bracelet, or watch.	○	○
9.	Lay head on hands and squeeze eyes shut as if sleeping.	○	○
10.	Blow to indicate something is hot.	○	○
11.	Hold plane and make it "fly".	○	○
12.	Put telephone to ear.	○	○
13.	Sniff flowers.	○	○
14.	Push toy car or truck.	○	○
15.	Throw a ball.	○	○
16.	Pour pretend liquid from one container to another.	○	○
17.	Stir pretend liquid in a cup or pan with a spoon.	○	○

D. Pretending to be a Parent

Here are some things that young children sometimes do with stuffed animals or dolls. Please mark the actions that you have seen your child do.

		Yes	No
1.	Put to bed.	○	○
2.	Cover with blanket.	○	○
3.	Feed with bottle.	○	○
4.	Feed with spoon.	○	○
5.	Brush/comb its hair.	○	○
6.	Pat or burp it.	○	○
7.	Push in stroller/buggy.	○	○
8.	Rock it.	○	○
9.	Kiss or hug it.	○	○
10.	Try to put shoe or sock or hat on it.	○	○
11.	Wipe its face or hands.	○	○
12.	Talk to it.	○	○
13.	Try to put diaper on it.	○	○

E. Imitating Other Adult Actions (Using real or toy implements)

Does your child do or try to do any of the following?

		Yes	No
1.	Sweep with broom or mop.	○	○
2.	Put key in door or lock.	○	○
3.	Pound with hammer or mallet.	○	○
4.	Attempt to use saw.	○	○
5.	"Type" at a typewriter or computer keyboard.	○	○
6.	"Read" (opens book, turns page).	○	○
7.	Vacuum.	○	○
8.	Water plants.	○	○
9.	Play musical instrument (e.g., piano, trumpet).	○	○
10.	"Drive" car by turning steering wheel.	○	○
11.	Wash dishes.	○	○
12.	Clean with cloth or duster.	○	○
13.	Write with a pen, pencil, or marker.	○	○
14.	Dig with a shovel.	○	○
15.	Put on glasses.	○	○

Appendix C. MacArthur-Bates Communicative Development Inventories (MCDI)

MacArthur-Bates Communicative Development Inventories

Child's name: _____ Gender: _____

Birthdate: _____ Today's date: _____

MacArthur-Bates CDI Words and Sentences

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This form may be scored by hand or with a desktop image scanner and special software.

1

Part I: Words Children Use

A. Vocabulary Checklist

Children understand many more words than they say. We are particularly interested in the words your child SAYS. Please go through the list and mark the words you have heard your child use. If your child uses a different pronunciation of a word (for example, "raffe" instead of "giraffe" or "sketti" for "spaghetti"), mark the word anyway. Remember that this is a "catalogue" of all the words that are used by many different children. Don't worry if your child knows only a few of these right now.

1. *Sound Effects and Animal Sounds* (12)

baa baa	grrr	ouch	vroom
choo choo	meow	quack quack	woof woof
cockadoodledoo	moo	uh oh	yum yum

2. *Animals (Real or Toy)* (43)

alligator	cow	horse	puppy
animal	deer	kitty	rooster
ant	dog	lamb	sheep
bear	donkey	lion	squirrel
bee	duck	monkey	teddybear
bird	elephant	moose	tiger
bug	fish	mouse	turkey
bunny	frog	owl	turtle
butterfly	giraffe	penguin	wolf
cat	goose	pig	zebra
chicken	hen	pony	

3. *Vehicles (Real or Toy)* (14)

airplane	car	sled	tricycle
bicycle	firetruck	stroller	truck
boat	helicopter	tractor	
bus	motorcycle	train	

4. *Toys* (18)

ball	bubbles	glue	puzzle
balloon	chalk	pen	story
bat	crayon	pencil	toy
block	doll	play dough	
book	game	present	

5. *Food and Drink* (68)

apple ○	corn ○	lollipop ○	pretzel ○
applesauce ○	cracker ○	meat ○	pudding ○
banana ○	donut ○	melon ○	pumpkin ○
beans ○	drink ○	milk ○	raisin ○
bread ○	egg ○	muffin ○	salt ○
butter ○	fish ○	noodles ○	sandwich ○
cake ○	food ○	nuts ○	sauce ○
candy ○	french fries ○	orange ○	soda/pop ○
carrots ○	grapes ○	pancake ○	soup ○
cereal ○	green beans ○	peanut butter ○	spaghetti ○
cheerios ○	gum ○	peas ○	strawberry ○
cheese ○	hamburger ○	pickle ○	toast ○
chicken ○	ice ○	pizza ○	tuna ○
chocolate ○	ice cream ○	popcorn ○	vanilla ○
coffee ○	jello ○	popsicle ○	vitamins ○
coke ○	jelly ○	potato ○	water ○
cookie ○	juice ○	potato chip ○	yogurt ○

6. *Clothing* (28)

beads ○	dress ○	pajamas ○	sneaker ○
belt ○	gloves ○	pants ○	snowsuit ○
bib ○	hat ○	scarf ○	sock ○
boots ○	jacket ○	shirt ○	sweater ○
button ○	jeans ○	shoe ○	tights ○
coat ○	mittens ○	shorts ○	underpants ○
diaper ○	necklace ○	slipper ○	zipper ○

7. *Body Parts* (27)

ankle ○	eye ○	knee ○	shoulder ○
arm ○	face ○	leg ○	tooth ○
belly button ○	feet ○	lips ○	toe ○
buttocks/bottom* ○	finger ○	mouth ○	tongue ○
cheek ○	hair ○	nose ○	tummy ○
chin ○	hand ○	owie/boo boo ○	vagina* ○
ear ○	head ○	penis* ○	

*or word used in your family

8. *Small Household Items* (50)

basket	dish	mop	spoon
blanket	fork	nail	tape
bottle	garbage	napkin	telephone
box	glass	paper	tissue/kleenex
bowl	glasses	penny	toothbrush
broom	hammer	picture	towel
brush	jar	pillow	trash
bucket	keys	plant	tray
camera	knife	plate	vacuum
can	lamp	purse	walker
clock	light	radio	watch
comb	medicine	scissors	
cup	money	soap	

9. *Furniture and Rooms* (33)

basement	crib	play pen	stairs
bathroom	door	porch	stove
bathtub	drawer	potty	table
bed	dryer	refrigerator	TV
bedroom	garage	rocking chair	washing machine
bench	high chair	room	window
chair	kitchen	shower	
closet	living room	sink	
couch	oven	sofa	

10. *Outside Things* (31)

backyard	lawn mower	sidewalk	stone
cloud	moon	sky	street
flag	pool	slide	sun
flower	rain	snow	swing
garden	rock	snowman	tree
grass	roof	sprinkler	water
hose	sandbox	star	wind
ladder	shovel	stick	

11. *Places to Go* (22)

beach	farm	park	woods
camping	gas station	party	work
church*	home	picnic	yard
circus	house	playground	zoo
country	movie	school	
downtown	outside	store	

*or word used in your family

12. *People* (29)

aunt	cowboy	lady	pet's name
baby	daddy*	mailman	police
babysitter	doctor	man	sister
babysitter's name	fireman	mommy*	teacher
boy	friend	nurse	uncle
brother	girl	child's own name	
child	grandma*	people	
clown	grandpa*	person	

*or word used in your family

13. *Games and Routines* (25)

bath	go potty	patty cake	thank you
breakfast	hi	peekaboo	this little piggy
bye	hello	please	turn around
call (on phone)	lunch	shh/shush/hush	yes
dinner	nap	shopping	
give me five!	night night	snack	
gonna get you!	no	so big!	

14. *Action Words* (103)

bite	catch	cry	dump
blow	chase	cut	eat
break	clap	dance	fall
bring	clean	draw	feed
build	climb	drink	find
bump	close	drive	finish
buy	cook	drop	fit
carry	cover	dry	fix

(continued)

get ○	listen ○	see ○	take ○
give ○	look ○	shake ○	talk ○
go ○	love ○	share ○	taste ○
hate ○	make ○	show ○	tear ○
have ○	open ○	sing ○	think ○
hear ○	paint ○	sit ○	throw ○
help ○	pick ○	skate ○	tickle ○
hide ○	play ○	sleep ○	touch ○
hit ○	pour ○	slide ○	wait ○
hold ○	pretend ○	smile ○	wake ○
hug ○	pull ○	spill ○	walk ○
hurry ○	push ○	splash ○	wash ○
jump ○	put ○	stand ○	watch ○
kick ○	read ○	stay ○	wipe ○
kiss ○	ride ○	stop ○	wish ○
knock ○	rip ○	sweep ○	work ○
lick ○	run ○	swim ○	write ○
like ○	say ○	swing ○	

15. *Descriptive Words* (63)

allgone ○	dry ○	last ○	scared ○
asleep ○	empty ○	little ○	sick ○
awake ○	fast ○	long ○	sleepy ○
bad ○	fine ○	loud ○	slow ○
better ○	first ○	mad ○	soft ○
big ○	full ○	naughty ○	sticky ○
black ○	gentle ○	new ○	stuck ○
blue ○	good ○	nice ○	thirsty ○
broken ○	green ○	noisy ○	tiny ○
brown ○	happy ○	old ○	tired ○
careful ○	hard ○	orange ○	wet ○
clean ○	heavy ○	poor ○	white ○
cold ○	high ○	pretty ○	windy ○
cute ○	hot ○	quiet ○	yellow ○
dark ○	hungry ○	red ○	yucky ○
dirty ○	hurt ○	sad ○	

16. *Words About Time* (12)

after	later	now	tomorrow
before	morning	time	tonight
day	night	today	yesterday

17. *Pronouns* (25)

he	me	their	we
her	mine	them	you
hers	my	these	your
him	myself	they	yourself
his	our	this	
I	she	those	
it	that	us	

18. *Question Words* (7)

how	when	which	why
what	where	who	

19. *Prepositions and Locations* (26)

about	beside	next to	there
above	by	of	to
around	down	off	under
at	for	on	up
away	here	on top of	with
back	inside/in	out	
behind	into	over	

20. *Quantifiers and Articles* (17)

a	any	not	the
all	each	none	too
a lot	every	other	
an	more	same	
another	much	some	

21. *Helping Verbs* (21)

am	○	do	○	is	○	were	○
are	○	does	○	lemme/let me	○	will	○
be	○	don't	○	need/need to	○	would	○
can	○	gonna/going to	○	try/try to	○		
could	○	gotta/got to	○	wanna/want to	○		
did/did ya	○	hafta/have to	○	was	○		

22. *Connecting Words* (6)

and	○	but	○	so	○
because	○	if	○	then	○

B. How Children Use Words

		Not Yet	Sometimes	Often
1.	Does your child ever talk about past events or people who are not present? For example, a child who saw a parade last week might later say parade, clown, or band.	○	○	○
2.	Does your child ever talk about something that's going to happen in the future, for example, saying "choo choo" or "airplane" before you leave the house for a trip, or saying "swing" when you are going to the park?	○	○	○
3.	Does your child talk about objects that are not present such as asking about a missing or absent toy, referring to a pet out of view, or asking about someone not present?	○	○	○
4.	Does your child understand if you ask for something that is not in the room, for example, by going to the bedroom to get a teddy bear when you say "where's the bear?"	○	○	○
5.	Does your child ever pick up or point to an object and name an absent person to whom the object belongs? For example, a child might point to mommy's shoe and say "mommy".	○	○	○

Part II: Sentences and Grammar

A. Word Endings/Part I

		Not Yet	Sometimes	Often
1.	To talk about more than one thing, we add an "s" to many words. Examples include cars (for more than one car), shoes, dogs, and keys. Has your child begun to do this?	○	○	○
2.	To talk about ownership, we add an "'s", for example, Daddy's key, kitty's dish, and baby's bottle. Has your child begun to do this?	○	○	○
3.	To talk about activities, we sometimes add "ing" to verbs. Examples include looking, running, and crying. Has your child begun to do this?	○	○	○
4.	To talk about things that happened in the past, we often add "ed" to the verb. Examples include kissed, opened, and pushed. Has your child begun to do this?	○	○	○

B. Word Forms

Following are some other words children learn. Please mark any of these words that your child uses.

Nouns

children	○	men	○	teeth	○
feet	○	mice	○		○

Verbs

ate	○	fell	○	made	○
blew	○	flew	○	ran	○
bought	○	got	○	sat	○
broke	○	had	○	saw	○
came	○	heard	○	took	○
drank	○	held	○	went	○
drove	○	lost	○		

C. Word Endings/Part 2

Young children often place the wrong endings on words. For example, a child might say "Auntie goed home." Mistakes like this are often a sign of progress in language. In the following lists, please mark all the mistakes of this kind you have heard your child say recently.

Nouns

blockses	○	foots	○	mouses	○	toeses	○
children	○	mans	○	shoeses	○	tooths	○
childs	○	mens	○	sockses	○		
feets	○	mices	○	teeths	○		

Verbs

ated	○	bringed	○	broked	○	doed	○
blewed	○	buyed	○	camed	○	dranked	○
blowed	○	breaked	○	comed	○	drinked	○

(continued)

eated	○	gotted	○	losted	○	satted	○
falled	○	haved	○	maked	○	sitted	○
flied	○	hearred	○	ranned	○	taked	○
getted	○	holded	○	runned	○	wented	○
goed	○	losed	○	seed	○		

	Not Yet	Sometimes	Often
Has your child begun to combine words yet, such as "nother cracker", or "doggie bite?"	○	○	○

If you answered not yet, please stop here. If you answered sometimes or often, please continue.

D. Examples

Please list three of the longest sentences you have heard your child say recently.

1. _____

2. _____

3. _____

E. Complexity

In each of the following pairs, please mark the one that sounds MOST like the way your child talks right now. If your child is saying sentences even more complicated than the two provided, just pick the second one.

1. Two shoe. ○
   Two shoes. ○
2. Two foot. ○
   Two feet. ○
3. Daddy car. ○
   Daddy's car. ○
4. (Talking about something happening right now)
   Kitty sleep. ○
   Kitty sleeping. ○
5. (Talking about something happening right now)
   I make tower. ○
   I making tower. ○
6. (Talking about something that already happened)
   I fall down. ○
   I fell down. ○
7. More cookie! ○
   More cookies! ○
8. These my tooth. ○
   These my teeth. ○
9. Baby blanket. ○
   Baby's blanket. ○
10. (Talking about something that already happened)
    Doggie kiss me. ○
    Doggie kissed me. ○
11. (Talking about something that already happened)
    Daddy pick me up. ○
    Daddy picked me up. ○
12. (Talking about something that already happened)
    Kitty go away. ○
    Kitty went away. ○
13. Doggie table. ○
    Doggie on table. ○
14. That my truck. ○
    That's my truck. ○
15. Baby crying. ○
    Baby is crying. ○
16. You fix it? ○
    Can you fix it? ○
17. Read me story, Mommy. ○
    Read me a story, Mommy. ○
18. No wash dolly. ○
    Don't wash dolly. ○
19. Want more juice. ○
    Want juice in there. ○
20. There a kitty. ○
    There's a kitty. ○
21. Go bye-bye. ○
    Wanna go bye-bye. ○
22. Where mommy go? ○
    Where did mommy go? ○
23. Coffee hot. ○
    That coffee hot. ○
24. I no do it. ○
    I can't do it. ○
25. I like read stories. ○
    I like to read stories. ○
26. Don't read book. ○
    Don't want you read that book. ○
27. Turn on light. ○
    Turn on the light so I can see. ○
28. I want that. ○
    I want that one you got. ○
29. Want cookies. ○
    Want cookies and milk. ○
30. Cookie mommy. ○
    Cookie for mommy. ○
31. Baby want eat. ○
    Baby want to eat. ○
32. Lookit me! ○
    Lookit me dancing! ○
33. Lookit! ○
    Lookit what I got! ○
34. Where's my dolly? ○
    Where's my dolly name Sam? ○
35. We made this. ○
    Me and Paul made this. ○
36. I sing song. ○
    I sing song for you. ○
37. Baby crying. ○
    Baby crying cuz she's sad. ○