The Timing Deficit Hypothesis of Dyslexia and Its Implications for Hebrew Reading

Matti Kaminsky, Zohar Eviatar and Joel Norman

University of Haifa, Israel

Vast amounts of neuropsychological evidence have been collected in recent years in support of the hypothesis that developmental dyslexia is caused not only by phonological deficits, but also by timing deficits that affect all senses (e.g., Tallal, Miller, & Fitch, 1995; Stein & Walsh, 1997). In parallel, recent developments in the study of Hebrew reading place heavy emphasis on root awareness in the mental lexicon and early root extraction in the process of word identification (e.g., Frost, Forster, & Deutch, 1997). The present study creates a link between the timing hypothesis and the special demands of Hebrew reading. The performance of dyslexics and normally reading children is compared on tasks requiring visual extraction of trigrams, that approximate extracting roots out of Hebrew words. Partial findings show that dyslexics take longer and make more errors while performing trigram extractions on all levels examined, and that sequentiality in the task affects dyslexics and skilled readers in different ways.

Introduction

In Hebrew, all verbs and most nouns are comprised of consonantal roots which are embedded in pre-existing morphological word patterns (constructed of affixes and vowels) to form the words of the lexicon. The root carries the core meaning of the words that are formed from it, while the form pattern indicates word class, tense, gender and quantity. It has been hypothesized that reading Hebrew requires morphological awareness, and that roots are lexical entities that enable lexical access to words (Frost and Bentin, 1992). Lexical access requires parallel detection of the three root letters (which have no significant features) and sequential processing to keep the unique letter order, which is crucial for the definitive identification of the root (Eviatar, 1999). Both processes happen rapidly and prior

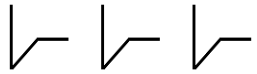
to lexical access. Given that timing deficits in dyslexics are posited to result from weakness in the magnocellular component of the visual and auditory system, deficient root extraction may be the core deficit in Hebrew dyslexia. It has been shown that dyslexic readers have less morphological awareness than skilled readers (Ben-Dror, Bentin, & Frost, 1995), but root awareness has never been examined in Hebrew-reading dyslexics.

The experiments described here explored the root extraction abilities by requiring dyslexics and skilled readers to extract trigrams out of arrays of 6 items, while manipulating the type and nature of these arrays. The experiments are subdivided into three array-structures: The Basic level used nonlinguistic stimuli, where sequential order of single items was not necessary for the task. In the Nonlinguistic-Sequential level, sequential order of nonlinguistic stimuli items was crucial for the task, approximating the extraction of three root letters in Hebrew words. In the Linguistic level, the stimuli were composed of letters. Half of the trigrams were not real roots, and they were embedded in pseudowords. In half, the roots were real, and were embedded in real words.

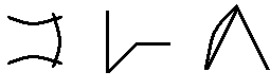
Method

Design: All the experiments involved a trigram identification paradigm. The trigrams were composed of either letter-like forms (Gibson, Gibson, Pick & Osser, 1962) or Hebrew letters. They were presented above a longer series of forms, in which the target trigram was embedded.

The Basic level: The trigrams were composed of identical elements embedded in an array of other elements. The subjects had to determine the presence of the trigram in the longer series. In half the trials, a distractor replaced one of the target elements, requiring a 'no' response. There were 72 trials divided into two blocks of 36 trials.

Example: 

The Nonlinguistic-Sequential level: Here order judgment was added to the tasks. The trigrams were comprised of three different letter-like forms. There were two types of trials requiring a 'no' response: Where an element was replaced by a distractor, and where all three elements of the trigram appeared, but in the wrong order. There were 144 trials, divided into 4 blocks of 36 trials.

Example: 

The Linguistic level : This task had the same design as the other tasks, except that the stimuli were trigrams of Hebrew letters. In the first block of 64 trials, the trigram-letters did not constitute a real Hebrew root, thus the series created a pseudoword. In the second block of 64 trials the stimuli were real roots creating real Hebrew words.

Example: 

/š v r/

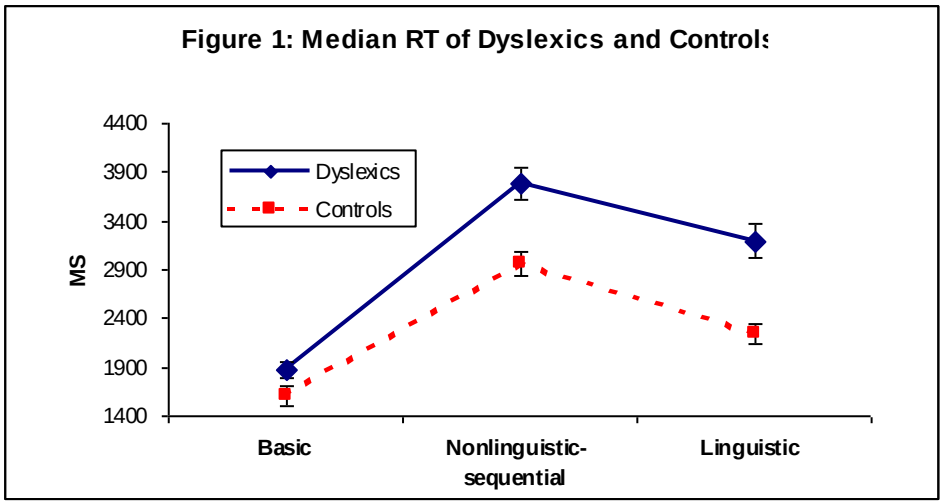
sh a v a r n u

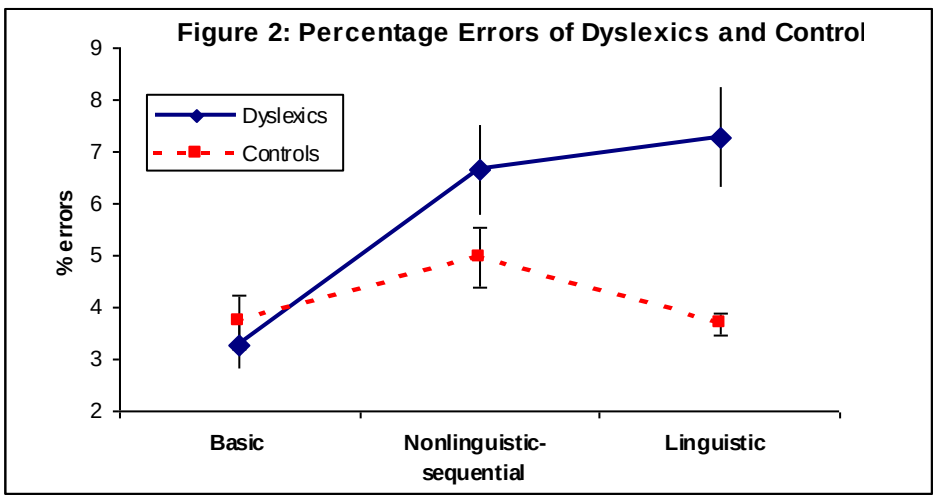
Participants: Twenty-eight dyslexic children from learning-disabilities centers in Israel and twenty-two controls with skilled reading abilities, all from the fifth and sixth grades, were tested. They were pretested to establish their reading level and profile of deficits. All

performed the experiments via a laptop computer. Median reaction-time (RT) and percentage errors (PE) served as the dependent variables.

Results

The data were analyzed in two separate 2-way mixed ANOVAS with 'Group' (dyslexic vs. controls) as a between-groups factor, and 'Level' (basic vs. nonlinguistic-sequential vs. linguistic) as a within-subject factor. Both dependent variables, RT and PE, revealed a significant interaction between Group and Level (RT: $F(2, 96)=9.39$; $p<0.002$; PE: $F(2, 96)=5.55$; $p<0.0053$). Both factors, Group and Level, showed significant main effects in both measures: Group: RT: $F(1, 48)=16.73$; $p<0.0002$; PE: $F(1, 48)=3.97$; $p=0.052$. Level: RT: $F(2, 48)=210.34$; $p<0.0001$; PE: $F(2, 48)=10.03$; $p<0.0001$ These effects are presented in Figures 1 and 2.





As can be seen in the Figures, tests of the simple interactions revealed that in both time and errors, the simple interaction between Group and Level (Basic vs. Nonlinguistic-Sequential) was significant, (RT:$F(1,48)=11.83$, $p<.005$; PE: $F(1,48)=4.10$, $p<.05$), whereas the simple interaction between Group and Level (Nonlinguistic-Sequential vs. Linguistic) was not significant (RT: $p>.4$; PE: $p>.11$).

Discussion

The results suggest that dyslexics have difficulties in efficiently extracting a visual trigram, that is, establishing its presence in the "word", and in keeping the original order of the components. The dyslexics were able to cope relatively well with the demand for extracting a trigram comprised of an identical repeated element at the Basic level. However, as soon as we introduced the demand for sequential order, the gap between dyslexics and controls widened. This finding agrees with the timing deficit theory hypothesis in more than one way: In addition to their difficulties with sequential order, in both nonlinguistic and linguistic tasks, the dyslexics were also significantly slower than the skilled readers at all of the levels, indicating a timing deficit.

Both the dyslexic and the control groups were faster in the Linguistic level than in the Nonlinguistic-Sequential level. We believe that both groups used morphological knowledge in the Linguistic level that was not available at the Nonlinguistic-Sequential level. That is, it seems that the dyslexics' root awareness has developed to a certain degree, due to 5-6 years of reading efforts. However, this morphological awareness in not as well developed as that of skilled Hebrew readers. The skilled readers are both faster and more accurate in the Linguistic level than in the Nonlinguistic-Sequential level. The dyslexics are faster in the Linguistic level than in the Nonlinguistic-Sequential level, but make the same amount of errors in the two levels. This suggests that in addition to the sequential deficit,

there may be a specific linguistic-morphological deficit that affects Hebrew reading dyslexics.

References

Ben-Dror, I; Bentin s.; Frost R. (1995). Semantic, phonological and morphological skills in reading disabled and normal children: Evidence from perception and production of spoken Hebrew. *Reading Research Quarterly*. *30(4*), 876-893.

Eviatar, Z. (1999). Cross-language tests of hemispheric strategies in reading nonwords. *Neuropsychology*, *13 (4),* 498-515.

Frost, R.& Bentin S., (1992a) "Reading consonants and guessing vowels: Visual word recognition in Hebrew orthography." In: Ram Frost & Leonard Katz. (eds.) Orthography, Phonology, Morphology and Meaning. Amsterdam: North Holland, 27-42.

Frost, R; Forster K.I. & Deutsch A. (1997). What can we learn from the morphology of Hebrew? A masked-priming investigation of morphological representation. *Journal of Experimental Psychology: Learning, Memory and Cognition. 23(4),* 1-28.

Gibson. E.J., Gibson, J.J., Pick, A.D. & Osser. H.A. (1962). Developmental study of the discrimination of letter-like forms. *Journal of Comparative and Physiological Psychology, 55,* 897-606.

Stein, J.F. & Walsh, V. (1997). To see but not to read: The magnocellular theory of dyslexia. *Trends in Neuroscience, 20(4),* 147-152.

Tallal, P.; Miller, S. & Fitch, R.H. (1995). Neurobiological basis of speech: A case for the preeminence of temporal processing. *The Irish Journal of Psychology, 16,* 194-219.

This study was supported by an internal grant from the Research Authority of the University of Haifa and by a grant from Gordon Teachers College