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Speed of Language Comprehension at 18 months Predicts School-Relevant Outcomes at 54 months in Children Born Preterm

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Abstract

Objective—Identifying which preterm children (PT) are at increased risk for language and learning differences increases opportunities for participation in interventions that improve outcomes. Speed in spoken language comprehension at early stages of language development requires information processing skills that may form the foundation for later language and school-relevant skills. In children born full term (FT), speed of comprehending words in an eye-tracking task at 2 years predicted language and non-verbal cognition at 8 years.[1] Here, we explore the extent to which speed of language comprehension at 1½ years predicts both verbal and non-verbal outcomes at 4½ years in children born PT.

Method—Participants were children born PT (n=47; ≤ 32 weeks gestation). Children were tested in the "looking-while-listening" (LWL) task at 18 months, adjusted for prematurity, to generate a measure of speed of language comprehension. Parent report and direct assessments of language were also administered. Children were later retested on a test battery of school-relevant skills at 4½ years.

Results—Speed of language comprehension at 18 months predicted significant unique variance (12–31%) in receptive vocabulary, global language abilities, and non-verbal intelligence (IQ) at 4½ years, controlling for socioeconomic status, gestational age, and medical complications of preterm birth. Speed of language comprehension remained uniquely predictive (5–12%) when also controlling for children's language skills at 18 months.

Conclusion—Individual differences in speed of spoken language comprehension may serve as a marker for neuropsychological processes that are critical for the development of school-relevant linguistic skills and non-verbal IQ in children born preterm.

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Key terms

Prematurity; speed of processing comprehension; language; non-verbal IQ

INTRODUCTION

Premature birth affects approximately 10% of all births[2] and is associated with increased risk of adverse neurodevelopmental outcomes, especially for those born very or extremely preterm (PT).[3] Language deficits are among the adverse outcomes affecting children born PT. Early identification of language deficits is important because those with poor early language skills are at increased risk for later adverse outcomes, including poor literacy and academic skills.[4] Language delays among children born PT are frequently identified during the toddler years[5,6] and persist to adolescence.[7–9] However, language outcomes after PT birth show variability at every developmental level.[6,10,11] In this study, we evaluated the use of an experimental task that measures speed of language comprehension to identify which toddlers born PT would be at highest risk for adverse outcomes and to interrogate the nature of their difficulties.

Rather than a unified construct, language ability can be conceptualized as an ensemble of critical subskills, including speed of processing, attention, and verbal memory.[12] The standardized tests and parent report measures traditionally used in clinical practice assess accumulated knowledge, such as vocabulary size or grammatical skills, but do not specifically evaluate the component subskills.[10,13] Directly assessing language subskills may be useful for understanding continuities of early skills and later outcomes within and beyond the language domain and may explain the neuropsychological processes underlying language delays.[14,15]

Measuring underlying subskills in young children who have limited tolerance for behavioral testing can be challenging. However, low-demand eye-tracking procedure can assess the speed of real-time spoken language comprehension. The "looking-while-listening" (LWL)[16] task monitors children's eye movements as they look at two pictures in response to verbal stimuli directing their attention to the target (e.g., "Where's the doggy?"), and away from the distracter picture. Speed of language comprehension is reflected in reaction time (RT) to shift gaze from distracter to target. Previous studies have found that FT children who showed faster RTs at 18 months had more rapid vocabulary growth over the 2nd and 3rd years[17] and higher IQ and working memory scores at 8 years.[1] Thus, how quickly FT children comprehend familiar words in this eye-tracking paradigm reflects information processing skills that support early vocabulary development and long-term verbal and non-verbal learning. The LWL task offers a promising approach for isolating neuropsychological processes fundamental to learning across many domains, and has the potential for identifying weaknesses that may accumulate to cause later disability in clinical populations, such as children born PT.[18–20]

Studies with school-aged children and adolescents born PT implicate slow language processing speed as a contribution to language and reading deficits.[21] These results suggest that speed of language processing may prove a reliable measure of individual differences at early ages and a predictor of neurodevelopmental progress. Among children born PT, speed of language comprehension on the LWL task was associated with standardized measures of general language at 18 months corrected age and predicted receptive vocabulary scores at age 3 years.[20]

The Current Study

In this study, we extend the previous findings by assessing the contributions of speed of language comprehension in the LWL task in PT children at age 18 months, adjusted for prematurity, to language abilities and also to non-verbal intelligence at 4½ years. We hypothesized that speed of language processing would predict not only vocabulary and general language skills, but also non-verbal IQ at 4½ years, controlling for demographic and medical variables known to be associated with outcomes in this population.

METHOD

Participants

Participants were 47 children (22 females) with GA ≤ 32 weeks and BW <1800 grams from an ongoing longitudinal study. Data on the predictor variables have been reported on previously for a sub-set of these children.[20] Families were recruited from the Neonatal Intensive Care Unit, the High-Risk Infant Follow-up Clinic, or a research registry. Exclusionary criteria were conditions, such visual/auditory impairments, that would limit participants from engaging in the study's tasks. All children were primarily English learners, exposed to < 25% of another language. The research protocol was approved by a university institutional review board; parents gave signed consent at each visit.

Children were tested at 18 months, adjusted for prematurity (*Mean (M)* = 18.7; range = 18.0–20.3 months; chronological age: *M* = 21.1, range = 20.2–22.8 months). Follow-up language and non-verbal IQ measures were administered when the children were 4½ years chronological age (*M* = 4.5, range = 4.3 – 4.9 years). An additional 25 participants were tested at 18 months did not return for testing at 4½ years because of the conclusion of funding.

Table 1 shows the characteristics of the sample. We measured socioeconomic status (SES) because it has been associated with neurodevelopmental outcomes in PT and FT children.[22] Participants were primarily from mid- to high-SES, as classified using a modification of the Hollingshead Four Factor Index (HI),[23] a composite based on parents' education and occupation (range = 8–66). Poor outcomes after PT birth have been linked to gestational age (GA) and birth weight (BW).[24] In this sample, GA and BW were highly correlated and we used GA in analyses.

Outcomes have also been associated with medical and neurological complications of PT birth.[25] Trained research assistants in consultation with the last author coded the presence/absence of 12 medical and neurological conditions associated with prematurity (Table 1). A composite score summed all medical conditions to generate a proxy for the severity of medical complications in the perinatal period.

Predictor Variables, Measures at Age 18 Months Adjusted Age

Vocabulary Size—Early vocabulary skills were assessed using the MacArthur-Bates CDI: Words & Gestures (CDI: W&G), a reliable, valid parent report instrument.[26] Parents marked words that their child "understands" and "understands and says." Total comprehension and production vocabulary sizes were derived (396 max). Percentiles were derived based on age, adjusted for degree of prematurity.

Cognition and Receptive/Expressive Language—Trained examiners administered the Bayley Scales of Infant and Toddler Development, 3rd edition (BSID-III).[27] Scores were computed for cognitive, receptive language, and expressive language sub-scales, as well as the total language composite. The language composite was used as a comprehensive evaluation of receptive and expressive language skills. Scaled scores were converted to standard full-scale scores based on adjusted age.

Speed of Language Comprehension—We used the looking-while-listening (LWL) procedure,[16] to measure speed of language comprehension. Children were tested in two visits approximately one week apart, and the data were later combined across sessions. The child sat on the caregiver's lap while pairs of pictures of objects appeared on a screen and a prerecorded voice named one of the pictures. A video camera between the pictures provided a video-record of the child's looking responses. Each session lasted approximately 5 minutes. Caregivers' vision was blocked so that they could not inadvertently bias their child's responses.

Visual stimuli were color pictures, presented in fixed pairs matched for animacy and salience. Target order and picture position were counterbalanced. Pictures were displayed for 2 seconds prior to speech onset and for 1 second after sound offset. Auditory stimuli presented the target noun in sentence-final position followed by an attention-getter (e.g., "Where's the doggy? Do you like it?"). Target nouns were selected to be familiar to children of this age range: ball–shoe, birdie– kitty, baby–doggy, and book–car. Target nouns were presented four times as target and distracter, with 4 filler trials, yielding 64 test trials. Because the LWL captures individual differences in the speed with which children process words that are familiar to them,[16] trials with target words which the parent reported that the child did not understand were excluded from analysis on a child-by-child basis. All children were reported to know at least five target words ($M = 7.5$, 93%).

All LWL sessions were coded offline based on the video-recordings of the child's eye movements by trained research assistants unaware of target side. Trials where the participant was inattentive or the parent interfered were excluded. For each 33-ms interval of each trial, eye gaze was coded as either fixed on one of the images (left or right), moving between the images, or not looking at either image. Trials were later designated as target-initial or distracter-initial based on where the child was fixated at target noun onset.

Reaction time (RT) was computed for each participant collapsing across all trials. RT is mean latency in milliseconds (ms) to initiate a gaze shift from distracter to target on all distracter-initial trials during a window of 300 ms to 1800 ms after target noun onset. Shifts initiated outside the window were excluded from computation of RT because they were less unlikely to be in response to the verbal stimulus. All children contributed at least 2 valid shifts to the computation of RT (M = 16.7 trials; range = 2–30). To establish reliability, 25% of the sessions were randomly selected and recoded. Inter-coder agreement was 96% for the proportion of frames within the window identified as on the target vs. the distracter. The proportion of trials on which RT agreed within one frame was 100%.

Outcome Variables, Measured at Age 4½ Years

Receptive Vocabulary—Children's receptive vocabulary was assessed using the Peabody Picture Vocabulary Test, 4th Ed. (PPVT-4).[28] Standard scores were based on chronological age. One child was missing a PPVT-4 score, so analyses with this outcome are based on n = 46.

General Language—Children's language skills were assessed using the Clinical Evaluation of Language Fundamentals-Preschool-2 (CELF-P2).[29] Standard scores were derived for Core Language based on chronological age. One child was missing a score on the CELF-P2, yielding a sample size for this outcome measure of n = 46. For selected analyses, children were classified into higher- (n = 22) and lower-language (n = 24) groups based on a median split of standard scores (Median = 106).

Non-Verbal IQ—Non-verbal IQ was assessed with the Brief-IQ sub-scale of the Leiter International Performance Scale-Revised (Leiter-R).[30] Administration and responses are non-verbal, capturing skill in problem solving and reasoning independent of a child's language abilities. Standard scores were based on chronological age. Two children were missing scores on this outcome, so final analyses are based on n = 45. Children were classified based on a median split (Median = 100) into higher- (n = 24) and lower-IQ (n = 21) groups.

Data Analysis

We derived descriptive statistics for the predictor and outcome variables. We applied a series of hierarchical multiple regressions to explore the predictive contribution of RT at 18 months to outcomes at 4½ years. SES, GA, and medical risk composite score were the control variables. We explored the predictive contribution of RT on each outcome measure beyond the control variables. We also explored the contribution of parent reported vocabulary size and scores on a standardized test of language on outcomes, beyond the control variables. Finally, we assessed the unique contribution of RT beyond demographic, medical, and scores on the early knowledge-based language and cognitive assessments. All tests were two-tailed and levels of significance were set at $p < .05$.

RESULTS

Description of Sample Performance

At 18 months, participants were reported to comprehend about 200 words and to produce about 65 words, on average (Table 2). These scores placed children significantly below normative levels on both measures; comprehension: $t(46) = 4.7$, $p = .001$, $d = .62$; production: $t(46) = 3.9$, $p = .001$, $d = .57$. Comprehension and production vocabulary size measures were correlated, $r(46) = .67$, $p = .001$. Mean scaled scores for the total language composite on the BSID-III (Table 2) were not significantly below normative expectations for corrected age, $t(46) = 1.2$, $p = .24$, $d = .17$. Scores on the BSID-III were significantly correlated (rs = .52 – .63), and we chose the total language composite as the primary measure in our predictive models. In the LWL task, the mean RT was about 790 ms. RT was moderately correlated with scores from the CDI and BSID-III (*r*s = −.27 to .50).

At 4½ years, children were, on average, performing above expected normative levels on the PPVT-4, $t(45) = 3.5$, $p = .001$, $d = .46$, and the CELF-P2, $t(45) = 2.1$, $p = .04$, $d = .31$. Scores on the Leiter-R were not significantly different from expected levels, $t(44) = 1.1$, $p = .27$, $d = .17$. For all measures, some children scored >1 SD below the normative mean (PPVT-4: $n = 5$, 11%; CELF-P2: $n = 4$, 9%; Leiter-R: $n = 11$, 24%). The two language measures were strongly correlated, $r(45) = .71$, $p < .0001$; both were moderately correlated with non-verbal IQ: PPVT-4, $r(43) = .45$, $p < .002$; CELF-P2, $r(43) = .49$, $p < .001$.

Predicting Performance on Outcome Measures at 4½ Years

Receptive vocabulary—In Table 3, the 3 control variables, SES, GA, and medical risk, accounted for about 29% of the variance in PPVT-4, $F(3, 42) = 5.7$, $p = .002$; GA was a unique predictor (Model 1). RT contributed nearly 15% additional variance (Model 2), $F(1,41) = 12.6$, $p = .001$. Without consideration of RT, production vocabulary size (CDI) and total language (BSID-III) contributed more than 23% variance, $F(2, 40) = 9.8$, $p = .001$, beyond control variables, but only production vocabulary size contributed significant unique variance (Model 3). In the final model, RT added nearly 5% variance beyond all other predictors $F(1,39) = 4.4$, $p = .06$ (Model 4); GA, production vocabulary size, and RT contributed unique variance to the outcome. All of the predictors accounted for nearly 60% of the variance, $F(6,39) = 8.6$, $p = .001$. A similar pattern of results was found when vocabulary comprehension was entered in the models; RT contributed 6.5% unique variance, $F(1, 39) = 5.3$, $p = .03$, beyond all other predictors.

General language—In Table 4, none of the control variables accounted for significant unique variance in CELF-P2 scores (Model 5), but the overall model accounted for about 21% of the variance. Adding RT accounted for about 30% additional variance, $F(1,41) = 26.3$, $p < .0001$ (Model 6). Without consideration of RT, production vocabulary size (CDI) and total language (BSID-III) also contributed about 30% additional variance after control variables, $F(2, 40) = 12.1$, $p = .001$; production vocabulary size, medical risk and BSID-III all remained unique predictors (Model 7). In the final model (Model 8), RT contributed nearly 12% additional variance beyond all other predictors, $F(1,39) = 12.3$, $p = .001$. None of the other predictors contributed unique variance. Taken together, the predictors accounted for more than 60% of the variance in CELF-P2 scores. A similar pattern of results was found when controlling for comprehension vocabulary size, with RT contributing 14.3% unique variance beyond all other predictors, $F(1,39) = 19.4$, $p = .001$.

The relation between RT at 18 months and later general language skill is illustrated by the time course plot of children's looking from the distractor to the target (Figure 1) as a function of time in ms from target noun onset; noun offset is indicated by the vertical dashed line. As the stimulus sentence unfolds in time, all children increased their proportion looking to the correct picture. However, children with higher CELF-P2 scores increased their proportion looking earlier in the stimulus sentence and reached a higher overall level of correct looking, compared to children with lower CELF-P2 scores. This difference in looking patterns is also reflected in faster mean RTs to shift from the distracter to target, on average, in children with higher (M = 716 ms, SD = 138) compared to lower (M = 841 ms, SD = 158) language scores, $t(44) = 2.8$, $p = .007$, $d = .84$.

Non-verbal IQ—In Table 5, demographic and medical factors accounted for 20% of the variance in Leiter-R; however, none of the covariates made a significant unique contribution (Model 9). RT accounted for an additional 12% of the variance, $F(2,39) = 2.0$, $p = .01$ (Model 10). Without RT in the model, none of the other variables contributed beyond the control variables (Model 11). RT at 18 months contributed about 10% variance beyond the control variables, $F(1, 36) = 10.0$, $p = .003$ (Model 12), and was the only significant unique predictor in the final model. Together, all predictors accounted for about 36% of the variance in non-verbal IQ. A similar pattern was observed when controlling for vocabulary comprehension; RT contributed 10.8% unique variance, $F(1,38) = 6.1$, $p = .02$. The pattern remained the same when controlling for scores on the cognitive subtest of the BSID-III, $F(1,38) = 4.6$, $p = .04$, with RT contributing 8.0% unique variance.

The plot of the time course of children's looking (Figure 2) shows that children with higher non-verbal IQ at 4 ½ years displayed different patterns of looking compared to children with lower non-verbal IQ. Children with higher-IQ increased their looking to the target sooner in the sentence and reached an overall higher proportion correct looking compared to children with lower-IQ scores. These looking patterns are also reflected in faster mean RTs to shift from distracter to target for children with higher (M = 712 ms, SD = 130), compared to lower non-verbal IQs (M = 868, SD = 174), $t(43) = 3.4$, $p = .001$, $d = 1.01$.

DISCUSSION

Speed of language comprehension at age 1½ years predicted individual differences in receptive vocabulary, general language skills, and non-verbal intelligence at age 4½ years in children born PT. Importantly, RT in the LWL task at 18 months of age, adjusted for the degree of prematurity, accounted for unique variance in neurodevelopmental outcomes that was not captured by demographic variables, the number of medical complications, and traditional assessments of language knowledge. These results extend earlier findings showing that RT at 18 months strongly predicted receptive vocabulary at 3 years in children born PT.[20] Here, RT also predicted individual differences in general receptive and expressive language skills at age 4½ years. Early speed of language comprehension also uniquely predicted children's non-verbal IQ whereas the results of traditional language assessments did not. This finding suggests that early RT indexes information processing skills that support learning in both the verbal and non-verbal domains, as has been found in children born full term.[1]

Speed of language comprehension in the LWL task reflects multiple information processing skills, including efficiency in encoding visual and auditory information, retaining that information in memory, and appropriately directing eye movements to the correct referent. The measure may also index language knowledge; words that are well-known may be processed more quickly than words that are less familiar. Speed of language comprehension thus reflects a host of neuropsychological processes that guide early linguistic skill and that are continuous with later assessments of language, problem-solving, reasoning, attention, and working memory. Traditional measures of early language knowledge, such as parent reports of vocabulary size and standardized assessments of receptive and expressive skills, capture children's accumulated knowledge; by contrast, RT reflects neuropsychological processes that facilitate efficient uptake of both linguistic and non-linguistic information during real-time interactions. Accumulated language knowledge and language processing skills are both important and are inter-correlated. The current findings show that children's general speed of information uptake during real-time language comprehension accounted for variance in school-relevant verbal and non-verbal skills.

Parent reports of vocabulary size also uniquely predicted later language outcomes, controlling for demographic and medical variables. However, associations of vocabulary size to later non-verbal IQ were not significant. Thus, early vocabulary size was a good estimate of accumulated linguistic knowledge that related to later language measures, but showed limited continuity with non-verbal measures that require a broader range of neuropsychological processes. Interestingly, scores on the BSID-III, a direct assessment of language knowledge that is widely used with clinical populations, showed only independent contributions to later CELF-P2 scores in this sample. Future studies should continue to explore the long-term independent continuities of measures such as the BSID-III in this population to language and cognitive outcome measures.

Where do individual differences in language processing speed come from? One possibility is the down-stream effects of early neurological disturbances associated with preterm birth.[31] Alterations in cerebral volumes and white matter pathways connecting them may influence speed of processing.[25] While medical risk and RT were modestly correlated here, $r(47) = .37$, $p < .01$, the unique contributions of RT to outcomes demonstrated here were above and beyond variance in an index of perinatal medical complications and injuries. This suggests that RT may reflect underlying variation in neurological processes that are not captured by a simple measure of medical risk.

Another possibility, consistent with a growing literature, is that the quantity and quality of the talk that children hear from caregivers affects development of vocabulary and language processing skills.[32,33] In a recent study examining caregiver talk in a matched group of FT and PT children, more caregiver talk was associated with better language outcomes in both FT and PT children, and among PT children who were more or less vulnerable to the adverse consequences of preterm birth.[34] Interventions which support increased caregiver-child engagement may effectively shape children's learning outcomes by tuning up those language processing skills that support learning in both PT and FT children.

Limitations

The sample size was relatively small and had a high proportion of children from affluent, highly-educated backgrounds. Given the association between PT birth and SES,[35] our results may not generalize to a more diverse sample of PT children. Our study assessed non-verbal outcomes using a single assessment measure. It is not known whether children's speed of language comprehension would be associated with other non-verbal skills, such as attention and executive functioning, that are also critical for school success.[36] Our index of medical risk was the sum of an equal weighting of many different conditions that have been associated with preterm birth. Further research is needed to determine which of these risk factors or combination of risk factors are most associated with adverse consequences in this population. Finally, we assessed outcomes only at 4½ years. Future studies should explore the longer-term impact of early speed of language comprehension in this population.

Implications and Conclusions

Early indices of language progress by parent report and direct standardized assessments accounted for variation in later language outcomes in children born preterm. However, individual differences in the speed of language comprehension at 18 months accounted for significant unique variation in both verbal and non-verbal outcomes at 4½ years. Thus, measures of early efficiency in processing linguistic input in real-time captures important information about early neuropsychological processes that traditional measures do not. Speed of language comprehension at young ages may serve as the foundation for the development of a broad range of verbal and non-verbal neuropsychological processes that are relevant to academic and life success in children across a range of skill levels.[4] Understanding the causes and consequences of the development of early speed of real-time language comprehension may elucidate and shape treatments of developmental delays in children born PT.

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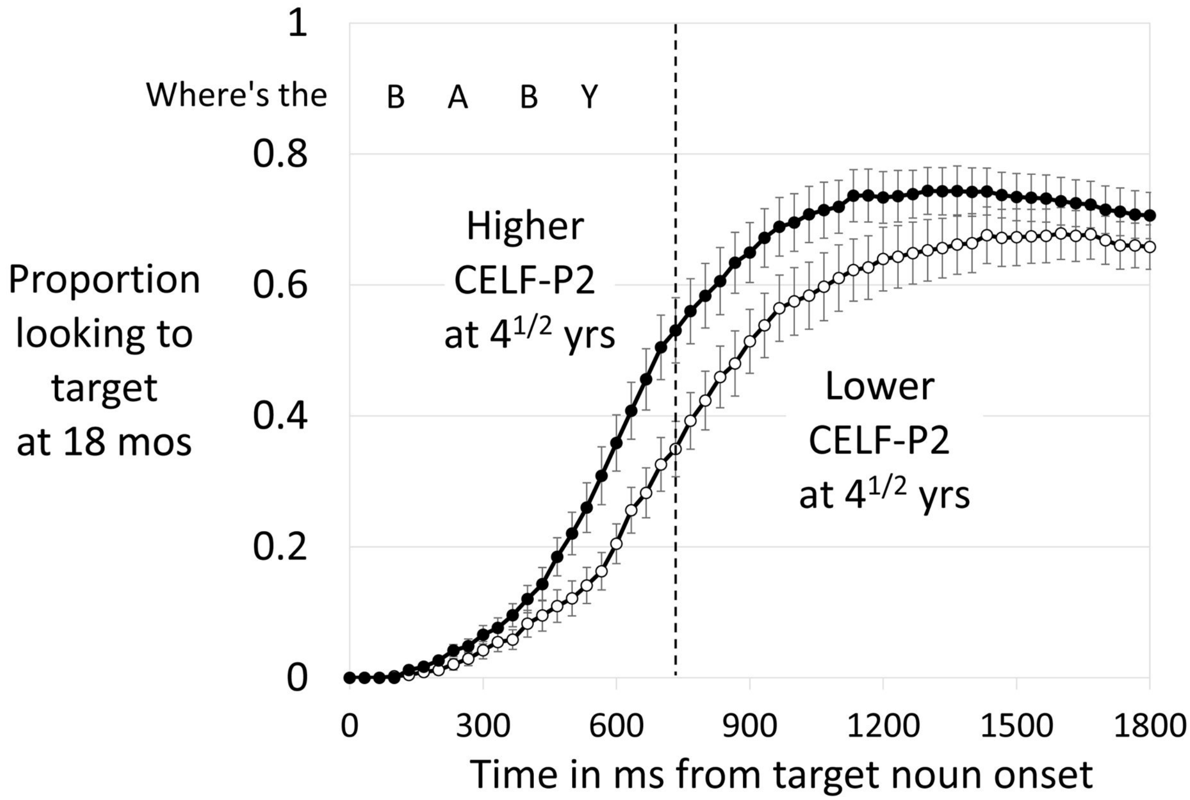

Figure 1.

Time course of shifts in gaze from distracter to target picture at 18 months in the LWL task in children born PT with higher (n=22) and lower (n=24) language outcomes on the CELF-P2 at 4½ years. Error bars represent +/− 1 SE of the mean over participants. Dashed vertical line indicates target noun offset.

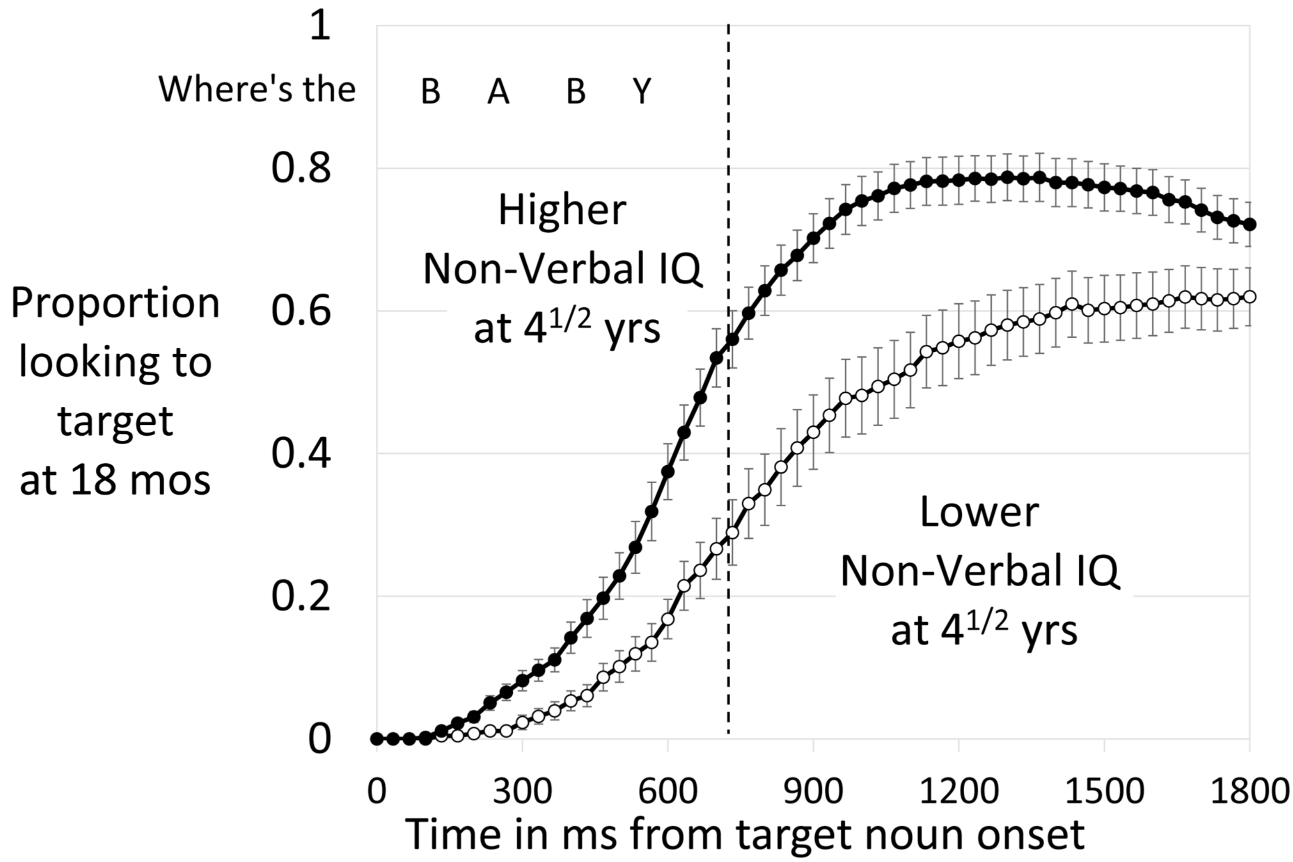

Figure 2.

Time course of shifts in gaze from distracter to target picture at 18 months in the LWL task in children born PT with higher (n=24) and lower (n=21) non-verbal IQ outcomes on the Leiter-R at 4½ years. Error bars represent +/− 1 SE of the mean over participants. Dashed vertical line indicates target noun offset.

Table 1

Descriptive statistics (Mean, SD, range) for sociodemographic, birth history, and medical risk ($n = 47$).

Demographics		***Mean* (*SD*)**	**range**
HI: SES[a]		56.9 (8.8)	30 – 66
Birth History			
Birth weight (g)		1241.2 (281.0)	670 – 1750
Gestational age (weeks)		29.6 (1.8)	25.3 – 32.7
Medical Risks[b]		% (n)	
1. Hearing Loss		0.0 (0)	
2. Seizure Disorder		0.0 (0)	
3. Periventricular Leukomalacia, on near term MRI		4.3 (2)	
4. Necrotizing Enterocolitis[c]		10.6 (5)	
5. Small for Gestational Age, birthweight < 10% for age		12.8 (6)	
6. Intraventricular Hemorrhage on any ultrasound[c]		17.0 (8)	
Grade I-II	*87.5 (7)*		
Grade III-IV	*12.5 (1)*		
7. Bronchopulmonary Dysplasia or Chronic lung disease[c]		29.8 (14)	
8. Patent Ductus Arteriosus[c]		29.8 (14)	
9. Retinopathy of Prematurity, any grade		34.0 (16)	
10. Hospital Stay > 51 days		53.2 (25)	
11. Respiratory Distress Syndrome[c]		80.9 (38)	
12. Hyperbilirubinemia[c] or phototherapy		91.5 (43)	
Composite Score M (*SD*)	range	3.9 (2.1)	1 – 9

[a]Hollingshead Four Factor Index of Socioeconomic Status (HI:SES)[23]; range = 8–66).

[b]Presence/absence of 12 conditions

[c]Based on diagnosis in the interim or hospital discharge summaries.

Table 2

Descriptives (*Mean*, *SD*, range) for measures at 18 months and 4 ½ years

18 months (Adjusted for Prematurity)	Mean (SD)	range
MB-CDI[a]		
Comprehension Vocabulary (Raw)	195.2 (87.7)	27 – 384
Comprehension Vocabulary (Percentile)	31.1 (27.4)	0 – 99
Production Vocabulary (Raw)	67.2 (72.8)	0 – 330
Production Vocabulary (Percentile)	32.6 (30.5)	1 – 99
BSID-III[b]		
Cognitive	9.7 (2.7)	3 – 16
Receptive Language	9.6 (3.7)	1 – 18
Expressive Language	9.4 (2.6)	2 – 16
Language Composite	97.2 (16.3)	59 – 129
LWL: RT (ms)[c]	789.7 (167.0)	526 – 1159
4 ½ years		
Receptive Vocabulary (PPVT-4)[d]	109.6 (18.8)	58 – 152
Core Language (CELF-P2)[e]	104.5 (14.3)	59 – 129
IQ (Leiter-R)[f]	96.6 (20.2)	52 – 145

[a] Raw and percentile scores for reported number of words comprehended or produced on the MacArthur-Bates CDI: Words & Gestures.[26]

[b] Scaled or standard scores based on age adjusted for prematurity on the cognitive, receptive language, and expressive language subscales, and the language composite from the BSID-III.[27]

[c] Mean reaction time (RT) to shift to target picture on distracter-initial trials in the Looking-While-Listening (LWL) task[16], including only shifts between 300–1800 ms from target noun onset.

[d] Standard scores based on chronological age on the Peabody Picture Vocabulary Test (PPVT-4).[28] ($n = 46$)

[e] Standard scores based on chronological age on the Core Language subtest of the Clinical Evaluation of Language Fundamentals-Preschool (CELF-P2).[29] ($n = 46$)

[f] Standard scores based on chronological age on the Brief IQ from the Leiter-R.[30] ($n = 45$)

Table 3

Prediction to PPVT-4 at 4 ½ years from 18 month demographic, medical, language, and language processing measures ($n = 46$). Unstandardized B (SE).

	Model 1	Model 2	Model 3	Model 4
HI: SES[a]	0.36 (0.29)	0.23 (0.26)	0.38 (0.25)	0.32 (0.24)
Gestational Age (GA)	**0.61 (0.26)** *	**0.76 (0.24)** **	0.38 (0.23)	**0.51 (0.23)** *
Medical Risk[b]	–0.79 (1.73)	1.53 (1.70)	–0.71 (1.49)	0.54 (1.57)
CDI: Vocabulary Production[c]	--	--	**0.11 (.04)** **	**0.10 (0.04)** *
BSID-III: Language[d]	--	--	0.15 (0.16)	0.04 (0.17)
LWL: RT[e]	--	**–0.05 (0.02)** **	--	**–0.03 (0.02)** *
r^2-change	--	**15.2%** **	**23.2%** **	**4.4%** #
Total R^2	**29.1%** **	**44.3%** **	**52.4%** **	**56.8%** **

Note:

# $p < .06$,

* $p < .05$,

** $p < .01$, significant effects also in bold.

[a] Hollingshead Four-Factor Index of Socioeconomic Status (HI:SES).[23]

[b] Composite score based on presence/absence of 12 conditions (See Table 1).

[c] Reported words produced on the MacArthur-Bates CDI: Words & Gestures[26] at 18 months.

[d] Standard scores on the Language composite (Expressive and Receptive subscales) of the BSID-III.[27]

[e] Mean latency to shift to target picture on distracter-initial trials in the Looking-while-listening task[16], including only shifts that occurred between 300 to 1800 ms from target noun onset.

Table 4

Prediction to Core Language (CELF-P2) at 4 ½ years from 18 month demographic, medical, language, and language processing measures ($n = 46$). Unstandardized B (SE).

	Model 5	Model 6	Model 7	Model 8
HI: SES[a]	0.32 (0.23)	0.14 (0.19)	0.29 (0.19)	0.18 (0.17)
Gestational Age (GA)	–0.01 (0.21)	0.17 (0.17)	–0.18 (0.18)	–0.01 (0.16)
Medical Risk[b]	**–2.91 (1.38)** *	–0.78 (1.2)	**–2.74 (1.14)** *	–1.34 (1.09)
CDI: Vocabulary Production[c]	--	--	**0.06 (0.03)** *	0.05 (0.03)
BSID-III: Language[d]	--	--	**0.29 (0.13)** *	0.17 (0.12)
LWL task: RT[e]	--	**–.05 (0.01)** **	--	**–0.04 (0.01)** **
r^2-change	--	**29.5%** **	**28.8%** **	**11.8%** **
Total R^2	**21.6%** *	**51.0%** **	**50.4%** **	**62.2%** **

Note:

* $p < .05$,

** $p < .01$, significant effects also in bold.

[a]Hollingshead Four-Factor Index of Socioeconomic Status (HI).[23]

[b]Composite score based on presence/absence of 12 medical conditions (See Table 1).

[c]Reported words produced on the MacArthur-Bates CDI: Words & Gestures[26] at 18 months.

[d]Standard scores on the Language composite (Expressive and Receptive) of the BSID-III.[27]

[e]Mean latency to shift to target picture on distracter-initial trials in the Looking-while-listening task,[16] including only shifts that occurred between 300 to 1800 ms from target noun onset.

Table 5

Prediction to non-verbal IQ (Leiter-R) at 4 ½ years from 18 month demographic, medical, language, and language processing measures ($n = 45$). Unstandardized B (SE).

	Model 9	**Model 10**	**Model 11**	**Model 12**
HI: SES[a]	0.62 (0.33)	0.47 (0.32)	0.64 (0.33)	0.54 (.32)
Gestational Age	–0.05 (0.30)	0.08 (0.29)	–0.21 (0.31)	0.01 (0.31)
Medical Risk[b]	–3.40 (1.98)	–1.44 (1.99)	–3.71 (1.97)	–1.86 (2.02)
CDI: Vocabulary Production[c]	--	--	0.08 (0.05)	0.07 (0.05)
BSID-III: Language[d]	--	--	–0.03 (0.23)	–0.24 (0.23)
LWL task: RT[e]	--	**–0.05 (0.02)** **	--	**–0.05 (0.02)** *
r^2-change	--	**12.1%** *	6.6%	**9.4%** *
Total R^2	**19.8%** *	**31.9%** **	**26.4%** *	**35.7%** **

Note:

* $p < .05$,

** $p < .01$, significant effects also in bold.

[a] Hollingshead Four-Factor Index of Socioeconomic Status (HI: SES).[23]

[b] Composite score based on presence/absence of 12 medical conditions (See Table 1).

[c] Reported words produced on the MacArthur-Bates CDI: Words & Gestures[26] at 18 months.

[d] Standard scores on the Language composite (Expressive and Receptive) of the BSID-III.[27]

[e] Mean latency to shift to target picture on distracter-initial trials in the Looking-while-listening (LWL) task,[16] including only shifts that occurred between 300 to 1800 ms from target noun onset.