PERCEPTION OF DURATION IN INFANTS WITH HIGH GENETIC RISK FOR DYSLEXIA

Ulla Richardson, Matti Leiwo, Paavo H.T. Leppänen, and Heikki Lyytinen
University of Jyväskylä, Finland

ABSTRACT

Developmental dyslexia (specific reading and spelling difficulty) can affect people's lives profoundly. The causes of the disorder are unknown. What is known is that there is strong tendency of dyslexia to be family aggregated. As yet very little is known of the early signs of the disorder. In this study the speech perception of infants of dyslexic parents as young as 6 months of age was found to differ significantly from that of infants with normal reading parents; infants born of dyslexic parents perceived the duration of an occluson of [t] in a markedly different way from infants born of normally reading parents. Similar percpetual tendencies were also found in the parents of the infants. The study suggests that a temporal processing deficiency in categorizing speech sounds may be an early sign of risk for dyslexia in infants.

1. INTRODUCTION

Developmental dyslexia, a serious difficulty in acquiring fluent reading skill, affects a substantial portion of individuals throughout their life span [1]. Dyslexia has often been associated with poor phonological skills. These skills are unusually resistant to ordinary training and they are apparently more so the later training support begins. The possibility of predicting and even preventing dyslexia by means of earlier help has lead researchers to look for early signs of dyslexia before children normally start to learn to read and write. The earliest signs of dyslexia found prior to the current study showed delayed development of syntactic and morphological skills among 2; 5 year-old children born of dyslexic parents [2]. In the present study, we investigated even younger infants. By doing this, we hoped to find early signs of reading and spelling difficulties before children start to speak.

This study is part of a large interdisciplinary research project that is investigating infants of dyslexic parents in comparison to infants whose parents have no difficulties with written language[1]. Numerous studies have shown that a genetic factor is behind the highly significant degree of family aggregation among dyslexics. For example, studies on twins have provided compelling evidence on the genetic factor behind dyslexia. It is estimated that there is at least a 55% risk of genetic transmission of dyslexia in families with a dyslexic parent [3, 4].

The question of interest is: which signs, if any, differentiate individuals who have inherited this deficit from those who have not? Research has shown that phonological processing skills may be deviant in dyslexics [5]. In addition, there is substantial evidence that the auditory processing skills of dyslexics differ from those of normal reading children and adults [6]. Thus, we investigated preverbal infant's perception of speech sounds.

The temporal aspect of speech was chosen as the focus of the present study. Controversial evidence on dyslexics' ability to process temporal information has been provided in the past. Some of this evidence indicates that school aged children with language disorders, including dyslexics, have an auditory temporal deficit in perceiving speech sounds as well as nonspeech sounds. Much of this evidence has been gained from a temporal order judgement task in which dyslexics performed significantly worse than nondyslexics when the rate of stimulus presentation was fast [7]. A study on adult dyslexics indicated that it is necessary for them to perceive longer silence duration than fluent readers in order to transfer their perception from one speech category to another (/sa/ to /sta/) [8]. These results, together with those of other similar studies [9], seem compelling, although there does exist some contradictory evidence [10].

In this investigation, infants are studied within the Finnish language environment, which offers a good opportunity to study temporality in its most straightforward manner, i.e., in terms of changes in duration. In the Finnish language it is sound duration alone which determines the quantity of a phoneme: there are two distinctive quantities and the use of the long instead of short quantity (i.e., short or long duration) can change the meaning of a word (e.g., *mato* [mato] 'a worm' and *matto* [mat:o] 'a carpet'). Ample variation in duration is possible in spoken Finnish but quantity categories or degrees, into which all the different physical durations are linguistically placed, are limited to two.

In terms of written language, the quantity of speech sounds is also visibly marked in Finnish spelling. Thus, the sound segment that is perceived as short when spoken is written with one letter, and that which is perceived as long is written with two identical letters. With regard to dyslexia, there is evidence that it is precisely in connection with this quantity aspect of language that dyslexics make most of their errors [11].

2. EXPERIMENT 1

2.1. Method

We examined the quantity aspect in a perception experiment for infants. Previous studies have shown that young infants are able to categorize perceptually distinct speech sounds in a manner similar to adults [12]. However, as yet there have been no studies on the categorization skills of infants focusing specifically on the question of duration in the quantity distinction. The crucial question here is if there is a difference between infants who are genetically at risk of suffering from dyslexia compared to control infants in the quantity categorization of stimuli with varying durational cues. If there is not, this would indicate that the categorization of duration is not an underlying feature of dyslexia or a sign of risk for the

disorder. If at-risk infants are different, perception of the temporal features of speech might be an early precursor, or one of the early precursors to the development of reading related disorders. Specifically, it is hypothesized that if there is a difference in the temporal processing skills of at-risk infants, the difference would be shown in the need for stimuli of a longer duration in order to shift their perception and quantity category from short to long.

2.2.1. Subjects. A total of 176 infants ranging in age from 5.5 to 7.1 months participated in the infant perception experiment. Eighty-eight of the infants (46 at-risk infant and 42 control infants) failed to show any reliable evidence of acquiring the head-turn response and were excluded from the study. Altogether 88 six-month old infants (mean age was 6 months 5 days) completed the test. The attrition rate of 50% in this experiment is similar to those of previous experiments using complex stimuli with young infants. All infants were healthy and full-term with normal hearing. Forty-three of the subjects belonged to the genetic risk for dyslexia group (at-risk infants) and 45 belonged to the control group (born of normally reading parents). Criteria for inclusion in the at-risk sample included at least one parent with identified dyslexia and reported reading problems in at least one other first or second degree relative. The parental assessment included a spelling test, two tests of reading aloud, a computer assisted FON-ORTHO system and the Raven Progressive Matrices Test (>85) [11,13].

2.2.2. Stimuli. For the experiment, a minimally differing set of eight stimuli was constructed from the pseudoword *ata* (Fig. 1). In the continuum, only duration was varied in stepwise fashion; all other acoustical aspects, such as fundamental frequency and intensity, were held constant. The eight stimuli were constructed by adding 20 millisecond increments of silence to the middle of the t-sound (in naturally produced speech sounds this occlusion part of the sound is made up of silence). The listener will perceive a shift at some point in the stimulus continuum from *ata* to *atta*.

	ATA-Category				ATTA-Category			
stimuli	Ata1	Ata2	Ata3	Ata4	Ata5	Ata6	Ata7	Ata8
occ. msec	95	115	135	155	175	195	215	255

Figugre 1.The stimuli continuum employed in the perception test. Duration of the silent closure stage of the word medial dental stop (the t sound) was augmented in stepwise fashion with increments of 20 msec. The original stimulus was taken from the speech of a female producing the pseudoword *ata*. Altogether 8 stimuli were constructed from the stimulus *ata1* ranging in total duration from 300 to 460 msec, and the impression of the perceived stimulus shifted from *ata* to *atta*.

2.2.3. Procedure. The categorization abilities of the infant subjects were assessed using the conditioned head-turn procedure. This widely used procedure relies on infants' instinct to turn their heads towards an interesting stimulus. In the procedure used here, infants were conditioned to turn their heads towards a visual reinforcer whenever they perceived a change within the auditory sequence. Correct head turns were visually reinforced using an animated toy. The original word *ata* (stimulus *ata1*) was used as a background stimulus that was continuously repeated, and the other stimuli with longer t-sounds were the target stimuli in the change trials. Throughout the experiment, the speech stimuli were presented with a constant offset-to-onset interstimulus interval of 1000 msec. An assistant seated on the right of the infant manipulated silent toys, and the loudspeaker and the visual reinforcement were located to the left of the infant. Stringent measures were employed in order to ensure that neither the assistant nor the parent on whose lap the infant was seated could influence the way in which infants behaved during the testing.

The experimental paradigm comprised three distinct phases: the conditioning, the criterion testing, and the categorization phases. In the conditioning phase infants learned to anticipate the appearance of the visual reinforcer and turned their heads toward it when they heard the *ata8* stimulus that had the longest sound duration. In the initial conditioning phase, the criterion for proceeding was three consecutive trials with correct head turns during the presentation of the target stimuli. The proceeding criterion in the criterion testing phase was 6 out of 8 correct responses (hits and correct rejections).

While only change trials were employed in the conditioning phase, the criterion testing phase comprised an equal number of change and control trials. In the control trials, only the background stimulus was presented to ascertain whether the infants turned their heads regardless of the stimuli. In the categorization phase, all the stimuli from the continuum were presented. In the categorization phase, all eight stimuli from the continuum occurred as targets in four trials. Only headturn responses in the trials with stimuli *ata5* to *ata8* were reinforced. This phase consisted of 32 trials (each stimulus was presented in four different trials in random order). The categorizing of the stimuli was indicated by the degree to which infants responded to each stimulus.

2.2. RESULTS

Percentages of *atta* categorizations (head turns) are graphically illustrated in Fig. 2.

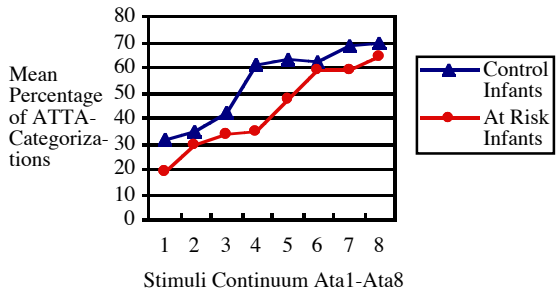

Figure 2. The mean percentage of atta-categorizations in the high genetic risk for dyslexia infants (at-risk) and those with no such risk (control). There is a highly significant difference in the responses between the two subject groups to the stimulus *ata4* (x^2 = 23,32, P = .0000) with the control infants categorizing the stimulus more often as *atta*.

These results show that both groups of infants' responses show similar categorical tendencies. However, the results of the at-risk and control groups differ remarkably. Specifically, responses in perceiving the stimulus located at or near the category boundary, *ata4*, differed most significantly between the two infant groups. The control infants categorized stimulus *ata4* more often as *atta* (they turned their heads in 61% of the trials) than did the at-risk infants (35%; $x^2 = 23.32$, P = .000).

However, since there was also a significant difference ($x^2 = 7.58$, P = .006) between the groups in responding to *ata1* (with the shortest duration) it is possible that the control infants were more inclined to turn their heads regardless of the stimulus. The responses to *ata1* and *ata4* were compared with a Stimulus (*ata1* or *ata4*) by Group (at-risk or control) one-way analysis of variance test (ANOVA) for repeated measures in order to take into account possible response biases. The ANOVA test confirmed that there was indeed a difference in the responses of the two subject groups in categorizing the two speech stimuli [F (1,86) = 2,84 P = 0.048; $\eta^2 = 0.25$].

3. EXPERIMENT 2

3.1. Method

The same perception test was also adapted for the parents. The adult perception experiment was exactly the same as that of the infants with the exception that the adults were orally instructed to press the response button as soon as they perceived that the repeated background stimulus *ata* had changed to the *atta* stimulus.

3.1.1.Subjects. Altogether 132 adults served as subjects. All of these adults were parents of the infants in the dyslexia projects. Fifty-five of the adults were diagnosed as dyslexic individuals and 77 of them were diagnosed as having no problems in reading or writing. The families were screened and recruited according to institutional informed consent procedures and participated in the Jyväskylä Longitudinal Study of Dyslexia (JLD). The inclusion criteria to the at-risk group were at least one parent's report of his/her own reading disorder, a comparable report concerning at least one his/her close relative and multiple diagnostic test results indicative of dyslexia.

3.2. Results

The categorization functions (Fig.3) indicate that the dyslexic adults differed from the control adults in their responses, as was the case with the infants.

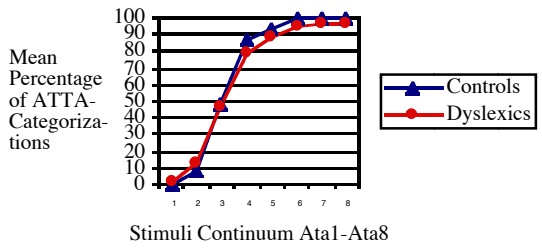

Figure 3. Categorization function for the dyslexic adults and the control adults in the perception experiment. The functions of the two groups are similar in form but there is a statistically significant difference in the responses for the stimulus *ata*4 ($x^2 = 7.699$, P = .005) in which the dyslexic adults gave *atta*-responses significantly less often in comparison to the control adults. Interestingly, this is exactly the same stimulus with which the largest difference was observed between the two infant groups.

Statistical tests confirmed the significance of the difference between the two subject groups in categorizing the stimuli (in *ata4*, a chi-square test $x^2 = 7.669$, and a Stimulus (*ata1* to *ata8*) by Group one-way ANOVA for repeated measures [F (7,910) = 1,884 P = 0.039; $\eta^2 = 0.096$], and a Stimulus (*ata1* and *ata4*) by Group (dyslexia and control) one-way ANOVA test for repeated measures [F (1,130) = 5,14 P = 0.013; $\eta^2 = 0.038$]).

3.3. Comparison of Infant and Adult Data

The infant data were analysed also using the control adults' data as a model in a planned contrast test. The hypothesis was that the at-risk infants needed longer duration (at least 20 msec) in order to categorize the stimuli as *atta* rather than *ata*. The ANOVA test for the planned contrast model based on the adult categorization data and using *ata1* as a covariate confirmed that there was a difference between the at-risk and the control infants in categorizing the stimuli of differing duration ([F (1,85) = 4.92 P = 0.018; $\eta^2 = 0.055$]). Also a Stimulus (*ata1* to *ata8*) by Group one-way ANOVA test for repeated measures [F (7,602) = 1,988 P = 0.033; $\eta^2 = 0.148$] revealed a difference between the two infant groups. This difference between the at-risk and control infants is even more remarkable than the figures suggest, since it can be estimated that perhaps only 55% percent of the at-risk infants will actually have problems in reading and spelling when they grow up.

4. CONCLUSION

Thus, our study shows that although infants with high genetic risk for dyslexia were able to categorize the stimuli according to duration they needed considerably longer duration in order to categorize stimuli as belonging to the long quantity category. Since the dyslexic parents showed similar tendencies to the at-risk infants in categorization, these results give evidence that dyslexia may involve a heritable deficiency in processing temporal information.

From the standpoint of dyslexia research, the results of this experiment have profound implications. The above findings suggest that infants who may well be dyslexics might not process short temporal information in the same way as nondyslexics. This is a significant aspect of the processing of spoken language since speech is very much interwoven with time. Moreover, when spoken language is further encoded in written language the difference in the categorization abilities of dyslexics may become increasingly important.

This study suggests that an early precursor of dyslexia or a sign of dyslexia may be present early in life in the form of a temporal processing deficiency in categorizing speech sounds. If assessment, and possible diagnosis, of those liable to suffer from the disorder can be carried out at an early age, there are possibilities for effective early intervention [14]. The upshot of this is that some time soon it might be possible to develop procedures of intervention that will result in less people having the misfortune to experience failures in reading and spelling.

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NOTES

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