Semantic and morphosyntactic language outcomes in biologically at-risk children

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Abstract

This study examines the language and cognitive outcomes for 69 children who were placed in neonatal intensive care units (NICUs) immediately postpartum. These children are known to be at risk for later cognitive and academic problems. This study focused on language outcomes in conjunction with cognitive outcomes. To obtain a view of language development beyond that available from general tests such as verbal IQ, specific aspects of semantic and morphosyntactic language performance were assessed at 4 years of age and their relationships with environmental and medical factors were examined. The results of the study show that these children have an elevated incidence of language and cognitive difficulties. Approximately 50\% of the children were experiencing problems in at least one aspect of language development. Semantic language outcomes were related to environmental variables such as maternal education and poverty, but unrelated to factors such as family history of language or learning problems, birth weight or gestational age. Syntactic outcomes, in contrast, showed no relationship to environmental factors. Importantly, the strength of the relationship between semantic performance and environmental variables varied as a function of language outcome. Children who showed profiles indicating normal language development showed the strongest relationships between semantic performance and environmental variables. In contrast, children with language

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and/or cognitive delays showed little to no benefits from higher levels of maternal education or higher income. © 1999 Elsevier Science Ltd. All rights reserved.

1. Semantic and morphosyntactic outcomes in biologically at-risk children

Medical advances across the past decade have sharply decreased the mortality rates for infants at risk due to factors such as prematurity, low birth weight (LBW) and respiratory distress. As more of these children are reaching school age, there is growing concern that early risk factors or medical interventions related to such factors may have long term consequences on academic performance. The physical and general cognitive consequences of early risk have been studied by focusing on groups such as premature infants with or without typically concomitant complications including LBW, infections due to mechanical ventilation, intraventricular hemorrhage or respiratory distress. These studies have made it clear that children in such groups have a higher than expected incidence of cognitive delays [1–4].

Some recent studies have gone a step further in order to identify specific aspects of cognition which appear to be depressed in children at early biological risk [5,6]. Such steps are necessary if we are to determine the likelihood that the children in these at-risk samples will go on to develop specific learning disabilities that will impact their academic fitness. While this perspective, which emphasizes specific performance within a domain, has gained in cognitive studies, it has been lacking in the studies of language outcomes for these children. The overall goal of this study is to examine the effects of early biological risk on general language outcomes, as well as on specific semantic and morphosyntactic outcomes.

The process of language acquisition is complex and some aspects, particularly vocabulary acquisition, may be strongly influenced by an individual’s cognitive abilities. In such a case, language acquisition might be negatively affected by the same risk factors that have later cognitive consequences. Alternately, it is also possible that early biological risk may differently affect cognition and language, such that in some children one domain is depressed while the other remains relatively unaffected, for example as in Williams syndrome [7] or specific language impairment (SLI).

Biological risk in this study is evident in children who were placed in the neonatal intensive care unit (NICU) immediately after birth, where risk is linked to prematurity, LBW and respiratory difficulties. All of these factors are known to be risk factors for later cognitive delay [1–3,8–12]. In this study we investigated whether the presence of biological risk might put the child at greater risk for later language impairments and if so, whether those impairments are language specific or only occur for children with cognitive delays. Further, we were interested in the domains of affected language and relationships to familial and environmental factors.

Language impairment is diagnosed when an individual displays poor
achievement in aspects of language despite normal hearing, social–emotional development and opportunity of acquisition. It is estimated that approximately 12% of all children starting school meet the criterion for having language impairment [13,14]. Of this 12%, approximately 7% is with SLI, a condition where the nonverbal intelligence levels are within normal range but a language deficit exists. Another 5% of children show both language and cognitive difficulties (general LI). Here we consider both groups.

1.1. Previous outcome studies

Previous investigations of the developmental outcomes for diverse at-risk groups, such as NICU children, have generally found that the majority of children score within the normal range on general IQ tests, but continue to show poorer academic outcomes than their peers [2,11,15,16]. In their study of 3–6-year-olds who had been admitted to the NICU at birth, Sell [15] found that as a group NICU children scored in the normal range on general developmental assessments. Yet, 50% of the children experienced academic problems including repeating a grade in school (12%) and/or receiving speech/language (6%) or other services initiated by the school (32% for problems in reading, spelling, or math). Similarly, Blackman et al. [2] examined 362 children at 5 years of age who had been identified as “high risk” immediately after birth due to medical conditions typically requiring admittance to the NICU (e.g. LBW, respiratory problems, infections, seizures, or low APGAR scores). Blackman et al. excluded an additional 155 high-risk children who had failed their developmental cognition screening at 30 months of age. One would think that the remaining children would provide the most optimistic picture of general developmental outcomes. Yet even though the group means were in the normal range, 18% of the children scored in the clinically impaired range.

Across a number of studies, the percentage of children at early risk whose general developmental scores fall more than 1 S.D. below the mean ranges from 5% to above 35% [1,3,17–23]. In addition, in every study that has reported academic performance as well as more general developmental measures, the rate of academic problems reported for these children is considerably higher than that expected from their IQ scores [3,15,17,24–26]. Clearly, the optimistic picture provided by mean outcome scores needs to be qualified by individual outcome measures. Moreover, the discrepancy between IQ outcomes and the number of children at academic risk suggests that rather than focusing on omnibus measures as the standard, it is important to examine factors such as performance on specific language measures and environmental measures, which are relevant to academic abilities.

The 4-year cognitive outcomes for the NICU children studied in the present paper have been described in a previous report [11]. As a group, the children scored in the low end of the average range for IQ, with 21% of them achieving a score below 80. Perinatal factors such as birth weight, estimated gestational age and length of NICU stay were not predictive of IQ scores. However, family
demographic variables such as poverty and minority status were moderately predictive of 4-year IQ scores. Similar relationships with IQ have been found for both economic and maternal factors using both clinical and nonclinical samples [27–32]. Taken together, these findings lead us to suspect that the presence of pre- or perinatal risk may have long-term consequences for both an individual’s cognitive and language abilities.

1.2. Language outcomes

Two of the more frequent reasons for NICU placement, prematurity and/or LBW, have been studied [19,20]. The majority of such studies have focused on general cognitive outcomes (i.e. performance on IQ tests). Those studies which have included language testing have chosen to use either omnibus measures of language, such as the verbal portion of the Weschler Intelligence Scales [33], or have confined language testing to a single domain, typically vocabulary development. Very few studies have included measures that assess the development of syntax and morphology, such as tense marking (e.g. past tense -ed as in “she walked” or third person singular -s as in “she walks”). This is an important gap because children with language impairments are known to have particular difficulty with the acquisition of grammatical morphemes that carry tense features [34,35]. Furthermore, neither mother’s education nor a child’s nonverbal IQ score predicted growth curve trajectories of tense marking from the ages of 3–7 years for either children with language impairment or unaffected control children [35]. Thus, a closer examination of the morphosyntactic development of children at early risk is warranted.

In general, the findings from the vocabulary acquisition and omnibus language literature mirror that of the findings in cognition for the general at-risk group of children. While premature and/or LBW children tend to score in the average range as a group, there is a considerable number of such children who score in the low-normal to impaired range [3,19–21,23,36,37]. Again, just as in the general at-risk population, it was found that although the majority of children scored within the normal range, academic performance tended to be problematic [21,38].

In one of the few studies to look specifically at language outcomes, Vohr et al. [36] evaluated 50 LBW children at 2 years of age. The authors found that LBW infants lagged behind their full-weight peers for both receptive and expressive language, with 28% of the children showing clinical levels of language delay. In contrast, Menyuk et al. [39] (see also Ref. [32]) collected measures of comprehension, production and morphosyntactic performance for 28 children who had been born premature with LBW. Menyuk et al. [39] report no differences in any of these measures as a function of birth status at 3 years of age. However, for a different sample followed into school-age, a time when emphasis shifts from basic language acquisition to language use in the service of academic pursuits, Menyuk et al. [38] report that at 7–8 years, children who were premature scored lower than controls on both language processing and reading measures [32,38].

With respect to morphosyntactic outcomes, Menyuk et al. [39] reported no
group differences in either the proportion of correct uses of regular past tense in obligatory context (45% for both the LBW and controls combined) or the percentage of children who had achieved "mastery" (36% for both groups combined). It is important to note that while both the Menyuk et al. study [39] and the present study both assessed the production of the regular past tense (-ed), the measurement of past tense, the ages of the children and the definition of outcome differ substantially between the two studies. Menyuk et al.'s findings [39] were based on spontaneous language samples collected longitudinally between 2 and 3 years of age. The authors defined mastery as at least two correct uses of regular past tense in the child's language sample. Moreover, the percent correct usage for the LBW and control groups combined was fairly low (45%) considering that many children did not use a given morpheme in their sample and were therefore excluded from the analysis. One possibility is that the reported lack of group differences between at-risk and control children was attributable to differential loss of subjects from the analysis. This is particularly likely if lower-functioning children were more likely to avoid contexts where the marking of past tense is obligatory. In our laboratory, we find regular past-tense stems to be used infrequently in young children's spontaneous language samples, and even more infrequently in samples from children with language impairments. Because of this, we have used an experimental probe measure in this study which allows us to examine morphological acquisition in children regardless of the presence or absence of language delays. Specifically, the past-tense probe allows us to assess percent correct usage for each subject relative to norms gathered from a control sample followed longitudinally [35]. Using this measure may allow us to obtain a more sensitive test of these children's morphosyntactic abilities.

1.3. Present study

In the present study, children were tested with both an omnibus language measure (WPPSI verbal IQ) and measures which more clearly targeted lexical/semantic abilities (PPVT) and morphosyntactic abilities (MLU and past-tense marking). By including tests designed to evaluate more specific aspects of language development we can obtain an enriched understanding of the language outcomes for these NICU children. The particular questions to be addressed in the present study are: (a) what are the language outcomes for children at risk due to early placement in the NICU?, (b) what percentage of these children are showing signs, such as language or cognitive delays which might put them at risk for later academic problems? and (c) how should we characterize the nature of the delay? For example, what percentages of the delayed children show evidence in both cognition and language versus delays in language alone?

Because environmental factors, including maternal education and income, and hereditary factors, such as whether there is a family history of language or learning problems, are suspected to influence children's cognitive and language development, we also examined the influence of these factors in the language outcomes for this sample of children [11,27,35,40–42]. We will show that (a)
despite their young age, many of these children are experiencing the kinds of language and/or cognitive difficulties that may well lead to poor academic performance (experiment 1), (b) the problems experienced by these children are not due to a higher proportion of familial language or learning problems (experiment 2) and (c) the relationship between environmental factors and language outcomes is variable. This relationship does not apply to all aspects of language, nor to children in all language outcome categories.

2. Experiment 1

2.1. Method

2.1.1. Participants

The participants in this study consisted of 69 4-year-olds (33 male, 36 female) that had received care in the NICU of an urban midwestern teaching hospital from mid-1989 to mid-1990. The data concerning the family demographic variables have been presented in greater detail elsewhere [11] and will only be summarized here. An additional 33 children who were recruited for participation in infancy were excluded from the 4-year follow-up study due to death (N = 8), severe physical or mental disabilities which precluded the use of our language and cognitive measures (N = 7) or resignation from the study due to moving or other factors before the child could be tested at 4 years (N = 18).

As is common with NICU populations (see Refs. [2,15]), the children participating in this study presented with a diverse set of perinatal histories. Fifty-one of the children (71%) were born prematurely, defined as prior to their 37th week of gestation. Twenty-five infants were born before their 32nd week of gestation. The estimated gestational age for the premature infants ranged from 24 to 36 weeks (M = 30.8 weeks, S.D. = 3.44 weeks). The mean estimated gestational

<table>
<thead>
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<th>19%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Married</td>
<td>68%</td>
</tr>
<tr>
<td>Separated/divorced</td>
<td>12%</td>
</tr>
<tr>
<td>Maternal education</td>
<td></td>
</tr>
<tr>
<td>Less than 4 years of High School</td>
<td>20%</td>
</tr>
<tr>
<td>High School Diploma or GED</td>
<td>36%</td>
</tr>
<tr>
<td>Some postsecondary education</td>
<td>43%</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>67%</td>
</tr>
<tr>
<td>African-American</td>
<td>29%</td>
</tr>
<tr>
<td>Other</td>
<td>4%</td>
</tr>
<tr>
<td>Receiving welfare benefits</td>
<td>45%</td>
</tr>
</tbody>
</table>
age for the entire NICU sample was 33.04 weeks (S.D. = 4.97 weeks, range = 24–42 weeks). As expected for such a population, the most prevalent perinatal complication was respiratory problems including respiratory distress syndrome (69%), hyaline membrane disease (7%) and apnea or asphyxiation (4%).

Consistent with the large number of premature births, there was a significant number of children who had lower than normal birth weights. Sixty-seven percent of the subjects had birth weights below 2500 g. For 33% of the sample, the birth weight was between 1501 and 2500 g while for 11% the birth weight was under 1000 g. None of the children retained in the study was so severely impaired that they could not complete the 4-year assessment. The demographic and family characteristics of the sample are presented in Table 1.

2.1.2. Procedure

All testing took place within the children’s home. Families were visited in the first few months after the infant’s discharge from the NICU in order to obtain information regarding perinatal status and family demographics. This information was updated on subsequent home visits approximately 6 months apart. At 48 months, children were administered tests of intellectual and language abilities. An audiotaped language sample was obtained through a free-play procedure similar to that used by Rice et al. [34] and involved at least 100 utterances per child. The sample was transcribed by research assistants trained to a high degree of reliability and analyzed using SALT procedures [43].

2.2. Measures

1. Child status. The variables included under child status included the child’s birth weight, estimated gestational age at birth and sex. These variables were taken from the subject’s hospital records and the information provided by the parent(s) on the initial intake visit.

2. Family status. The variables included under family status were ethnicity, whether the family met the criteria for receiving welfare benefits (a measure of poverty) and the level of maternal education.

3. Intelligence. At 48 months, all children received the Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R: Ref. [33]). The WPPSI is a standardized intelligence test that provides separate subscales for verbal and nonverbal (performance) abilities as well as a full-scale IQ score. Each of these measures is normed with a mean of 100 and a standard deviation of 15. One subject could not be administered the performance subscale due to motor problems associated with cerebral palsy. For that subject, the full-scale IQ score was based on performance on the verbal subscale alone.

4. Language. In addition to the global language assessment provided by the WPPSI verbal subscale, three additional language measures were obtained. The
The first measure was the Peabody Picture Vocabulary Test-Revised (PPVT-R, Ref. [44]). The PPVT is a receptive language test that assesses understanding of word meaning. It is normed with a mean of 100 and a standard deviation of 15. The second and third measures used here, mean length of utterance (MLU) and regular past-tense marking, were chosen for their ability to assess aspects of grammar. Poor performance on both MLU and tense marking has been shown to be indicative of language impairments.

The child’s MLU was calculated based on the spontaneous utterances gathered in the language sample. The MLU was based on at least 100 utterances per child. MLU was calculated with respect to both words and morphemes, then compared to normative information provided by Leadholm and Miller [45]. The test–retest reliabilities for MLU with comparable sample sizes and subject ages are reported to be 0.75–0.85 [46]. Last, a picture elicitation probe for regular past tense was administered. This past-tense probe consisted of 12 pictures depicting people in the process of doing something or having completed an activity. The child was shown the picture of an ongoing activity and told, for example, “The boy is climbing the ladder. Now he’s all done.” The child was then shown a picture depicting the completed activity and asked “What happened?” The child’s responses were coded on line and the proportion of trials for which past tense was correctly marked (i.e. “He climbed”) was calculated. Experimental test–retest reliabilities with both a clinical sample of specifically language-impaired children and normal controls has shown 85% agreement for this measure for children in this age range. This past-tense probe has been used extensively by Rice and Wexler in their work on identifying grammatical delays in children with SLI [35]. This work has clearly shown that children with language impairments have a lower accuracy of tense marking (e.g. responses such as “He climb”) both in spontaneous utterances and probes of this type when compared to agemates [35,40].

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean</th>
<th>S.D.</th>
<th>% subjects scoring outside normal range</th>
</tr>
</thead>
<tbody>
<tr>
<td>WPPSI Full Scale IQ</td>
<td>91</td>
<td>13</td>
<td>35</td>
</tr>
<tr>
<td>WPPSI Performance IQ</td>
<td>90</td>
<td>13</td>
<td>37</td>
</tr>
<tr>
<td>WPPSI verbal IQ</td>
<td>93</td>
<td>12</td>
<td>26</td>
</tr>
<tr>
<td>PPVT-R</td>
<td>84</td>
<td>16</td>
<td>46</td>
</tr>
<tr>
<td>MLU (morphemes)</td>
<td>3.87</td>
<td>0.66</td>
<td>14</td>
</tr>
<tr>
<td>MLU (words)</td>
<td>3.32</td>
<td>0.58</td>
<td>-</td>
</tr>
<tr>
<td>Tense marking</td>
<td>0.57</td>
<td>0.25</td>
<td>59</td>
</tr>
</tbody>
</table>

  a Standard score with a mean of 100 and standard deviation of 15.
  b Expected mean of 4.22 (S.D. = 1.02) according to Leadholm and Miller [45].
  c Expected mean of 0.84 (S.D. = 0.23) accuracy in obligatory context according to Rice et al. [35].
3. Results and discussion

3.1. Intelligence

The mean WPPSI scores for the NICU children are presented in Table 2. As reported by O’Brien et al. [11], these NICU children as a group scored within the lower end of the normal range for cognition. With respect to individual outcomes, 35% of the children scored at least 1 S.D. below the mean for full-scale IQ, and 37% scored at least 1 S.D. below the mean for performance IQ.

3.2. Language

The children’s mean scores on the language measures are shown in Table 2. As a group, these NICU children were significantly below normative expectation for many of the language tests. One exception was the verbal subtest of the WPPSI. Recall that this is one of the omnibus measures of language that has been the main gauge of language ability in many studies. Unlike their performance on many of the other language measures used here, the NICU sample scored within the normal range (M = 93) of the verbal portion of the WPPSI. Even so, 26% of subjects scored at least 1 S.D. below the mean for their age. The average PPVT score was 84, which is one S.D. below the mean for their age, indicating that, on average, the children in this sample show poor performance on lexical/semantic tasks. With respect to individual outcomes on the PPVT, 46% scored at least 1 S.D. below the mean for their age and 22% scored at least 2 S.D. below the mean for their age. Thus, despite the fairly optimistic picture provided by the group averaged verbal IQ score observed both here and in previous studies, a substantial number of the NICU children are showing strong evidence of receptive language delay at age 4.

Evidence from the grammar measures also show the children in this study to be at risk for language delay. According to Leadholm and Miller [45], the expected MLU in morphemes at this age is 4.22 (S.D. = 1.02), indicating considerable variation across children in the normative range. Ten of the children scored at least 1 S.D. below normative expectation for MLU in morphemes. With respect to tense marking, the average proportion correct on the regular past-tense probes was 0.57 (S.D. = 0.25). According to normative data collected by Rice et al. [55], the expected mean for this age group is 0.84 (S.D. = 0.23). Forty-one of the 69 children (59%) scored at least 1 S.D. below the normative accuracy rate for past-tense marking.

Of the 32 children who scored below normative expectation on the PPVT, 22 (69%) also scored below expectation on the tense-marking measure. The remaining 31% were discordant for semantic versus morphosyntactic delays. Thus, while a substantial proportion of the NICU children showed evidence of language delays in both the lexical/semantic and grammar domains, measures of semantic and morphosyntactic development do not provide completely overlapping information. This suggests that separate measures of lexical/semantic and
morphosyntactic abilities should be included in the assessment of at-risk children rather than relying on a single global measure such as the WPPSI.

3.3. Nature of language delay

To address the question of whether the language deficits of biologically at-risk children are related to general cognitive delay versus more specific language impairments, we followed clinical practice to divide the sample into three groups; generally language impaired (LI), language impaired with normal cognition (SLI) and normally developing (ND) children. LI children were defined as those children that had a performance IQ at least 1 S.D. below the mean and either a standard score below 87 on the PPVT or MLU scores which were more than 1 S.D. below normative expectation (cf. Ref. [13], who used −1.0 S.D. and validated that level with clinician judgments). SLI children were defined as those children with performance IQ scores within 1 S.D. of the mean and either standard scores below 87 on the PPVT or MLU scores which were more than 1 S.D. below the mean for their age. Normally developing children were defined as those children who performed within normal limits on performance IQ, PPVT and MLU.

The two categories of language-impaired children (LI and SLI) accounted for 61% of the NICU sample at 4 years of age. Twenty-two children (32%) met the criteria for LI and 20 children (29%) met the criteria for SLI. Despite the difference in their cognitive abilities (performance IQ $M = 77$ vs. 93) the LI and SLI groups showed similar language performance on the PPVT ($M = 73$ vs. 79) and similar MLUs ($M = 3.6$ vs. 3.8). The remaining 27 children (39%) scored within the normal range for both language and cognition.

Performance on the PPVT and MLU measures was used to divide the children

![Box plot showing past tense proportions for LI, SLI, and ND groups](image)

Fig. 1. Children's performance on tense marking as a function of group. The middle line represents the median value, and the upper box edge represents the 25th percentile and the lower box edge the 75th percentile. The outer lines are the range.
into the three groups, and thus group differences in those measures would be expected. However, performance on the tense-marking measure used to assess morphosyntactic abilities was not used to determine subject grouping. Recall that previous studies have shown that children with language disorders are less accurate in their tense marking than agemates [35]. To determine whether the language-impaired groups in this sample would also show reduced accuracy on this measure, a one-way ANOVA was performed on the proportion of correctly marked past-tense verbs by group. The results showed a significant effect for group ($F(2, 66) = 5.88, p < 0.01$). The mean proportion correct for each group is presented in Fig. 1. A Tukey HSD procedure ($p < 0.05$) indicated that LI subjects were less accurate in marking the past tense ($M = 0.42$, S.D. = 0.28), than were ND children ($M = 0.62$, S.D. = 0.22). The performance of the SLI children fell into a middle range ($M = 0.59$, S.D. = 0.24). Of the 22 LI children, 68% scored at least 1 S.D. below normative expectation. Of the 20 SLI children, 60% scored at least 1 S.D. below normative expectation. This is in stark contrast to the 33% of the ND children who scored below $-1$ S.D..

3.4. Perinatal and family demographic variables as predictors of outcomes

Correlational analyses were conducted to assess the relationship between perinatal health status and family demographic variables to children's later language performance. These correlations are presented in Table 3. Similar to the findings of O'Brien et al. [11] in their study of cognitive outcomes for these children, birth weight and estimated gestational age did not predict language outcomes (see also Ref. [32]). The low correlations were not attributable to differences in perinatal status, insofar as all three groups of children (LI, SLI and ND) included a large number of premature and LBW infants and associated conditions, such as respiratory distress, were evident in all three groups. Of course, the lack of correlations does not mean there is no risk associated with the

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Correlations between perinatal and family variables and language performance and language outcome group$^*$</th>
</tr>
</thead>
<tbody>
<tr>
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<td>PIQ</td>
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<tr>
<td><strong>Perinatal status</strong></td>
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<td>Birthweight</td>
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<tr>
<td>Gestational age</td>
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<td>Gender</td>
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<tr>
<td><strong>Family status</strong></td>
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<tr>
<td>Ethnicity</td>
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</tr>
<tr>
<td>Maternal education</td>
<td>0.25$^{*}$</td>
</tr>
<tr>
<td>Welfare services</td>
<td>0.24$^{*}$</td>
</tr>
</tbody>
</table>

$^{*} p < 0.05; ^{**} p < 0.01.$
perinatal health status of children. It means that these particular predictor variables do not explain the observed individual variations in language outcomes at 4 years. Presumably, other unidentified variables are implicated.

Family demographic variables, however, did provide moderate prediction of language outcomes. Ethnicity was moderately predictive of language outcome ($r = 0.32$), accounting for $10\%$ of the variance. In a large scale epidemiology study of kindergartners, Tomblin et al. [14] report a slightly elevated rate of language impairments in African-American children. As Tomblin et al. observe, ethnicity is also highly associated with family income and maternal education, as is the case with the data reported here. In a study of outcomes of LBW and premature children, Brookes-Gunn et al. [28] found that family income and maternal educational levels are more significant influences on IQ outcomes than ethnicity.

Maternal education and welfare status predicted verbal IQ (general language abilities, $r = 0.25$–$0.28$, $p < 0.05$) and PPVT (lexical/semantic abilities, $r = 0.25$–$0.31$, $p < 0.05$). Both maternal education and welfare status predicted the language group to which the child was assigned based on his or her performance ($r = 0.25$–$0.28$, $p < 0.05$). However, neither family demographic variables nor perinatal variables were related to performance on tense marking or MLU. This finding corroborates that of Rice et al. [35] who found no predictive effect of maternal education on children's growth in tense marking. Unlike lexical/semantic measures or general measures which draw heavily on such measures, specific grammatical abilities such as tense marking appear to be unrelated to environmental variables (cf. Ref. [31] for similar conclusions).

To examine whether the relationship between maternal education and PPVT scores held equally across the three outcome groups, a MANOVA procedure was conducted. The analysis showed a significant interaction between maternal education and language group ($F(2, 65) = 24.24$, $p < 0.001$). Pairwise comparisons indicated that the relationships between maternal education and language outcome were similar for the LI and SLI groups, both of which differed from the ND children. This effect can be most readily seen in the zero-order correlation between maternal education and the PPVT raw score for each group (LI group: $r = 0.02$; SLI group $r = 0.02$; and ND group: $r = 0.26$). The difference in the relationship for the three groups is illustrated in the scatterplot of Fig. 2, where the regression line for the ND group shows a greater slope than for the other two groups. These findings show that the level of mother's education and her child's semantic (PPVT) performance at age 4 were positively related for the normal language outcome group only. Children in the two language delayed groups (LI and SLI) showed no benefits from higher maternal education.

Welfare status was also correlated with language outcomes. Analyses conducted on welfare status provided results that also varied as a function of the severity of the language and cognitive impairment. The analyses conducted on PPVT performance showed a significant interaction between welfare status and language group ($F(2, 65) = 22.88$, $p < 0.001$). The zero-order correlations showed a pattern which was similar to that described for maternal education. The relationship is
Fig. 2. Relationship between maternal education and PPVT performance at age 4 for the three language groups. Levels 5–9 indicate education levels below a high school diploma or equivalent. Level 10 indicates achieving a high school diploma or equivalent. Levels 11–16 indicate college education experience ranging from attending some college classes, to achieving an Associates or Bachelors degree.

Weakest for the LI children ($r = -0.05$), with moderate relationships for the ND group ($r = 0.29$) and the SLI group ($r = 0.35$).

The goal of this study was to examine the long-term language outcomes in children admitted to NICUs immediately postpartum in order to gain an understanding of the potential for developmental risk. The results of the study are clear. Infants who experience complications due to conditions such as prematurity, LBW or respiratory complications which require them to be admitted to the NICU are more likely to have language and cognitive scores which are below normative expectation for their age. Approximately 60% of the children performed outside of the normal range in at least one language test, particularly tense marking. Before we conclude that the language impairments were a consequence of early perinatal risk, other factors should be ruled out. One factor is the extent to which the families of these children report a positive family history of either language or learning difficulties.

4. Experiment 2

4.1. Family history of language/learning impairments in NICU children

Over the past decade it has become clear that language impairments and learning impairments tend to aggregate in families. That is to say, a child whose parents or siblings are language impaired will be more likely to be diagnosed with a language impairment and in turn be more likely to have future offspring who develop language problems [12,41,42,47–49]. Aggregation within families has been shown for speech/articulation difficulties [50], both general LI and SLI [42,51] and
SLI with grammatical impairments including tense-marking deficits [41,52]. A heritable basis for some aspects of language has also been found in behavioral genetic studies by Ganger et al. [53]. Ganger's studies of early language acquisition have shown significant differences in the degree to which heritability versus environmentality account for variability in non-impaired children's performance on lexical/semantic tests (e.g. productive vocabulary size) versus early syntax (e.g. early word combinations). From Ganger's work it appears that while early vocabulary size shows strong influences attributable to the child's environment, early syntax is fairly impervious to environmental effects and shows moderate heritability effects. This view would be consistent with the pattern of results seen in experiment 1, where environmental effects, such as maternal education, were strongly related to semantic outcomes, but not morphosyntactic outcomes even in normally developing children who show the highest relationships.

Considering both the literature on familial language and learning impairments and that on the sources of genetic and environmental variation in normal language acquisition one might ask whether the language impairment seen in the 60% of the children in the NICU sample might have a familial origin. Specifically, the question is whether there is a greater likelihood that the children in the two language delayed groups (SLI and LI) were more likely to have first- or second-degree relatives who also report having language and learning problems. In such a case, it is unclear whether their language and cognitive difficulties are related to their early perinatal risk factors or to the genetic and environmental consequences of having family members who are themselves at greater academic risk due to their history of language and/or learning problems. It is important to note that positive evidence of familiality could be attributed to either genetic or environmental influences, or a possible interaction. On the other hand, if no familiality effects are evident, it would point away from familial factors and toward early prenatal risk factors for individual children.

4.2. Method

4.2.1. Participants
The participants in the study were drawn from the families of the original NICU sample. A total of 34 families agreed to participate. The NICU children were divided into two language outcome groups; one which consisted of children who met the criterion for either LI or SLI as described in experiment 1 (here called "LI"), and one normally developing group based on the criteria in experiment 1. Thus there were 18 LI children and 16 ND children or probands in the study. With respect to the total number of family members within each group, in addition to the proband, there were 275 family members in the LI group and 261 family members in the ND group, not including children under 3 years of age.

4.2.2. Measures
The variable included here involved the extent to which other first-degree
relatives or extended family members were also reported to have problems in language, speech, reading or learning. This information was obtained through a family history interview conducted either via telephone or in person for each family in the original NICU sample. In each nuclear family, an informant, usually the mother, was asked to provide the name, birthdate and sex of each relative as well as to indicate whether that individual had a history of speech, language, reading, spelling or learning difficulties (see Ref. [41] for details). Only blood relatives of the proband child were included. Relatives by marriage (stepfamily members) and adopted relatives were excluded from the analysis. If the informant indicated that there was a speech, language, reading, spelling or math problem for a given individual, he or she was asked to describe the nature of the problem (e.g. if speech problems were indicated, were these problems limited to an early lisp vs. a persistent speech problem). We acknowledge that while such family report methods are widespread in the literature, they do have drawbacks [41,42]. In particular, the individual reporting the family members' status may not have complete information on previously or presently existing problems and parents of children with known impairments may be overly sensitive to even normal variations in language development in close family members [41]. It would have been preferable to have familial affectedness based on actual testing, but that was not possible.

Affectedness rates for family members were calculated for LI and ND children for each relative type. This rate is calculated, for example, by dividing the number of LI family members reported to be affected by the total number of LI family members. The probands themselves (LI and ND children) were not included in the calculation. Children under the age of 3 were also excluded since it was felt that these children were too young for parents to report either normal or atypical language development. Chi-square analyses were used to indicate whether the differences in proportion between LI and ND family members were statistically significant.

5. Results

The percentage of family members reported to have a history of speech and/or language impairment, for 97 individuals in the nuclear families (parents and siblings), was 3.5% for the SLI/LI group and 3.5% for the comparison group, a nonsignificant difference by \( \chi^2 \) analysis. When the definition of "affectedness" is broadened to include reading and learning problems, 6.1% of the parents and siblings in the SLI/LI group are reported to be affected and 5.9% of the control group, also a nonsignificant difference. Broadening the family to include extended relatives for a total sample of 534 persons, 2% of the SLI/LI proband's relatives are reported to have a history of speech and/or language impairments and 2% of the controls' relatives; for reading and learning problems, 1.6% of the SLI/LI family members have a positive history and 3.5% of the control family members, a statistically significant difference (Pearson \( \chi^2 = 4.34, p = 0.04 \)) although in the
wrong direction. There were no significant sex differences on any measures. The general conclusion is that there is no evidence in support of a familial pattern of language impairment or reading/learning problems in this sample of NICU babies. Because this sample of language-impaired children was not clinically ascertained, it offers a rare opportunity to estimate the likelihood that parents will detect a language impairment in 4-year-old children. In the family questionnaire, we asked the informant to evaluate the proband’s status as well. In the SLI/LI group, 22% of the probands were identified, compared to 25% of the children in the control group. This can be compared to the epidemiological study of Tomblin et al. [14], in which 27% of children similar to the ones identified in this study were reported by their parents as language impaired. It is obvious that language risk is often undetected. In the NICU sample studied here, only a few of the SLI/LI children were reported by their parents to be receiving special services for the problem.

6. Discussion

The goal of this study was to examine the long-term language outcomes of children at perinatal risk, due to factors causing them to be admitted to the NICU. These children are known to be at risk for cognitive and academic problems later in life. The results of the study and their implications for specific aspects of language abilities are clear. Infants who experience early medical complications are at considerable risk for long-term language consequences. Approximately 60% of these children scored at least 1 S.D. below normative expectation for at least one aspect of language. Almost half of the children studied had PPVT standard scores that were below the normal range for their age. More than half of the children had accuracy scores on regular past-tense marking which were below the normal range. Interestingly, these lower language scores were not associated with a higher rate of reported speech, language or learning impairments in relatives.

Are these children simply “late talkers” who will catch up with peers if given an enriched language environment? The morphosyntactic findings suggest otherwise. On tests of grammatical development, such as MLU and tense marking, these children scored poorly, even given the broad range of values tolerated as “normal” within the tests used here. Low MLUs and low percentages of tense marking have been shown to be characteristic of preschool and school-aged children with persistent language impairments [34,35,34]. Furthermore, longitudinal follow-up study of kindergarten children with language impairment (with and without cognitive delays) shows that 73% of them are likely to be language impaired relative to age peers at 19 years of age [13]. Thus there is strong reason to be concerned about the developmental prognosis for 4-year-old children with language impairments.

This study also added to previous findings suggesting that environmental influences as indexed by mother’s education are more associated with vocabulary
development than with grammatical indices such as tense-marking and length of utterance. We regard mother's education as an indirect indicator of variations in maternal behaviors that may influence vocabulary growth. This variable is known to be associated with the amount of talking to children \[29,55,56\], which in turn is predictive of children's vocabulary development (cf. Ref. [57]). Thus it is not surprising that maternal education is associated with performance on the PPVT-R and verbal IQ (as well as performance IQ). The new findings here show that the environmental-semantic relationship was strongest in those children developing normally. In contrast, children who had low language scores with normal cognitive performance were able to benefit by higher income levels, but not by higher levels of maternal education. Most importantly, those children who needed these benefits the most, specifically those with both language and cognitive impairments, showed no benefits of family environment. This suggests an interaction of aptitude and input, whereby the increased frequency and diversity of lexical input associated with higher levels of mother education are not sufficient for youngsters with limited language aptitude.

Maternal education, in contrast, was not associated with MLU or performance on the tense probes. With regard to tense-marking, a possible explanation is that the higher verbal output and richer vocabularies of more educated mothers do not influence children's knowledge of the obligatory properties of tense-marking. This is not to say that children are insensitive to distributional properties of English. For example, past tense is more likely to appear with achievement verbs (such as "come" and "turn") and progressing -ing is more likely to appear with activity verbs (such as "sleep" and "cry"). A distribution evident in their mothers' speech (cf. Ref. [58]). In such lexical distributions, children's language, as could be expected, seems to parallel the distribution of mothers' input. The interesting thing about tense-marking is that it consistently appears in obligatory contexts in maternal input and yet is omitted by children. The findings suggest that variations in the input that facilitate learning new words do not act in the same way for obligatory tense-marking. This may be because the necessary frequency of tense-marking contexts (with positive evidence of correct use) is available across a wide range of maternal education levels. For children with ordinary levels of language aptitude, this frequency level may be sufficient, so an effect of mothers' education is not evident. In contrast, children with limited language aptitude may not benefit from the higher input levels associated with an increase in mothers' education, thereby further weakening any possible effects of maternal education.

The large number of children who evidenced language problems in this sample was considerably higher than the expected 7% incidence rate of SLI \[13,14\]. Although further investigation is needed for the specific grammatical measures explored here, we believe that the higher proportion of children with language problems in our sample supports the working conclusion that children at perinatal risk due to diverse medical diagnoses are at greater risk for long-term language consequences and need to be followed for possible intervention requirements as they go into school.

Only one previous study has provided similar measures of morphosyntax,
namely the Menyuk et al. study [32]. In contrast to Menyuk et al. who reported no group differences in morphosyntax as a function of early perinatal risk, the present study found that children at early risk were considerably lower in their accuracy of marking regular past tense than expected. The differences in the results for the two studies could be due to differences in population (premature vs. the general NICU population). To test this possibility we repeated the analysis of past-tense accuracy for only those children who were born prematurely. The results were quite similar to those for the sample as a whole. The mean proportion correct for premature infants was 0.56 (S.D. = 0.26) while for the sample as a whole, the mean accuracy was 0.57 (S.D. = 0.25). Thus, it is unlikely that population differences caused the differences between the two studies. Instead it is likely that the different results are due to differences in subjects and/or the method used to analyze past-tense marking. Our children were 1 year older at test than those of the Menyuk et al. sample. The accurate use of morphosyntax increases rapidly with age during the preschool period [35] and the additional year may have made the measure of past-tense marking more sensitive as a test of language delay. There were also important differences in the way that the acquisition of morphology was analyzed. Menyuk et al. analyzed accuracy based on spontaneous language samples. As previously stated, occurrences of regular past tense are infrequent in children's spontaneous language, particularly for children with language impairments. For this reason, we have used a probe measure that could be applied equally across all children. It is possible that the probe had greater measurement sensitivity and therefore identified morphosyntactic difficulties in a greater number of children.

The results of the study as a whole indicate that as a group NICU children are at risk for language delays. There are strong implications for intervention and treatment policies. While it is not practical to screen all children with a NICU history, clinicians and teachers should particularly monitor the language of those children at perinatal risk in cases where environmental factors, such as lower levels of maternal education and lower income levels, place the child at even greater risk for long-term problems in vocabulary production and comprehension. A further and crucially important consideration is that the assessment of young children's language development should go beyond measures that weigh heavily on semantic knowledge. Children in the language-impaired groups showed delays in MLU and the acquisition of regular past tense, both of which are known to predict persistent language problems across the preschool and school age. Furthermore, deficits in morphosyntactic development were not predicted by environmental risk factors. The import of these observations is that etiological contributions to risk for language impairments may arise from different sources, and these unique sources exert unequal effects on differential parts of the emerging linguistic system. Constitutional factors in infants' emerging neurocognitive systems are strong sources of risk for all aspects of language acquisition. Not surprisingly, environmental risk factors can further multiply constitutional risk, just as environmental benefits may ameliorate some of the language consequences caused by constitutional risk (e.g. vocabulary growth, PPVT performance) but not
others (e.g. grammar development). Thus, it is essential that grammatical
measures as well as semantically-weighted measures be examined, and that
important aspects of the environment be included in studies of the language
development of biologically at-risk children.

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