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**Research Report**

# Predictive validity of verbal and non-verbal communication and mother–child turn-taking at 12 months on language outcomes at 24 and 36 months in a cohort of infants experiencing adversity: a preliminary study

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**Abstract**

*Background:* Parent-reported measures of early communication have limitations for use with infants experiencing adversity. Observational measures of early non-verbal and verbal communicative behaviours and mother–child turn-taking may provide a complementary method of capturing early communication skills for these children.
*Aims:* To explore the predictive validity of verbal and non-verbal behaviours and mother–child conversational turn-taking (fluency and connectedness) at child age 12 months in relation to language measures at 24 and 36 months in a cohort of infants experiencing adversity.
*Methods & Procedures:* Pregnant women experiencing adversity were recruited from maternity hospitals in Australia. At 12 months, 190 infants were videoed during mother–child free-play. Verbal and non-verbal communicative behaviours and fluency and connectedness were measured from the 12-month videos. Predictive validity of 12-month behaviours was calculated in relation to mean

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length of utterance and number of unique words at 24 months and Clinical Evaluation of Language Fundamentals Preschool—Second Edition (CELF-P2) Core Language scores at 36 months.
*Outcomes & Results:* All 12-month behaviours had adequate specificity but poor sensitivity when compared with other predictive validity studies using published early language measures. However, in adjusted regression models, fluency and connectedness and verbal behaviours at 12 months predicted unique words at 24 months. Fluency and connectedness also predicted CELF-P2 scores at 36 months.
*Conclusions & Implications:* Findings reconfirm the difficulty in early identification of children at risk of later language difficulties. All 12-month measures were more accurate at identifying those children who will have better language than those children who will not. As fluency and connectedness was the only measure to predict 24- and 36-month language in adjusted regression models, it may be an important factor to consider when measuring early language skills for infants experiencing adversity. Future research could combine observational measures of early communication and fluency and connectedness with other predictors of language to try to increase prediction accuracy.

*Keywords:* language development, screening, validity.

<A>**What this paper adds**
<B>*What is already known on the subject*
Early identification of children at risk of poorer language is important for provision of timely intervention to optimize outcomes. Accurately measuring early communication is challenging, particularly for infants experiencing adversity.

<B>*What this paper adds to existing knowledge*
This study evaluated the predictive validity of non-verbal and verbal communicative behaviours and fluency and connectedness of mother–child conversation in relation to later language skills in a cohort of infants experiencing adversity. Although predictive validity was poor across all measures, fluency and connectedness and verbal skills at 12 months were positively associated with later language.

<B>*What are the potential or actual clinical implications of this work?*
Brief observational measures collected at 12 months were poor at identifying children with language difficulties at 24 and 36 months. However, accurate prediction of children with language difficulties could be increased by incorporating measures of early verbal skills and fluency and connectedness of adult–child conversation alongside other factors related to language development.

<A>**Introduction**
Early identification of children at risk of lower language is important for provision of timely intervention to improve outcomes. Early detection may be particularly valuable for children at risk of lower language where modifiable environmental differences may play a role (over and above genetic or biological factors, such as child gender and family history of communication difficulties). If environmental differences contribute to poorer language, but are also mutable, there is an opportunity to modify a child's language learning environment to optimize early language



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acquisition. Although there is language variability within cohorts, environmental risk factors for poorer language include lower socioeconomic status (SES) measures, such as reduced household income (Arriaga *et al.* 1998). Other environmental risk factors include teen parenthood, lone parenthood and parental mental health difficulties (Pan *et al.* 2005, Keown *et al.* 2001). For the purpose of the current study, the term 'adversity' will be used to encompass the array of risk factors associated with poorer language.

<B>*Early communication, language and play*

In infancy, meaningful language comprises non-verbal and verbal communication. Both types of communication rely on an underlying capacity to use conventional symbols to transmit messages to another person (Bates *et al.* 1979). Early intentional communication is typified by vocalizations (e.g., consistently using the same sound/s in routine situations to request) and gestures (e.g., pointing to or showing an adult an object). Developing communicative intent is important for meaningful language use as it signifies when a child becomes aware of their role as a communicator, able to send purposeful signals to a partner (Rowland and Fried-Oken 2010). Although vocalizations are present from birth, first words and word approximations are expected around 12 months of age (Oller 2000). Early gestures commence around 10 months with holdouts and gives developing before declarative pointing (Cameron-Faulkner *et al.* 2015). At this stage of development, early play is also emerging. Although ages vary, simple pretend play (e.g., pretending to drink from a cup) begins around 12 months (Bates *et al.* 1979). As a child develops more spoken language, verbal communication begins to usurp non-verbal gestures and vocalizations but, between 9 and 13 months, expansion of a child's early communicative repertoire suggests children are adding to, rather than replacing, early communicative behaviours (Bates *et al.* 1979).

<B>*Measurement of early language*

Unsurprisingly, frequency of vocalizations and early words has been positively related to later language skills (McCathren *et al.* 1999, Eadie *et al.* 2010). Early gesture and play skills have also been positively associated with later language (Bates *et al.* 1979, Eadie *et al.* 2010). Differences in early gesture have also helped explain SES disparities in vocabulary size when children entered school (Rowe and Goldin-Meadow 2009). Despite identification of communicative behaviours associated with later language, accurately predicting child language trajectories remains problematic in infancy and toddlerhood, especially for children experiencing adversity (Feldman *et al.* 2005).

Due to fluctuations in early language trajectories, the best method for accurately capturing infant language and communication remains unclear (Feldman *et al.* 2005). However, two routinely used measures for assessing early language and communication within research studies are The MacArthur–Bates Communicative Development Inventories (MCDI; Fenson *et al.* 1994) and the Communication and Symbolic Behavior Scales—Developmental Profile (CSBS DP; Wetherby and Prizant 2001). The MCDI contains two checklists that require parents to report on their child's understanding and use of vocabulary across semantic categories. The CSBS DP comprises a brief parent-reported checklist, a follow-up caregiver questionnaire (CQ) and a behaviour sample (BS) assessing child skills using a standardized structure. The CSBS DP checklist, CQ and BS all measure seven prelinguistic aspects of development.



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<B>*Predictive validity*

The predictive validity of the CSBS DP and MCDI has been explored. Predictive validity is the extent to which an earlier test score predicts a later one. Predictive validity is defined by sensitivity (true positives) and specificity (true negatives). In the context of language assessment, sensitivity refers to the ability of a test to detect those children who have language difficulties; specificity refers to the ability of a test to detect those children who do not have language difficulties. Predictive validity also includes the negative predictive value (NPV, i.e., the probability that children with a negative screening test do not actually have language difficulties) and the positive predictive value (PPV, i.e., the probability that children with a positive screening test do have language difficulties). There are no concrete recommendations regarding adequate levels of sensitivity and specificity for language measures, but > .80 is deemed acceptable (Law *et al.* 2000).

<tab 1>

Table 1 presents the predictive validity of the MCDI and CSBS DP. Only studies reporting the predictive (not concurrent) validity, including explicitly reporting sensitivity and specificity, have been included. Predictive validity, particularly sensitivity, is higher when used with middle-class cohorts (Wetherby and Prizant 2001, Wetherby *et al.* 2003, Heilmann *et al.* 2005), than with cohorts experiencing adversity (Feldman *et al.* 2005). A caveat to this finding is that published research with low-income families typically use the MCDI (Pan *et al.* 2004, Feldman *et al.* 2005, Arriaga *et al.* 1998), so less is known about the predictive validity of the CSBS DP with cohorts experiencing adversity.

<B>*Limitations of the MCDI and CSBS DP for children experiencing adversity*

The fact that the predictive validity of the MCDI is lower when used with children experiencing adversity is one drawback, but there are other limitations with using the MCDI and CSBS DP with these children. Parental reporting can vary depending on SES whereby lower SES parents can under and over report skills, particularly vocabulary knowledge (Roberts *et al.* 1999). Differences in reporting may be less problematic for the CSBS DP, as it reports on skills beyond vocabulary (Eadie *et al.* 2010). As the MCDI is more frequently used with cohorts experiencing adversity, and focuses on vocabulary understanding and use, variations in parental reporting may confound MCDI results to a greater extent. Moreover, at 12 months of age, behavioural samples may provide a more robust method of capturing communication when compared with parent report as, at this stage of development (i.e., before children routinely use consistent words), it can be particularly difficult for parents to describe less overt communicative skills, such as prelinguistic behaviours (Eadie *et al.* 2010). Parent reported measures, such as the MCDI, CSBS DP checklist and the CSBS CQ, may therefore be less accurate at assessing prelinguistic and early linguistic skills in children experiencing adversity. Although the CSBS DP BS is a useful observational measure, it can take around 30–40 min to complete. Plus, only one measure of early communication may not be enough to identify accurately future language difficulties for these children (McKean *et al.* 2016, Feldman *et al.* 2005).

<B>*Importance of the parent–child interaction*

Another limitation with using the MCDI and CSBS DP with cohorts experiencing adversity is that they fail to include a measure of parent–child interaction; yet the parent–child dynamic may contribute more to language outcomes for these children (Baydar and Akcinar 2015). The reason why parenting may contribute more to their language development is that fiscal restrictions can limit the learning experiences (e.g., extracurricular excursions, access to educational materials and access to high-



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quality education services) that the family can afford to provide for the child (Brooks-Gunn and Duncan 1997). As such, parent–child interactions may play a more substantive role in language learning for these children (Baydar and Akcinar 2015). Furthermore, parents experiencing adversity can be less sensitive and more intrusive in adult–child interactions, with less sensitive, more intrusive parenting related to poorer language outcomes (Keown *et al.* 2001). Consequently, parent–child interactions within families experiencing adversity may have more influence on language development, yet be less conducive to language acquisition.

One key feature of parent–child interactions which has been related to later language is the communication dynamic between the mother and child (Roe and Drivas 1997). Reciprocal, balanced mother–child interactions can promote joint attention and encourage topic continuation thus helping facilitate associations between words (Song *et al.* 2014). Reciprocal early conversations also allow the child to practise using their words meaningfully within a communicative context (Roe and Drivas 1997). The mother–child dynamic has been found to be especially important for infants experiencing adversity, as evidenced by one study of low-income children (Hirsh-Pasek *et al.* 2015). In Hirsh-Pasek *et al.* (2015), the fluency and connectedness of mother–child conversation at 24 months was the strongest predictor of 36-month language; a stronger predictor than child words per minute or maternal sensitivity at 24 months.

<B>*Rationale for the current study*

Eadie *et al.* (2010) propose that observational or behavioural samples are more accurate at capturing communication skills of 12-month-old children. The CSBS DP BS can take around 30–40 min to complete. Plus there is limited literature reporting on the predictive validity of this measure with families experiencing adversity. Furthermore, to identify accurately future language difficulties for these children, measurement of additional factors beyond just the child's early language (e.g., a measure of adult–child interaction) may be necessary (McKean *et al.* 2016, Feldman *et al.* 2005). Capturing verbal and non-verbal behaviours and the mother–child communication dynamic, via a more efficient method, could be valuable for predicting later language. Exploring these behaviours in a cohort of children at greater risk of language difficulties who are typically underrepresented in the literature is also an important addition to the literature (Pan *et al.* 2004).

<B>*Current study*

This study investigated the predictive validity of verbal and non-verbal communicative behaviours *and* the fluency and connectedness of mother–child conversation at 12 months in relation to language at 24 and 36 months in a large cohort experiencing adversity (*n* = 190).

<A>**Materials and methods**

<B>*Study participants*

The current study is nested within [AQ2] the XXX trial. The trial is an ongoing, randomized controlled trial (RCT) exploring the effectiveness of sustained nurse home visiting provided to women experiencing adversity from pregnancy to child age 2 years. A total of 722 pregnant women experiencing adversity were recruited to the trial between April 2013 and September 2014 from public maternity hospitals in Victoria and Tasmania, Australia.

Before recruitment to the RCT, a pilot screening survey was carried out to ascertain risk factors that would best capture women suitable [AQ2] for XXX support. The screening survey was



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piloted on 166 women in antenatal hospital waiting rooms in Victoria in February–March 2013. The screening survey contained questions designed to elicit maternal risk factors. To test the validity of the data collected, consent was gained to link the screening data with midwifery collected information from hospital electronic records. These records contained more sensitive information than was included in the screening survey, e.g., drug use, domestic violence and mental health difficulties. Following the screening and data linkage, a statistician used an algorithm to identify suitable women for the trial. Analysis revealed that eligibility on any two of the following risk factors would capture women suitable for the trial: current smoking, young pregnancy (< 23 years), no support during pregnancy, poor/fair/good health (versus very good/excellent general health), anxious mood, not finishing high school, not having a household income, a long-term illness, not living with another adult and/or never having a job. All women in the current study had two or more of these risk factors. For more details [AQ2] about XXX trial, see Goldfeld *et al.* (2017).

Following an initial baseline assessment at home, participants were randomized to intervention and control arms. Women from the control arm who completed mother–child free-play videos at face-to-face assessments at 12 and 24 months were included in this study (*n* = 190). The control arm was chosen to eliminate any intervention effects. Those women were followed up at 36 months where child language was directly assessed. Retention was 77.9% (*n* = 148) at the 36-month follow-up.

Table 2 presents baseline information about mothers and their infants. At baseline, average maternal age was 28.3 years. According to the Socio-Economic Indexes for Areas (SEIFA), 34.2% of families lived in the most disadvantaged quintile and almost one-fifth were experiencing housing problems (18.9%). A total of 15 mothers spoke English as an additional language; home languages included Bengali, Urdu, Tamil, Punjabi and Filipino. Average infant age was 12.2 months. One-third of infants were first born (30.5%) and just under half were female (46.8%). Mothers were asked to report on any diagnosed medical conditions including hearing status at 36 months; no children were reportedly diagnosed with hearing loss.
<tab 2>

<B>*Ethics*
[AQ2] Ethical approval was gained from XX (HREC Number 32296A) for the XXX study. Ethical approval was also gained from XXXX, Human Research Ethics Committee for the current study (Ethics Application ID 1545222.1).

<B>*Procedures*
[AQ2] The XXX researchers conducted the 12-, 24- and 36-month face-to-face assessments in the home. Videos of mother–child free-play were taken during the 12- and 24-month assessments. An iPad was used to record 8 min of free-play. At both assessments, an identical set of age-appropriate toys was provided. The data for this current study come from analysis of 5 min or 300 s of footage from the middle of each video. A total of 5 min of footage was chosen in the middle of the videos to allow for warm up and fatigue. A period of 5 min was deemed suitable for the purpose of the coding scheme as previous research found that 13-month-old infants used a verbal or gestural initiative directed towards their mother approximately every 20 s during 5 min of footage (Lloyd and Masur 2014). Child language was directly assessed at 36 months using the Clinical Evaluation of Language Fundamentals Preschool—Second Edition (CELF-P2; Wiig *et al.* 2006).



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<B>*Twelve-month verbal, non-verbal and fluency and connectedness*

Eleven measures of early communication were initially reviewed to generate suitable communicative behaviours to code from video footage including the CSBS DP, MCDI; Communication Matrix (Rowland and Fried-Oken 2010), Rossetti Infant–Toddler Language Scale (Rossetti 2006); and Child Development Inventory (Ireton 1992). Communicative behaviours listed in the measures were considered in relation to their developmental stage of communication to ensure suitability of chosen behaviours (Bates *et al.* 1979). Behaviours also needed to be relatively frequent and easily observable during mother–child free-play and be related to later language skills.

Eleven non-verbal and verbal behaviours were originally selected and piloted on 10 videos. Table 3 lists communicative behaviours and studies reporting association between these behaviours and later language skills. The behaviour of 'responding to words within speech' initially included multiple words (*look*, *stop*, *wait*, *in*, *out*, *me*, *my*, *come*, *more*, *off* and *child's name*). However, frequency of individual words was low (aside from *look* and the *child's name*) and coding was too complex. As such, only responding to *look* and *name* were chosen to be coded. At this point, a second coder was trained in using the scheme. Following the pilot, five behaviours were initially discontinued as consistent interrater reliability could not be met (< 80% agreement). Excluded behaviours were infant reaching for an object, responding to look, responding to name, responding to request to give/show and following pointing. Reaching behaviours occur in response to a desired object and can be classified as arm and shoulder movement against gravity and midline grasping (Bruner 1973). Reaching can be subdivided into no touch, touch and grasp (Fetters and Todd 1987). During coding, it was problematic to operationalize these definitions using the available videos. For instance, how to code when the child's hand was obscured by toys or the mother, the distance the child's arm needed to be outstretched to qualify as a reach and whether or not a reach was counted if the child did not physically touch the desired object.

<tab 3>

For the behaviours of responding to look, responding to name, responding to request to give/show and following pointing, poor reliability was due to lack of consensus on whether a child had understood and responded to only the spoken instruction. For instance, it was problematic to delineate if a child's response was based on an additional cue provided with the verbal instruction, like the mother banging an object or touching the child's arm. Infant behaviours were therefore only included if they were not elicited by the mother and not in response to maternal behaviour (Lloyd and Masur 2014). In total, four non-verbal (looking to mother's face, showing/giving mother an object, pointing and pretend play) and two verbal (vocalizations and words) behaviours were coded at 12 months. Behaviours were coded using Observer® XT software by the first author for the 5 min in the middle of the 12-month videos. See table 4 for detailed descriptions of 12-month verbal and non-verbal behaviours.

<tab 4>

The balance and reciprocity of adult–child conversation was also measured at 12 months using the fluency and connectedness rating scale from Hirsh-Pasek *et al.* (2015). The rating scale was assigned using the technical report procedure from the Communication Foundation Rating Items (Adamson *et al.* 2012). To measure fluency and connectedness, the same 5 min of 12-month video footage was rewatched and scored. See table 5 for details about fluency and connectedness scoring.

<tab 5>



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<B>*Conversationally derived language measures at 24 months*

A total of 5 min of each 24-month video were transcribed using the Systematic Analysis of Language Transcripts (SALT) software to generate 24-month language measures. All videos were transcribed by the first author, an experienced paediatric speech and language therapist (SLT). Coding conventions were consistent with SALT software. The child's mean length of utterance (MLU) and number of unique words were calculated from the videos.

<B>*Thirty-six-month child language (outcome measure)*

Three subtests of the CELF-P2 were administered at 36 months: Sentence Structure (SS), Word Structure (WS) and Expressive Vocabulary (EV). The three subtests scores combine to achieve a Core Language (CL) score.

<B>*Reliability*

For infant behaviours at 12 months and child language at 24 months, interrater reliability was conducted on 10% of the sample. Intraclass correlation coefficients were considered suitable to assess interrater reliability. Videos were randomly selected and coded by a second coder. Reliability was acceptable for 12-month communicative behaviours with the following coefficients: looks to face (1.0), words (0.96), vocalizations (0.96) and give/show (0.80). There were no instances or pointing or pretend play in the interrated infant videos, hence coefficients are unavailable for either measure. Reliability was also acceptable for 24-month language measures with the following coefficients: MLU (0.99) and unique words (0.94). For fluency and connectedness, the weighted kappa-statistic was used to measure interrater agreement; agreement was met when both raters achieved the same score or one score apart. Substantial agreement was met between raters ($k$ = 0.80). Regarding 36-month CELF-P2 assessments, all subtests were initially scored and entered into [AQ2] the XXX database by the administering research assistant. All assessment data was then cross-scored and checked by a colleague. Any difficult scoring decisions were sent to [AQ2] the XXX research coordinator who liaised with the first author (a speech and language therapist—SLT) to make the final scoring decisions.

<B>*Analysis*

The predictive validity of fluency and connectedness, non-verbal behaviours and verbal behaviours at 12 months was calculated in relation to 24- and 36-month language outcomes. Communication behaviours were grouped together based on Eadie *et al.* (2010) who found that the seven prelinguistic aspects of development in the CSBS DP fitted into three composites: speech, social and symbolic. Vocalizations and words were summed to create a verbal (speech) variable. Looking to its mother's face, showing/giving its mother an object, pointing and pretend play were summed to create a non-verbal (social) variable. In the Eadie *et al.* study, object use was included in the symbolic composite along with understanding. As understanding of language could not be accurately measured in this study, pretend play was included in the non-verbal variable as it has been positively associated with children's gesture use (Hall *et al.* 2013).



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<B>*Failed performance criteria*

To align with past research (Feldman *et al.* 2005, Wetherby *et al.* 2003, Wetherby and Prizant 2001), failed performance was determined as scoring ≤ 10th percentile, unless otherwise stated. For non-verbal behaviours at 12 months, failed performance was a score of zero. For verbal behaviours at 12 months, failed performance was a score ≤ 2. Failed performance on fluency and connectedness was a score of 1 (reflecting that no conversation had been established between the mother and infant for the duration of the video). Only 5.8% of children had a fluency and connectedness score of one (*n* = 11). For 24-month unique words, failed performance was ≤ 5 words. For 24-month MLU, failed performance was ≤ 18th percentile as (aside from a score of zero) the lowest MLU a child could achieve was 1. For 36-month CELF-P2 scores, failed performance was a score ≤ 70.

<B>*Calculating predictive validity*

Sensitivity was determined by calculating the proportion of children with scores ≤ 10th percentile at 12 months (or a score of 1 for fluency and connectedness) who had scores ≤ 10th percentile (≤ 18th percentile for MLU) at 24 or 36 months. Specificity was determined by calculating the proportion of children with scores > 10th percentile at 12 months (or a score > 1 for fluency and connectedness) who had scores > 10th percentile (> 18th percentile for MLU) at 24 or 36 months. The PPV was calculated by taking the proportion of children scoring in the bottom range at both ages (≤ 10th percentile unless otherwise stated) out of the total number of children within the bottom range at 24 or 36 months. The NPV was calculated by taking the proportion of children scoring above the bottom range at both ages (> 10th percentile unless otherwise stated) out of the total number of children scoring above the bottom range at 24 or 36 months (see Wetherby *et al.* 2003 for more details). As per previous research, no differentiation was made between genders (Feldman *et al.* 2005).

<B>*Adjusted linear regressions*

Adjusted regression analyses were then conducted to explore if fluency and connectedness, non-verbal behaviours and verbal behaviours at 12 months predicted 24- and 36-month language outcomes. Figures were adjusted for potential confounders including: age at assessments; child gender; maternal education; birth order; main language; and family history of communication difficulties.

<A>**Results**

<B>*Descriptive statistics*

Table 6 presents mean scores, standard deviations and ranges for the 12-, 24- and 36-month measures. In the 12-month videos, around half of the children used words (47.4%) and almost all vocalized (95.8%). Eight children (4.2%) did not vocalize during the 12-month videos. Looks to face was the most common 12-month non-verbal behaviour demonstrated (86.3%). Very few children exhibited pretend play (7.9%) or pointing (3.2%). At 24 months, the average MLU was 1.26 and the mean number of unique words was 19. Four children (2.1%) did not talk during the 24-month videos. The average CELF-P2 score at 36 months was 0.62 SDs below the population mean (100) at 90.72.

<tab 6>



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<B>*Predictive validity*

Table 7 presents the sensitivity, specificity, PPV and NPV of 12-month fluency and connectedness, verbal behaviours and non-verbal behaviours in relation to MLU and unique words at 24 months and CELF-P2 scores at 36 months. Across all values, specificity was markedly higher than sensitivity and the NPV was higher than the PPV. No 12-month measure demonstrated adequate predictive validity defined as > 0.80 for both sensitivity and specificity. Sensitivity scores were particularly low ranging from 0.6 to 0.39.

<tab 7>

<B>*Adjusted regression analyses*

Adjusted regression analyses were conducted to explore if fluency and connectedness, verbal behaviours and non-verbal behaviours at 12 months predicted MLU and unique words at 24 months and CELF-P2 scores at 36 months in the presence of potential confounders. Table 8 presents adjusted regression models. Fluency and connectedness at 12 months predicted 24-month unique words (coefficient = 1.81, 95% confidence interval (CI) [0.09, 3.53], $p = 0.040$) and 36-month CELF-P2 scores (coefficient = 2.67, 95% CI [0.00, 5.33], $p = 0.050$). Verbal behaviours at 12 months predicted 24-month unique words (coefficient = 1.83, 95% CI [0.53, 3.12], $p = 0.006$). No other adjusted regressions were significant.

<tab 8>

<A>**Discussion**

This study aimed to explore the predictive validity of verbal behaviours, non-verbal behaviours, and the fluency and connectedness of mother–child conversation at 12 months in relation to MLU and unique words at 24 months and CELF-P2 scores at 36 months. Across all 12-month measures, specificity and the NPV were higher than sensitivity and the PPV, reflecting that measures collected at 12 months were poorer at identifying children who had low language at 24 and 36 months than those who did not have low language at 24 and 36 months. These results reflect previously published predictive validity studies using the MCDI and CSBS DP where there was a trend for sensitivity to be higher than specificity. Although predictive validity was poor across all measures at 12 months in the current study, fluency and connectedness predicted unique words at 24 months and CELF-P2 scores at 36 months in adjusted regression models. Verbal behaviours at 12 months predicted unique words at 24 months in adjusted models.

<B>*Poor predictive validity*

Language measures collected in laboratory environments across the second year have been found to have limited stability (Fenson *et al.* 2007). In accordance with the current research, Feldman *et al.* (2005) also reported poor predictive validity using the MCDI with 2-year-old children. In their discussion the authors warned that language measures collected at 2 years are too unstable for use in clinical or research settings. Furthermore, the Feldman *et al.* (2005) and the current study comprised children experiencing adversity. Poorer language skills in these groups of children (reflected in the children in the current study having mean CELF-P2 scores 0.6 SDs below the mean) may have impacted predictive validity in both studies due to less within-group variation of scores (Arriaga *et al.* 1998). Poor predictive validity in the current study could also be due to the shorter play duration and the type of free-play activity captured at 12 months. Lower frequencies of some



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behaviours (e.g., pointing and pretend play) and small numbers of children scoring in the bottom range (e.g., only 11 children had a fluency and connectedness score of 1) may further explain poor prediction accuracy. Potentially there were too few children scoring in the bottom ranges, particularly for fluency and connectedness, to make accurate predictions. A different or extended free-play task may have provided more suitable data for measuring predictive validity for the purpose of the current study.

<B>*Fluency and connectedness and verbal skills*

Although predictive validity was poor using all measures collected at 12 months, fluency and connectedness and verbal skills predicted later language scores in adjusted regression analyses. The fact that earlier verbal skills predicted later verbal skill is unsurprising as this has been consistently reported in the literature (McCathren *et al.* 1999). This study reproduced previous research by demonstrating the value of fluency and connectedness to later language outcomes; the current study extended this research by showing that fluency and connectedness was important for language learning as young as 12 months of age (Hirsh-Pasek *et al.* 2015). When considered with other factors related to language development, fluency and connectedness and verbal skills at 12 months were important for later language skills. Unlike earlier research, non-verbal behaviours were unrelated to later language in adjusted regression models (Bavin *et al.* 2008). As spontaneous speech samples are influenced by materials, communication partners and setting (Pan *et al.* 2004), potentially the free-play scenario used for this research was not conducive to gesture use and pretend play.

<B>*Limitations*

Neither the CSBS DP nor the MCDI were collected at 12 months so the predictive validity of 12-month behaviours could not be directly compared with either measure. Furthermore, no receptive measures were collected at 12 months so the predictive validity of early comprehension was not measured. Also, only 5 min of footage, during one activity, may have limited the amount and variety of behaviours children could display at both 12 and 24 months, impacting the validity of measures. Additionally, video data may not be entirely representative of typical interactions; this is a drawback of all observational research that must be balanced alongside the strengths and limitations of other measurement options, such as parent report. Finally, concurrent gesture-plus-word combinations have been related to earlier production of two-word combinations (Iverson and Goldin-Meadow 2005) so not measuring co-occurring behaviours is a limitation.

Future research could combine observational measures of 12-month behaviours and fluency and connectedness with other predictors of language to try to increase prediction accuracy. Capturing communicative behaviours and fluency and connectedness during extended interactions in a typical mother–child exchange would also be worthwhile.

<A>**Conclusions**

Measures of non-verbal communication, verbal communication and fluency and connectedness at 12 months were poor at predicting language at 24 and 36 months. Poor predictive validity in the current study reiterates the difficulty with identifying children at risk of poorer language in infancy. Adjusted regression models demonstrated that fluency and connectedness of mother–child conversation has the potential to provide important information about language development.



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Further exploration of mother–child dynamics in relation to language trajectories will be important in future studies.

[AQ3] <A>**Acknowledgements**

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<<t/s Set names in caps and scaps as per usual style>>

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<<t/s table 1 is composed of 5 mini-tables. Do not merge them. Set as shown>>

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**Table 1. Predictive validity of The MacArthur–Bates Communicative Development Inventories (MCDI) and the Communication and Symbolic Behavior Scales—Developmental Profile (CSBS DP) from earlier studies**

Study 1. Predictive validity of the CSBS DP caregiver questionnaire (CQ) and behaviour sample (BS) compared with follow-up standardized language assessment (Wetherby *et al.* 2003)[a]

| MCDI/CSBS score | *n* | Mean age (months) | Sensitivity (true positives) | Specificity (true negatives) | PPV | NPV |
|---|---|---|---|---|---|---|
| CSBS DP CQ < 10th percentile | 246 | 14.5 | .81 | .79 | .64 | .90 |
| CSBS-DP BS < 10th percentile | 197 | 19.2 | .81 | .86 | .75 | .90 |

Study 2. Predictive validity of the CSBS DP compared with standardized testing at 25 months (Wetherby and Prizant 2001)[b]

| MCDI/CSBS score | *n* | Mean age (months) | Sensitivity (true positives) | Specificity (true negatives) | PPV | NPV |
|---|---|---|---|---|---|---|
| CSBS CQ < 10th percentile | 142 | 14 | .78 | .84 | n.a. | n.a. |
| CSBS-DP BS < 10th percentile | 88 | 21 | .89 | .85 | n.a. | n.a. |

Study 3. Predictive validity of MCDI-WS reported at 24 months compared with direct assessment at 30 months (Heilmann *et al.* 2005)[c]

| MCDI/CSBS score | *n* | Mean age (months) | Sensitivity (true positives) | Specificity (true negatives) | PPV | NPV |
|---|---|---|---|---|---|---|
| MCDI-WS 11th percentile | 100 | 24 | .68 | .98 | .96 | .81 |

Study 4. Predictive validity of MCDI-WS reported at 24 months compared with parent-reported 'language delay' at 36 months (Feldman *et al.* 2005)

| MCDI/CSBS score | *n* | Mean age (months) | Sensitivity (true positives) | Specificity (true negatives) | PPV | NPV |
|---|---|---|---|---|---|---|
| MCDI-WS < 10th percentile | 113 | 24 | .50 | .90 | .64 | .83 |

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Study 5. Predictive validity of MCDI-WS reported at 24 months compared with conversationally derived 'language delay' at 36 months (Feldman *et al.* 2005)

| MCDI/CSBS score | *n* | Mean age (months) | Sensitivity (true positives) | Specificity (true negatives) | PPV | NPV |
|---|---|---|---|---|---|---|
| MCDI-WS < 10th percentile | 113 | 24 | .53 | .85 | .41 | .90 |

Notes: [a]Age of follow-up language test varied with children reassessed at 2 or 3 years of age: mean age of reassessment at about 25 months.
[b]The Mullen Scales of Early Learning.
[c]Direct testing included a standardized expressive measure and analysis of language transcripts.
MCDI, MacArthur–Bates Communicative Development Inventories; MCDI-WS, MacArthur–Bates Communicative Development Inventories – Words and Sentences; CSBS DP, Communication and Symbolic Behavior Scales – Developmental Profile; PPV, positive predictive value; NPV, negative predictive value.

**Table 2. Baseline characteristics of mothers and infants in the study**

| | Participants (*n* = 190) |
|---|---|
| Mean maternal age: years, months (SD) | 28.3 (6.2) |
| Mean infant age at 12-month assessment: months (SD) | 12.2 (.94) |
| | |
| *Maternal characteristics* | *n (%)* |
| Teen parenthood (< 20 years) | 14 (7.4) |
| Did not complete high school | 39 (20.5) |
| Employed | 76 (40.0) |
| | |
| *Infant characteristics* | *n (%)* |
| First born | 58 (30.5) |
| Female | 89 (46.8) |
| | |
| *Family/household* | *n (%)* |
| SEIFA Index of Social Disadvantage Quintile[a] | |
| 1 | 65 (34.2) |
| 2 | 14 (7.4) |
| 3 | 78 (41.1) |
| 4 | 19 (10.0) |
| 5 | 7 (3.7) |
| Benefit/pension | 64 (33.7) |
| Current housing problems | 36 (18.9) |

Note: [a]Lowest scoring 20% of areas receive a quintile number of 1; highest scoring 20% receive a quintile number of 5.



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**Table 3. Non-verbal and verbal behaviours originally selected and piloted on 12-month videos**

| Communication behaviour | Previous research relating behaviour to later language |
|---|---|
| Child looks to its mother's face | [AQ6] Laakso *et al.* (1999) |
| Child shows/gives its mother an object | Özçaliskan and Dimitrova (2013) |
| Child points | Bates *et al.* (1979) |
| Child reaches for an object | Fogel *et al.* (1992) |
| Pretend play | Bates *et al.* (1979) |
| Child follows pointing | Acredolo and Goodwyn (2002) |
| Child responds to words within speech | Junge and Cutler (2014) |
| Child vocalizes | [AQ6] Laakso *et al.* (1999) |
| Word approximation | Bates *et al.* (1979) |

**Table 4. Detailed description of behaviours measured at 12 months**

| Infant behaviour | Definition | Example |
|---|---|---|
| Vocalizations | Vocalizations were counted using a time-sampling procedure whereby the infant was observed over 15-s intervals; one mark was awarded if the infant vocalized during each interval. For every 15-s period in which the infant exhibited the criterion behaviour at least once, they received a tally mark (maximum score of 20) | Infant making noises to itself whilst playing |
| Total words | Cumulative words spoken over the 5-min video. Owing to the idiosyncrasy of early words, six criteria were used to differentiate vocalizations from lexical items (Furey 2011) | Infant pushed the toy figurine down the slide and said '*ga*!' |
| Looks to face | Coded each time an infant gazed towards its mother's face | Infant looked up to its mother and smiled |
| Pointing | Coded each time the child extended its index finger (plus or minus its arm) towards an object/person | Infant pointed with its index finger to an object that was out of reach |
| Pretend play | Pretend play behaviours were based on the MCDI Words and Gestures Part II Actions and Objects survey (Fenson *et al.* 2007). Each action with an object, pretending to be a parent or imitating adult actions, counted | Child picked up a toy horse and made it gallop |
| Gives/shows | Coded each time an infant placed an object in the proximity of its mother: in here hand, lap or on the floor in front of her (*give*). Also included the extension of an object towards its mother without being relinquished (*show*) | Infant struggled to put a block on top of a tower, so it handed the block to its mother for help |

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**Table 5:** Fluency and connectedness scale with anchor behaviours.

| Item | Anchors | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1= | 2= | 3= | 4= | 5= | 6= | 7= |
| Fluency and connectedness of conversation: characterizes the flow of the conversation | No conversation established | Some fleeting verbal/non-verbal exchanges | Instances of the child initiating and its mother responding | Conversation lacks smoothness, appears to be largely dominated by one partner | Shared topic throughout. Both partners engaged in relatively equal turn-taking | Extension of interaction and play from both mother and child | Fluid and balanced conversation that is often sustained |

Source: Modified from Adamson *et al.* (2012) and Hirsh-Pasek *et al.* (2015).

**Table 6. Descriptive statistics of 12-, 24- and 36-month measures**

| | Mean | SD | Range | *n* (% of children ) |
|---|---|---|---|---|
| *12-month infant behaviours: verbal*[a] | | | | |
| Vocalizations | 8.86 | 4.82 | 0–20 | 182 (95.8) |
| Total words | 1.45 | 2.42 | 0–15 | 90 (47.4) |
| | | | | |
| *12-month infant behaviours: non-verbal*[a] | | | | |
| Looks to face | 4.87 | 4.88 | 0–24 | 164 (86.3) |
| Give/show<br>Pretend play<br>Pointing | 1.01<br>0.20<br>0.04 | 2.23<br>1.01<br>0.25 | 0–14<br>0–9<br>0–2 | 64 (33.7)<br>15 (7.9)<br>6 (3.2) |
| | | | | |
| *12-month fluency and connectedness*[a] | 2.87 | 1.00 | 1–5 | 190 (100) |
| | | | | |
| *24-month conversational measures*[a] | | | | |
| Mean length of utterance (MLU) | 1.26 | 0.38 | 0–3.52 | 187 (98.4) |
| Unique words | 19 | 10.54 | 0–51 | 187 (98.4) |
| | | | | |
| *36-month CELF-P2 CL scores* | 90.72 | 15.39 | 59–124 | 148 (77.9) |

Notes: [a]Total number of behaviours across 5 min for 12- and 24-month behaviours.
CELF-P2 CL, Clinical Evaluation of Language Fundamentals Preschool—Second Edition Core Language scores.



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**Table 7. Predictive validity of 12-month fluency and connectedness, non-verbal and verbal behaviours in relation to 24- and 36-month language outcomes**

| 12-month measures | Age at follow-up (FUP) (months) | Outcome | *n* | *n* ≤ 10th at FUP | Sensitivity (true positives) | Specificity (true negatives) | PPV | NPV |
|---|---|---|---|---|---|---|---|---|
| Fluency and connectedness[a] | 24 | MLU < 18th percentile[d] | 190 | 34 | .12 | .96 | .36 | .83 |
| Fluency and connectedness | 24 | Unique words < 10th percentile[e] | 190 | 18 | .06 | .94 | .09 | .91 |
| Fluency and connectedness | 36 | CELF-P2 < 70 (10th percentile) | 148 | 18 | .11 | .97 | .25 | .91 |
| Non-verbal behaviours[b] | 24 | MLU < 18th percentile | 190 | 34 | .15 | .88 | .22 | .83 |
| Non-verbal behaviours | 24 | Unique words < 10th percentile | 190 | 18 | .11 | .88 | .09 | .90 |
| Non-verbal behaviours | 36 | CELF-P2 < 70 (10th percentile) | 148 | 18 | .17 | .91 | .20 | .89 |
| Verbal behaviours[c] | 24 | MLU < 18th percentile | 190 | 34 | .24 | .94 | .44 | .85 |
| Verbal behaviours | 24 | Unique words < 10th percentile | 190 | 18 | .39 | .94 | .39 | .94 |
| Verbal behaviours | 36 | CELF-P2 CL < 70 (10th percentile) | 148 | 18 | .11 | .88 | .12 | .88 |

Notes: [a]Fluency and connectedness score = 1.

[b]Non-verbal behaviours were summed looks to face, gives/shows, pointing and pretend play.

[c]Verbal behaviours were summed vocalizations and words.

[d]The 18th percentile was chosen as only 2% had an MLU = 0 (four children) and 18% had an MLU ≤ 1.

[e]Less than or equal to five words.

PPV, positive predictive value; NPV, negative predictive value; MLU, mean length of utterance; CELF-P2, Clinical Evaluation of Language Fundamentals Preschool—Second Edition Core Language score.

**Table 8. Adjusted[a] regression analyses examining the associations between fluency and connectedness, verbal behaviours and non-verbal behaviours at 12 months and language scores at 24 and 36 months**

| Predictor | Age at follow-up (months) | Outcome | Coefficient (95% confidence interval (CI)) | *p* | Adjusted $R^2$ |
|---|---|---|---|---|---|
| Fluency and connectedness | 24 | MLU | [AQ7] 0.05 (–0.01–0.12) | .090 | .15 |
| Fluency and connectedness | 24 | Unique words | **1.81 (0.09–3.53)** | **.040** | **.17** |



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| | | | | | |
|---|---|---|---|---|---|
| Fluency and connectedness | 36 | CELF-P2 CL scores | **2.67 (0.00–5.33)** | **.050** | **.11** |
| Non-verbal behaviours[b] | 24 | MLU | –0.01 (–0.07–0.04) | .674 | .14 |
| Non-verbal behaviours | 24 | Unique words | –0.07 (–1.62–1.47) | .925 | .14 |
| Non-verbal behaviours | 36 | CELF-P2 CL scores | –1.61 (–4.03–0.82) | .192 | .10 |
| Verbal behaviours[c] | 24 | MLU | 0.03 (–0.02–0.07) | .302 | .14 |
| Verbal behaviours | 24 | Unique words | **1.83 (0.53–3.12)** | **.006** | **.19** |
| Verbal behaviours | 36 | CELF-P2 CL scores | –0.09 (–2.27–2.09) | .935 | .80 |

Notes: [a]Figures adjusted for potential confounders: age at assessments, gender, maternal education, birth order, main language, family history of language difficulties, scores shown in bold ≤ 0.05, all adjusted $R^2$.

[b]Non-verbal behaviours are summed looks to face, gives/shows, pointing and pretend play.

[c]Verbal behaviours are summed vocalizations and words.

MLU, mean length of utterance; CELF-P2, Clinical Evaluation of Language Fundamentals Preschool—Second Edition Core Language scores.

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