

DEVELOPMENTAL NEGLECT DYSLEXIA IN A HEBREW-READING CHILD

Naama Friedmann and Ivana Nachman-Katz

(Tel Aviv University, Israel)¹

ABSTRACT

This paper describes for the first time a detailed study of a child with neglect dyslexia. NT is 10-year-old child, with left word-based neglect dyslexia, without clinical signs of visuo-spatial neglect. Since he is a native speaker of Hebrew, which is read from right to left, his neglect dyslexia manifests in omissions and substitutions of final letters. He is severely impaired in single words, with 96% of his errors being omissions and substitutions of final letters. When presented with more than one word, in word pairs, sentences or text, he neglects the left part of each word, but never omits whole words on the left side of the page. His reading improves considerably when the same word is presented vertically or when manipulations are done to shift his attention to the left – with colored final letter, flashing light, or tapping his finger to the left of each word. NT's neglect dyslexia is very selective, with good reading of numbers and symbols, and even good performance on letter sequences when no reading is required. A dissociation is also detected between his impaired reading due to neglect dyslexia and his normal performance on conventional clinical tests of general visual neglect visual of line, object and letter cancellation, line bisection, object drawing and copying. His neglect dyslexia seems to be developmental as no abrupt onset is reported.

INTRODUCTION

This year we celebrate twenty-five years of research on representational neglect. Visuo-spatial neglect and neglect dyslexia (or “neglexia”) have been thoroughly studied and reported over the last century. However, cases of neglect in children have been sparsely reported, and as far as we know no case of pure neglect dyslexia in a child has been explored until now. Several detailed case studies of children with developmental or early acquired unilateral visual neglect have been reported (Ferro et al., 1984; Ferro and Martins, 1990; Manly et al., 1997; Moss and Turnbull, 1996; Thompson et al., 1991; see also Johnston and Shapiro, 1986 for right visual neglect, and Grossi et al., 2001 for neglect in walking). Some of the reported children with neglect also showed neglect in

¹ We thank Aviah Gvion, Michal Biran and Ricardo Nachman for interesting discussions, and for their help during this study, Vered Eliezri for some halves of the chimeras, and Claudio Luzzatti for his comments on earlier version of this paper and for inadvertently coining the beautiful term “neglexia” during a high-spirited dinner.

reading or writing. Manly et al. (1997) presented a child with developmental visual neglect who also suffered some reading delay due to his neglect, but they report “inconclusive results” with respect to his reading ability and that his reading age caught up with his chronological age within a few months. Similarly, Johnston and Shapiro (1986) report a 14 years old case with right visual hemi-inattention following traumatic brain injury and only note that “Inconsistent performance was exhibited on reading isolated words.”, and that “he performed at or above grade levels on tasks measuring reading comprehension”. One of the children with acquired neglect reported by Ferro et al. (1984) omitted half of her sentences and her words in writing, and tended to use only the right part of the paper; two cases in Weintraub and Mesulam (1983) manifested preference to write on the right side of the sheet. None of the papers, however, has described specific patterns of neglect dyslexia in a child.

In this paper we present a case study of a 10 year-old child, NT, who suffers from neglect only in reading words but who does not show clinical symptoms of visual neglect. In addition, this will be the first report of neglect dyslexia in Hebrew, which is read from right to left and has unique orthographic characteristics. We will report the characteristics of NT’s reading of Hebrew words as well as his general spatial and attentional performance.

CASE REPORT

NT is a right-handed child who is a native speaker of Hebrew. He was not identified with neglect dyslexia or any type of dyslexia until he was referred to us, at the age of 9;0 with “language problems”. Possibly due to the lack of awareness to neglect in its developmental form, he was described as having general inability to stay concentrated in class, but with no report of his specific deficit. The investigations described here occurred between the ages of 9;0 and 10;0 years. No significant improvement was witnessed in his reading during the time of assessment until the beginning of the treatment phase.

The history described by his parents and teacher indicates no sudden onset of neglect, no concussion, head injury, or severe illnesses as a child, and no known complications at birth. An MRI scan at the time of testing indicated no focal lesion and no brain abnormality (MRI scans are given in Figure 1 in the Appendix). Parental reports on early development include normal motor development and somewhat delayed language development - single words at the age of 1;6-2;0 years, and sentences at age 3;0. From age 5;6 he received language therapy for mild naming difficulties and poor speech intelligibility which has resolved by the time of testing.

By the time of testing, NT is a friendly and smart child with high social skills. He studies in a small class for children with what is termed “learning disabilities” and receives a weekly session of speech therapy. He has a deficit in naming colors, mild deficit in word retrieval, and in left-right orientation. He can recognize numbers but his mathematical abilities are somewhat low for his age (in third grade he was assessed as having an end-

of-second grade level). To test whether this was part of a Gerstmann syndrome we assessed his ability to identify fingers. It seems that he does not have finger agnosia, as he was able to discriminate among individual fingers, to show the correct finger after the experimenter showed her own finger, and to name and identify the names of three of the fingers (not many Hebrew-speaking children in his age know the names of the third and the fourth fingers). The Development Test of Visual Perception (DVPT-2, Hammill, et al., 1998) administered at age 10;0 indicated perceptual age of 10;7 on subtests of Figure-Ground, Visual Closure and Form Constancy, and a lower-than-normal performance on the Position in Space subtest (percentile 16, perceptual age 7;9). A computerized assessment of attentional abilities administered and analyzed by Lilach Shalev yielded a normal orienting of attention following endogenous cueing (central arrows) both to the right and to the left visual fields in a cost-benefit paradigm (Posner, 1980; Posner, Snyder, & Davidson, 1980). His phonological awareness is limited to syllable and rime and does not reach the phoneme level (not surprising given his severe reading deficit), he finds it hard to concentrate in class (with a general diagnosis of ADHD), and is frustrated by his difficulties in school, mainly in reading and writing. Despite his severe deficit in words, he does not show a similar deficit in objects and numbers, copying and describing them well.

BIT

NT was tested with the conventional tests of the Behavioural Inattention Test (BIT, Wilson *et al.*, 1987), and showed no clinical sign of general spatial neglect. His performance on the BIT was normal, with a final score of 143/146, where the overall cut-off for normal performance is 130/146 (Halligan *et al.*, 1991). He showed good performance on all subtests: line crossing (36/36), letter cancellation (40/40), and star cancellation (53/54). On these tests, he systematically cancelled and circled all stimuli on the left of the page, except for one star. Line bisection was 9/9, with an average rightward error of 0.6 cm to the right,¹ figure and shape copying 3/4, representational drawing 2/3 (omission of one digit from the clock). Of special interest is his good performance in letter cancellation which indicates that when letters appear in arrays rather than within words or word-like sequences he does not neglect the left letters (see Figure 2).

¹ Hebrew readers without impairments were found to bisect lines to the right of the middle, unlike readers of left-to-right languages who bisect slightly left of the middle (Chokron and Imbert, 1993). Chokron et al. (1995) tested Hebrew readers at different ages and found that eight year old boys tended to have a rightward deviation of subjective middle of 0.77 cm on the average, which means that NT's performance on line bisection was normal.

Figure 2. Letter cancellation from the BIT. The target letters were ה and צ.

בענשצנכטהאזהעצףסגקצחדבהסענשצנכטהא
 רצוקףשהחדבהסמהצלסרצואהחוצרקףשהחדב
 הערותצקסנססנהוצלטוניטקרעחדבהערותצקסנ
 קבטצרערעלונצדיפעלדהבזצמזהקבטצרערעלון
 טהוצובהמחצבגחהקסזוצהלתקצנטהדצובהמח

צ ה

Copying and drawing from memory

We asked NT to copy 9 line drawings of objects, three horizontal triplets (in addition to the three objects in the BIT). He copied them without any significant disadvantage for the left object or for the left side of each object. See Figures 3a and 3b for examples of his copying.

Figure 3a. Picture copying – the original flower on the left, the copy on the right.

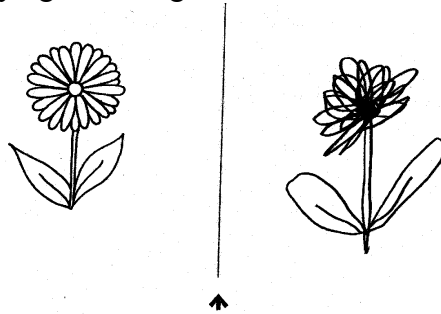


Figure 3b. Picture copying – the original fence, house and tree on top, the copy below.



We also asked NT to draw objects from memory, and there, too, no neglect was evident. An example of his drawing from memory of a clock and a flower are given in Figure 4a and his drawing of a person, a butterfly and a clock are given in Figure 4b. Note that the clock on Figure 4b misses the “11”, perhaps the only hint of some deficit on the left side of objects (but this missing “11” would have to be on the center or on the right side if NT had included it in sequence, and was possibly omitted because he ran out of space).

Figure 4a. Drawing from memory: a flower and a clock

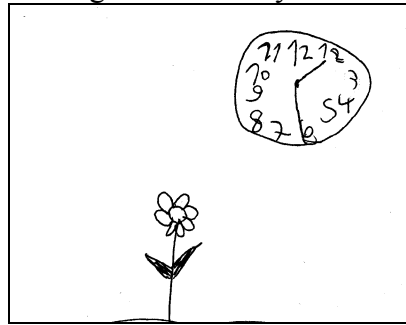


Figure 4b. Drawing from memory: person, butterfly, clock. The clock is missing “11”.

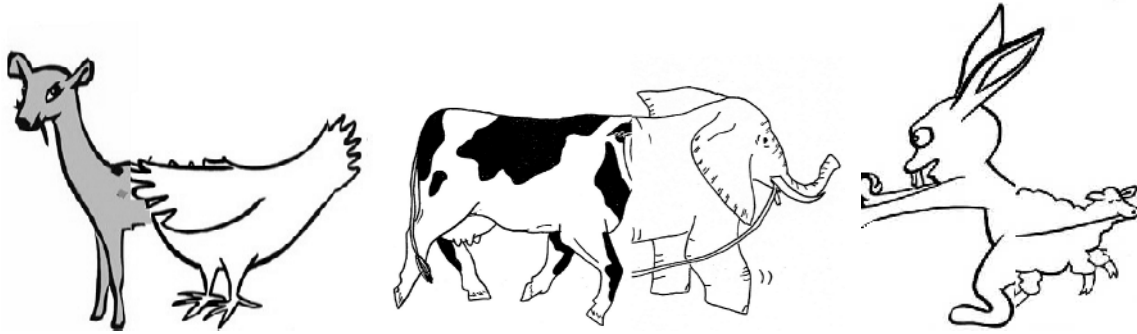


NT’s copying of Rey’s Figure included some omissions in both sides of the figure, but was not significantly different from two age-matched children without impairment we tested.

Chimeras

We showed NT 12 chimeras (examples are given in Figure 5) and asked him to say what he saw. It was very easy for him and he reported all half-animals presented and detected the abnormality of the pictures.

Figure 5. Examples for chimeras presented to NT.



Clock reading

To further assess NT's spatial abilities and to compare right and left, we examined his ability to read the clock when the hands are either on the left or on the right side. We showed him 16 clocks drawn on paper. In half of the clocks the hour hand was on the right side of the clock, and in the other half it was on the left. NT read 14/16 clocks correctly, and had one error on the left (reading 7:30 as 6:30) and one error on the right (reading 4:00 as "twelve and 40 minutes... 24 minutes...28 minutes", possibly the result of confusing the minute and the hour hands and knowing how to read only full and half hours).

READING TASKS

Some background on Hebrew orthography

Hebrew is a Semitic language, written in Hebrew letters from right to left. This direction of reading causes, in the presence of left unilateral neglect, a problem with the final letters of words, rather than the first letters, as in English, Italian and other languages in which neglect dyslexia has been studied. Another property of Hebrew orthography that is relevant for the difference between the manifestation of neglect dyslexia in Hebrew and in other languages is the underrepresentation of vowels. Hebrew has two orthography systems: one, which is used in children's books, prayer books, and poetry includes diacritical markers of vowels that are added to the consonant letters. The other, which is more common and is used in all other books, newspapers, and signs, is a non-pointed system, without diacritical signs, in which vowels are usually not represented in the orthography, and many written words comprise only consonant letters. The vowels /a/ and /e/ are almost never represented (except at the end of words); the vowels /i/, /o/ and /u/ are represented only in some of the words. For example the word סֵפֶר with the diacritical signs can only be read as /sefer/ (= book), but without the diacritical signs ספר can be read as /sefer/, /safar/, /siper/, /sper/, /sapar/, /saper/ or /sfar/. (=book, counted, told, spare, barber, tell!, border). Thus, the correct reading of words in unpointed Hebrew relies on lexical knowledge that completes the vowels missing from the orthographic representation (as well as information on stress placement and heterophonic words that are written with homophonic letters).

Word stimuli used in the tests

All the word stimuli in the reading tasks were created specifically to suit NT's reading and lexical level and his specific difficulties in order to provide the best measure of his reading ability. Words were chosen only from school books he already completed and that were read in class, and all the words chosen were regular. An initial testing showed that although NT was already in fourth grade, he read all words with the vowel /a/ (usually the first vowel taught in Hebrew reading instruction) and had not yet acquired the rest of the vowels. Thus, he could not read correctly even one of 26 words with vowels other than /a/ (significantly different from his performance with words with /a/, $\chi^2 = 23.81, p < .0001$). Therefore, all the words that were included in the studies reported below were presented with diacritics and included only the vowel /a/. Given that NT could identify only print letters but no script letters, all words were presented in print (Interestingly, the patient reported in Patterson & Wilson, 1990 showed a similar pattern of better reading of upper case than lower case letters). The words in all the studies reported below were chosen so that another existing word that NT knew could be created by final letter omission or substitution.

Single words*Oral reading of single words*

NT read 183 single words, 2-to 4-letters long (mean length 3 letters), presented in 12 sessions. He read 93/183 (50.8%) correctly, and 96% of his errors related to the final (left) letters. He made 49 errors of final letter omission, 33 errors of final letter substitution, 3 errors of addition of final letters, 4 substitutions of middle or initial letters, and one transposition of final letters. (These numbers relate to the last attempt for each word. When counting all attempts, he had 93 correct responses out of 220 attempts.) When asked about the meaning of each word he read, he defined each word according to the way he read it orally. Given his severe deficit in reading, it seems that his orthographic lexical knowledge is very limited, and therefore homophone errors were not counted as errors. For an analysis of various effects on single word reading, see the end of this chapter. When we interviewed NT on his difficulties in reading (after a period of treatment) he said "*I read not really all the time. Reading the finals... that's hard for me.*", indicating some awareness to his neglect dyslexia.

Nonword reading

NT's performance in nonword reading was poor, with an error pattern similar to that of words. Nonwords were created by changing one letter in words that were taken from his school textbook. NT read correctly only 14 out of 34 nonwords of 3-4 letters (mean length 3.1) (41.2%). His errors were 7 final letter omissions, 10 substitutions (8 final letter substitutions, 2 middle letter substitutions), and 3 additions. Eleven of his errors were lexicalizations.

Lexical decision

Thirty five 3-4 letter sequences were presented to NT, 19 were words, 16 nonwords for lexical decision. NT made 12 errors on this task (6 errors judging words as nonwords, 6 errors judging nonwords as words), which is a performance level not significantly different from chance (using the binomial distribution). Judging by his oral reading of these sequences, all his errors stemmed from reading the end of the sequences incorrectly, which turned some words into nonwords, and some nonwords into words.

Naming letters in words and word-number sequences

We presented 15 3-letter words to NT, and asked him to name the letters without reading the whole word. He named correctly all letters in all words (45/45). Since we asked him to either say the name of the letter or to say its sound (for “b” either say “bee” or “ba”) in some words he actually, without noticing it, read the word that he was previously unable to read as a whole word.

In addition we presented 16 sequences of mixed digits and letters. each sequence included two digits and two letters, the left item in half of the sequences was a letter, and in half – a digit. NT named all digits and letters correctly (a total of 64/64 letters and digits).

Reading of words in different positions on the page

In order to assess NT's reading of words in various locations on the page, we presented 16 words, 4 in each corner of the page. NT did not omit any whole word, neither from the left side nor from the right. He did make errors on the single word level, making omissions and substitutions of final letter – once on the right side of the sheet and three times on the left. Although the numbers are small, the fact that he made errors on both sides but did not omit any word on any side indicate that his impairment is not at the retinocentric level (Caramazza and Hillis, 1990).

Reading vertical words

A list of 29 words was presented twice to NT, once horizontally, and once vertically (with the letters ordered top first to bottom last, each letter in the regular upright position). The presentations were three weeks apart. A clear dissociation emerged between his good reading of vertical words, and his severely impaired reading of horizontal words. While he read correctly only 13/29 (45%) horizontally presented words, he read 26 out of the same 29 words when presented vertically (90%). The difference between reading of horizontal and vertical words was statistically significant, $\chi^2 = 13.23$, $p = .0003$. (Out of the 3 errors in vertical presentation, 2 occurred when the final letter was γ (final N) which, in vertical presentation loses its most distinctive feature – its length compared to the rest of the letters which distinguishes it from γ (V); it was once read as γ and once omitted). This difference between vertical and horizontal words also indicates that the deficit is related to a stimulus-centred deficit rather than to a word-centred grapheme level (Caramazza and Hillis, 1990; Haywood and Coltheart, 2001) (or, in Katz and Sevush [1989] terms, that the deficit is related to neglect dyslexia and to the

left side of the word rather than to positional dyslexia in final letters). Finally, NT's good reading of vertical words rules out an alternative explanation of a short-term-memory deficit that led to his omissions of final letters.

A vertical presentation of words by rotating the whole word 90° counterclockwise was not efficient and yielded 21/30 correct compared to 24/30 correct in horizontal presentation, and protest from NT, who tried, when the words were rotated, to turn his head or convince us he should sit on the other side of the table. (The rotation study was already done after the treatment phase has begun, hence the better overall performance).

Writing

We asked NT to write 20 words. He succeeded to write only three words (15%) – his name, אבא (ABA = /'aba/ = dad), and another word with a homophone error. Even given the small number of items, it seems obvious that he has significant difficulty in writing that relates to the ends of the words. Just like in reading, he could write several words from right to left, but omitted or substituted the left part of each word. He sometimes even wrote a single letter (the first letter) for a three-letter word, although Hebrew has no one-letter words. This is in contrast to some reported cases of adults with neglect dyslexia who do not miss off letters in writing (Haywood & Coltheart, 2001; Riddoch, 1990; Riddoch et al. 1990) but similar to NG in Caramazza and Hillis (1990) and TB in Patterson and Wilson (1990. See also Ellis, Young & Flude, 1993 for a review). An example of his writing is given in Figures 6a and 6b.

Figure 6a. writing. Target words: 4-הלח, 3-תמר, 2-אבא, 1-לבש Written: 4-הלח, 3-ת, 2-אבא, 1-לשר
(LBS → LSR ; ABA → ABA; TMR → T; XLH → XLR)

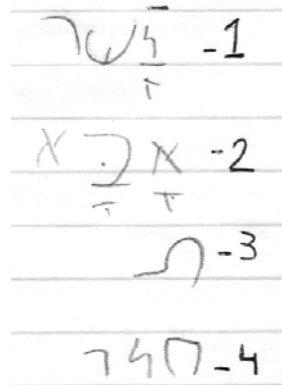
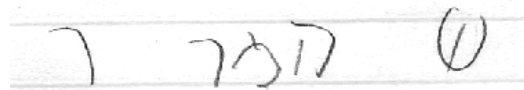


Figure 6b. NT's writing. Target words: רצה, אמר, שתה Written: ש המר ר
(STH → S ; AMR → HMR (homophone); RCH → R)



An analysis of some lexical effects (or lack thereof) on single word reading

No lexical category effect. As can be seen in Table 1, the lexical category of the target word did not significantly affect NT's reading. There was no significant difference between his performance in verb and noun reading, $\chi^2 = .85$, $p = .36$. Nor did we find significant difference between adjectives and nouns or between adjectives and verbs ($\chi^2 = .18$, $p = .67$ and $\chi^2 = .003$, $p = .96$ respectively; function words were not included in the stimulus lists). There was some tendency for difference between nouns and verbs with respect to error types. While in verbs 64% of the errors were final omissions, in nouns only 51% were omissions. This difference was not significant statistically and may have resulted from lexical factors such as the number of existing words that are created from omission or substitution in each category (the difference was not due to morphological origins, such as verb inflection suffixes that can be omitted, because we only used verbs in the past, 3rd person singular masculine, which is the non-suffixed form).

Table 1. Reading of words by lexical category (correct/total, percentage correct)

	V	N	A
Final response	47/86 (54.7%)	37/78 (47.4%)	7/13 (53.8%)
All attempts	47/104 (45.2%)	37/88 (42.1%)	7/17 (41.2%)

Table 2. Reading of words by number of letters (correct/total, percentage correct)

	2	3	4
Final response	6/11 (54.7%)	84/161 (52.2%)	3/11 (27.3%)
All attempts	6/13 (46.2%)	84/196 (42.9%)	3/11 (27.3%)

No word length effect. An analysis by word length of NT's reading is given in Table 2. The analysis shows that number of letters did not affect his reading. The reading of 2- and 3-letter words did not differ significantly ($\chi^2 = .02$, $p = .88$) nor did 3- and 4-letter words or 2- and 4-letter words ($\chi^2 = 2.55$, $p = .11$ and $\chi^2 = 1.69$, $p = .19$ respectively). The analysis of all reading attempts (rather than last response) showed the same absence of word length effect. Note, however, that the small sample of 2- and 4-letter words might be the reason for the lack of significance.

No effect of final letter size. The Hebrew alphabet includes five letters that extend below the sentence line (ץ,ף,ך,ג,י). We wanted to test whether, given their relative perceptual saliency, these letters at the end of the words would attract more attention and would be less vulnerable to neglect. The results however showed that words that ended with these longer letters were not read better than the rest. Words with the longer final letters were read 12/33 (36.4%) correct, compared to 81/150 (54%) of words that ended with short letters. This difference was not significant ($\chi^2 = 3.37$, $p = .07$), and if anything – long final letters were slightly more impaired. They also did not differ from words with short final letters with respect to the rate of final omissions and substitutions ($\chi^2 = .71$, $p = .4$).

Given that four of the long letters appear only in word-final position (and have another form when they appear in the beginning or middle of the word), it might be that they were slightly more impaired than the other letters because, given his left neglect dyslexia, NT usually does not notice these letters. For this reason, we compared a long letter that appears in all word positions (ק) to the long letters that appear only word-finally, and found that it was read to a similar extent to regular-sized letters (6/13, 46%), while long letter that appear only word-finally were read 6/20 (30%), less well than regular sized letters ($\chi^2 = 4.07, p = .04$). It thus seems that the longer letters are not different or salient enough to draw NT's attention, and that the ones that appear only word finally are even slightly more impaired.

Final vowel letters. The vowel /a/ is generally not represented in the Hebrew orthography, except for when it is word-final, and is represented by one of the letters ע/א/ה. Compare for example the word פרה (/para/) which ends with /a/ and therefore with ה (PRH =cow) to the word פרה (/parax/, PRX =bloomed) in which the /a/ appears sentence internally and therefore the word does not contain an orthographic representation of the vowel. Given that NT has a tendency to read every consonant with the vowel /a/, we hypothesized that omissions of final letters that represent the vowel /a/ would go undetected, and hence these words would show better performance than words that end with consonants (possibly comparable to the number of correct readings of words that end with consonants plus the number of omissions). We gave NT 45 words that end with ע/א/ה and indeed his reading of these words was 32/45 (71%) correct, significantly better than the reading of words that end with a consonant letter, $\chi^2 = 6.00, p = .01$, and not significantly different from the rate of correct + omission responses in words that end with consonant letters, $\chi^2 = 0.84, p = .36$.

Word pairs and sentences

Word pair reading

In order to assess whether NT has attentional dyslexia (which manifests in letter migrations between words) in addition to his neglect dyslexia, and in order to examine whether when given two words he would neglect the left word altogether or whether he would neglect the left side of both words, we asked NT to read 23 word pairs in which the two words were presented side by side. These word pairs were constructed to allow for migrations between words (namely, so that migrations of letters between words would create existing words). NT omitted or substituted the final letters of both words, and read only two pairs correctly (both of them ending with the letter for the vowel /a/). Even when the words included two letters each, he would read a single letter from each word. Thus, for example, when asked to read דק דק (DF DK) he read “da da”. Importantly, he never omitted the left word altogether (unlike, for example, patient SP reported in Young et al., 1991), thus indicating word-based neglect dyslexia without space-based neglect dyslexia. NT had no error of migration between words, ruling out attentional dyslexia (Shallice and Warrington, 1977; Warrington, et al., 1993; Davis and Coltheart, 2002) (nor

did he have migration within words that would indicate Letter Position Dyslexia, Friedmann and Gvion, 2001).

Same-different decision

We asked NT to make same-different decisions for 75 word pairs (presented in three sessions). The words were 2-5 letters long (eight 2-letter words, ninety nine 3-letter words, twenty three 4-letter words, five 5-letter words). In 53 of the pairs the words differed – 31 in final letter, 22 in initial or middle letter; 22 pairs were the same. NT was asked to look at the word pairs and to decide whether they were same or different, without reading them aloud. Surprisingly, he succeeded in 69/75 (92%) of the word pairs when he did not read the words aloud, a level which is significantly above chance (using binom). His errors were: 4 “same” decision for different pairs, 2 “different” decisions for same pairs. In the last session, during which he made same-different decision for 30 words, we asked him, for each word pair, to make the decision without reading aloud and then to read the pair aloud. The difference between his performance in decision and in reading for the same word pairs was remarkable. He read aloud correctly only 11 of 30 pairs (37%), but made the correct decision for 28 of the 30 pairs (93%). This difference was significant, $\chi^2 = 21.07$, $p < .0001$. NT commented that when he made the same-different decision he did not read the words, and compared them visually, symbol by symbol. As will be seen in his performance on reading symbols and numbers, once he treats a sequence as a symbol sequence, or at least not as an orthographic sequence, his neglect errors disappear (or almost disappear).

Sentence level reading

NT could not read sentences. When required to read a sentence he would read the first part of each word, and omit or substitute the final letters of each word, and try to guess the ends of the words in a way that would make sense as a sentence (which sometimes caused substitutions of larger parts of the left side of the words, leaving only the first letter and substituting all the rest). Importantly, he never omitted any whole word on the left hand side of the sentence (similar to the performance of the patient with acquired neglect dyslexia reported by Patterson and Wilson, 1990). Two examples for his sentence reading are given in (1) and (2) below. The sentence in Hebrew is given first, then a letter-by letter transcription, the way the sentences sound below, and in the last line – the translation into English.

- (1) מירה כתבה רוצים ללמוד את הדינים ⇔ מר כרמון רצה למכור את הדירה
 MR KRMON RCH LMKOR AT HDIRH ⇔ MIRH KTBH ROCIM LLMOD AT HDINIM
 mar carmon racah limkor et hadira ⇔ mira katva rocim lilmod et hadinim
Mr. Carmon wanted to sell the apartment ⇔ Mira wrote want to study the laws
- (2) דני עמד על הספר ⇔ דנה עמדה על הספסל
 DNI AMD AL HSFR ⇔ DNH AMDH AL HSFSL
 dana amda al hasafsal ⇔ dani amad al hasefer
Dana stood(feminine) on the bench ⇔ Danni stood(masculine) on the book

Given this severe deficit he could not understand any of the sentences he read, and of course failed on written comprehension questions relating to sentences and texts, as he would read both the text and the comprehension questions incorrectly. We tested him with 6 short sentences followed by a short question and 4 possible answers from his school textbook, and he could not perform the task at all, reading the beginning of every word correctly and neglecting the ends of the words in the target sentences, in the comprehension questions and in the answers.

Reading numbers and symbols

Number reading

Thirty 3-digit numbers were presented to NT for reading as a whole number (356 as three hundred fifty six). In marked contrast to his reading of 3-letter words, he read correctly all of the numbers (two of them on second attempt, after he made transposition of digits on the right side). This yielded a significant difference between his reading of 3-letter words and 3-digit numbers, $\chi^2 = 24.04, p < .0001$). In addition, to determine whether the difference stemmed from the different type of stimuli or from the fact that numbers are read from left to right, whereas Hebrew words are read from right to left, we asked him to read numbers digit-by-digit from right to left. He read correctly eight out of eight 2-6 digit numbers. In a same-different decision task with numbers that differed on the leftmost digits, he also scored 8/8 correct. (Similar, in this respect, to his good performance in letter-by-letter naming and same/different decision in words).

Reading of sequences that can be interpreted either as words or as numbers

We saw that there is a clear difference between the way NT reads numbers and the way he reads letters in words. We were interested whether this difference would be preserved when exactly the same sequence was presented and only the interpretation was different. Luckily, in Hebrew there are several letters that look like numbers for example, **o** is the letter S, **7** is R, **1** is O, U, W and V, and **9** could be (with some effort) P. Thus, **o1o** is a horse, and **7979** is a butterfly. We harnessed this fact for the sake of the study of NT's neglect, and asked him to read sequences that are built from these digits/letters, once as a word list and once as a number list. We could only find 5 words that qualified for this double play and we presented them to NT. The results were very impressive – when he was instructed to read these sequences as words, he read 0/5, namely – he could not read a single sequence as a word. Afterwards, when he was instructed to read these same sequences as numbers he read all 5 effortlessly. A cautionary note should be given here, though – it is possible that his failure on the letters (especially the letter 9) stemmed from his inability to recognize them in a somewhat tilted form.

Symbol sequence naming

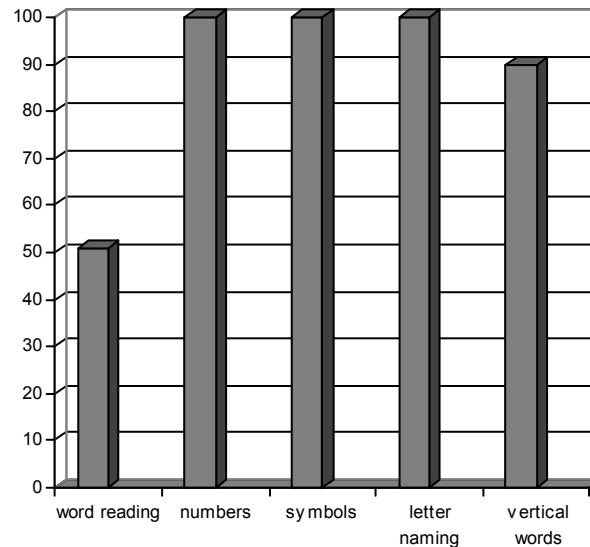
NT was presented with 12 sequences of 5 symbols each, as shown in example (3). The symbols were taken from a pool of 10 different symbols.

(3) 

After an initial stage of naming each of the different 10 symbols separately, he was asked to name the symbols in each sequence from right to left (the same as the direction in Hebrew word reading). He performed very well on this test, and named all 12 sequences flawlessly (60/60 symbols).

Figure 7 summarizes the results of NT's reading of numbers, symbols, words in tasks that do not require word reading (letter by letter naming), and vertical words, compared to word reading.

Figure 7. Performance on different sequence types: word reading, numbers, symbols, vertical words and words in a letter naming task without reading aloud.



INITIAL ATTEMPTS AT IMPROVING WORD READING

We used four methods to try and shift NT's attention to the left of the word. We put a flashing light to the left of each printed word, asked him to tap his finger to the left of each word, colored the final letter of the word in green, or drew a green line to the left of each word in a sentence. It seemed that these word-level methods had a positive effect on NT's reading, but more research is required to see whether these methods can have a longer-lasting effect on his reading.

Manipulations of attention by a light flickering to the left of the word

We built a small device that included a small red light (LED) flashing once every 1.3 seconds. We presented a printed list of 30 words twice; once without any device, and once three weeks later, with the flashing light to the left of each target word. NT's reading was considerably better with the device to the left of each word – he read 22/30 words correctly (73%) (4 final letter omissions, 3 final letter substitutions, and 1 addition), compared to 11/30 (37%) without the light. This difference was significant, $\chi^2 = 8.15, p = .004$.

Manipulations of attention by finger tapping to the left of each word

We also tried to find a way NT would be able to use on his own without additional devices or help from others – we asked him to tap his left index finger on the table or the page to the left of each of the words. This method was quite successful – he read 12/16 (75%) words when tapping his finger (4 substitutions and no omission), compared to only 5/16 (31%) of the same words without tapping (significant difference, $\chi^2 = 6.15$, $p = .01$). Surprisingly, he kept reading the following words correctly even after he stopped moving his finger.

Manipulations of attention by coloring the final letter

Another method we used in order to try and shift NT's attention to the left of the word was to color the final letter of each word green, in a list of 14 3-letter words (based on the procedures described by Ellis *et al.*, 1993). This seemed to have a positive effect as well – NT read 10/14 (71%) words correctly with this type of presentation. His performance differed significantly from words without manipulation – $\chi^2 = 4.62$, $p = .03$. Interestingly, the pattern of errors also differed – this was the only task in which NT made no final letter omissions. He made 3 substitutions that kept the final letter and added an /a/ vowel instead of the schwa (reading /katav/ as /katva/, its feminine form) and one transposition of second and last (third) letter.

Manipulations of attention by a green vertical line to the left of each word in a sentence

An additional method we used was based on the left-end flanking used by Riddoch *et al.* (1990) and Patterson and Wilson (1990). We drew a green vertical line to the left of each word within 11 sentences (including a total of 36 words). NT read 24/36 (67%) of the words with vertical lines correctly, and when presented with the same sentences without the vertical lines he read 20/36 (56%) correctly, $\chi^2 = .94$, $p = .33$. Thus, like TB (Patterson and Wilson, 1990), but unlike JB (Riddoch *et al.*, 1990), this method did not yield a significant improvement for NT. The difference could be related to the fact that while these methods, when used in left-to-right languages require the reader to start at the left end flanker and continue reading from there, in Hebrew, which is read from right to left, the reader is required to start reading and reach the flank only after the word.

DISCUSSION

Several points can be made based on the pattern of performance manifested by NT. Possibly the most important is that neglect dyslexia can be observed in children, and with patterns of reading that are in many respects similar to these found in adults with acquired word-based neglect dyslexia.²

² Just before this article went to press, we diagnosed another ten years old child with developmental word-based neglect. His reading pattern was very similar to that of NT, he read correctly only 109 of 240 words (45%), with omissions and substitutions of final (left) letters, and neglect of the left side of each word in sentences, without omissions of words on the left side. He benefited from vertical presentation of words (66% correct) and from tracking each word letter-by-letter with his finger (73%

The main characteristics of NT's performance can be summarized as follows:

1. Neglect of the left side of words that manifests in single words, word pairs and sentences, without omissions of whole words on the left side of the sheet.
2. No signs of visuo-spatial neglect in standard clinical tests such as the BIT, picture copying, clock reading, drawing from memory and chimeras.
3. Selective impairment in sequence reading: only word reading is impaired, while reading of number sequences and symbol sequences is unimpaired, and no neglect dyslexia in words when no reading is required (but rather letter naming or a same-different decision).
4. Good reading of vertically presented words.
5. The neglect of the left side of words manifests mainly in omissions and substitutions of final letters (which constitute 96% of his errors).
6. Impaired writing with omissions and substitutions of the end of each word.
7. Significant improvement when attention is attracted to the end of each word using flashing light or tapping finger to the left of each word or using colored final letters.

NT shows neglect dyslexia in the absence of Visuo-spatial neglect – at least as measured by conventional clinical tests. He does not show spatial neglect as shown by his good performance on the BIT and on attentional cost-benefit tasks, nor does he show object-based neglect as shown by his copying, drawing from memory and chimera descriptions. This dissociation is similar to that reported for adults with acquired neglect dyslexia without spatial neglect by Bisiach et al. (1986); Bisiach et al. (1990), Haywood and Coltheart (2001), and Patterson and Wilson, 1990, see also Miceli and Capasso (2001) for neglect dyslexia with only very minor visual neglect. A similar dissociation has also been reported in cases of "Paradoxical neglect": patients who show left neglect dyslexia and right visuo-spatial neglect (Cubelli et al., 1991; De Lacy Costello and Warrington, 1987; Riddoch et al., 1995). The intriguing finding here is that a system specialized in reading is apparently already present prior to reading acquisition.

Even within different types of sequences, a dissociation emerges, as NT could read numbers and symbol sequences. It seems that once his visual system recognizes an input stimulus as a word, the neglect appears. Whenever a stimulus is not perceived as a word, either when it is a number, a symbol sequence, a vertical word or a word in a task that does not require word reading, the left items become available. This very selective pattern of impairment might suggest that a module that is responsible for word reading is separate from those used for reading other types of sequences, and that it can be selectively impaired. (Quite a surprising result, considering the short time in evolution terms, around 3700 years, that the human brain has tackled the alphabet and written words. A possible explanation might lie in that it is the treatment of a sequence as a

correct). Unlike NT, he had difficulties in same-different decisions for numbers that differed in the left digit, and in picture copying, and he did not show neglect errors in writing.

linguistic material that makes it special, but this is too wide a question to be answered based on this study).

If we take the three-level model of visual word recognition proposed by Caramazza and Hillis (1990) as a model that can describe also word-specific deficits (see also Haywood and Coltheart, 2001 for a similar view), the pattern of reading manifested by NT could be accounted for by an impairment related to the second stage of the model – that of stimulus-centred level of representation. He was not influenced by the position of the word in the visual field, and neglected the left side of words regardless of where they were presented in the visual field, so he could not be taken to be impaired at the first, retinocentric, level. He was not impaired at the third, retinocentric, level as can be inferred from his good reading of vertically presented words. In this respect he resembles several reported cases of adults with acquired neglect dyslexia (such as RR in Haywood and Coltheart, 2001).

What does the large number of omission errors say about NT's ability to code word length? This can either be ascribed to the nature of Hebrew orthography or to lexicality effects. Compared to English and Italian, Hebrew speakers with neglect omit more letters in the neglected side. A case study of a Hebrew-Italian bilingual with neglect dyslexia yielded almost three times more omissions in Hebrew than in Italian for the same patient (Gvion and Friedmann, in prep). This can be ascribed to the fact that the neglected letters in Hebrew are the final rather than the first letters in the word. Thus, if letter position knowledge is preserved, first letter omissions will be excluded, but final letter omissions, which will not change the position of other letters in the word, can still occur. However, given the lexicality effects that are known to determine the relative rate of substitutions and omissions, at least in some patients (Arduino et al., in press; Arguin and Bub 1997; Patterson and Wilson, 1990) it might be that the omissions occurred when this was lexically tempting, for example when a frequent word resulted from final letter omission. However, it is important to note here that given the early onset of NT's neglect dyslexia, conclusions regarding lexical effects on neglect dyslexia acquired after a period of skilled reading should be made very carefully (or not at all). Although many similarities can be detected between the neglect dyslexia of NT and the neglect dyslexia reported for some adults with acquired neglect dyslexia, the main difference lies in the fact that they once acquired reading, while NT's neglect stands in the way of normal reading acquisition (for a similar point see Johnston and Shapiro, 1986). Thus, we believe that his homophone errors that resulted from a lexicon that has not been established yet, are an indirect result of his neglect dyslexia hampering normal reading acquisition. Similarly, his delayed phonemic awareness might be related to his difficulties in reading, as this last stage of phonological awareness has been found to be a consequence of learning to read an alphabetic language, and illiterate adults do not get to this phonological awareness stage (Adrian et al., 1995; Morais et al., 1979, 1986; Share and Breznitz, 1997). It is possible that using the methods presented here to attract NT's attention to the final letter will improve his reading, and thus enable him to build an orthographic lexicon, so that a decrease in homophone errors and improved phonemic awareness would follow.

REFERENCES

- ARDUINO LS, BURANI C, and VALLAR G. Lexical effects in left neglect dyslexia: A study in Italian patients. *Cognitive Neuropsychology*. in press.
- ARGUIN M and BUB D. Lexical constraints on reading accuracy in neglect dyslexia. *Cognitive Neuropsychology*, 14: 765-800, 1997.
- BISIACH E, MEREGALLI S, and BERTI A. Mechanisms of production control and belief fixation in human visuospatial processing: Clinical evidence from hemispatial neglect and misrepresentation. In: Commons ML, Herrnstein RJ, Kosslyn SM, and Mumford DB. (Eds) *Quantitative analyses of behavior: Computational and clinical approaches to pattern recognition and concept formation* (Vol. IX). Hillsdale: Erlbaum. pp. 3-21, 1990.
- BISIACH E, VALLAR G, PERANI D, PAPAGNO C, and BERTI A. Unawareness of disease following lesions of the right hemisphere: Anosognosia for hemiplegia and anosognosia for hemianopia. *Neuropsychologia*, 24: 471-482, 1986.
- CARAMAZZA A and HILLIS AE. Levels of representation, Co-ordinate frames, and unilateral neglect. *Cognitive Neuropsychology*, 7, 391-445, 1990.
- CHOKRON S and IMBERT M. Influence of reading habits on line bisection. *Cognitive Brain Research*, 1: 219-222, 1993.
- CHOKRON S and De AGOSTINI M. Reading habits and line bisection: a developmental approach. *Cognitive Brain Research*, 3: 51-58, 1995.
- CUBELLI R, NICHELLI P, BONITO V, DE-TANTI A, and INZAGHI, MG. Different patterns of dissociation in unilateral spatial neglect. *Brain and Cognition*, 15: 139-159, 1991.
- DAVIS CJ and COLTHEART M. Paying attention to reading errors in acquired dyslexia. *Trends in Cognitive Sciences*, 6: 359-361, 2002.
- DE LACY COSTELLO AD and WARRINGTON EK. The dissociation of visuospatial neglect and neglect dyslexia. *Journal of Neurology, Neurosurgery and Psychiatry*, 50: 1110-1116, 1987.
- ELLIS AW, YOUNG AW, and FLUDE, BM. Neglect and visual language. In Robertson IH and Marshall JC (Eds), *Unilateral neglect: Clinical and experimental studies*. Hove: Erlbaum, 1993, ch. 11, pp 233-255.
- FERRO JM and MARTINS IP. Some new aspects of neglect in children. *Behavioural Neurology*, 3: 1-6, 1990.
- FERRO JM, MARTINS IP, and TÀVORA L. Neglect in children. *Annals of Neurology*, 15: 281-284, 1984.
- FRIEDMANN N and GVION A. Letter position dyslexia. *Cognitive Neuropsychology*, 18: 673-696, 2001.
- GROSSI D, LEPORE M, NAPOLITANO A, and TROJANO L. On Selective Left Neglect during Walking in a Child. *Brain and Cognition*, 47: 539-544, 2001.
- HALLIGAN PW, COCKBURN J, and WILSON BA. The behavioural assessment of visual neglect. *Neuropsychological Rehabilitation*, 1: 5-32, 1991.
- HAMMILL DD, PEARSON NA, and VORESS JK. *Development Test of Visual Perception (DVPT-2)*. London: The Psychological Corporation, 1998.
- HAYWOOD M and COLTHEART M. Neglect dyslexia with a stimulus-centred deficit and without visuospatial neglect. *Cognitive Neuropsychology*, 18: 577 - 615, 2001.
- JOHNSTON CW and SHAPIRO E. Unilateral neglect after early brain damage. *Cortex*, 22: 279-297, 1986.
- KATZ RB and SEVUSH S. Positional dyslexia. *Brain and Language*, 37: 266-289, 1989.

- MANLY T, ROBERTSON IH, and VERITY C. Developmental unilateral visual neglect: A single case study. *Neurocase*, 3: 19–29, 1997.
- MICELI G and CAPASSO R. Word centered neglect dyslexia: Evidence from a new case. *Neurocase*, 7: 221-237, 2001.
- MORAIS J, BERTELSON P, CARY L, and ALEGRIA J. Literacy training and speech segmentation. *Cognition*, 24: 45-64, 1986.
- MORAIS, J, CARY, L., ALEGRIA, J., and BERTELSON, P. Does awareness of speech as a sequence of phonemes arise spontaneously? *Cognition*, 7: 323–331, 1979.
- MOSS AD and TURNBULL OH. Hatred of the hemiparetic limbs (misoplegia) in a 10 year old child. *Journal of Neurology, Neurosurgery and Psychiatry*, 61: 210-211, 1996.
- PATTERSON K and WILSON B. A ROSE is ROSE or a NOSE. A deficit in initial letter identification. *Cognitive Neuropsychology*, 7: 447-477, 1990.
- POSNER MI. Orienting of attention. *Quarterly Journal of Experimental Psychology*, 32: 25-42, 1980.
- POSNER MI, SNYDER CRR, and DAVIDSON BJ. Attention and the detection of signals. *Journal of Experimental Psychology: General*, 109: 160-174, 1980.
- RIDDOCH J. Neglect and the peripheral dyslexias. *Cognitive Neuropsychology*, 7: 369-389, 1990.
- RIDDOCH J, HUMPHREYS G, CLETON P, and FERY P. Interaction of attentional and lexical processes in neglect dyslexia. *Cognitive Neuropsychology*, 7: 479-517, 1990.
- RIDDOCH MJ, HUMPHREYS GW, LUCKHURST L, BURROUGHS E, and BATEMAN A. "Paradoxical neglect": Spatial representations, hemisphere-specific activation, and spatial cueing. *Cognitive Neuropsychology*, 12: 569-604, 1995.
- SHALLICE T, and WARRINGTON EK. The possible role of selective attention in acquired dyslexia. *Neuropsychologia*, 15: 31-41, 1977.
- SHARE DL and BREZNITZ, Z. *Awareness of phonemes among Semitic-speaking nonliterate*s. unpublished manuscript, 1997.
- THOMPSON NM, EWING-COBBS L, FLETCHER JM, MINER ME, and HARVEY SL. Left unilateral neglect in a preschool child. *Developmental Medicine and Child Neurology*, 33: 640-644, 1991.
- WARRINGTON EK, CIPOLOTTI L, and MCNEIL J. Attentional dyslexia: A single case study. *Neuropsychologia*, 31: 871-885, 1993.
- WEINTRAUB S and MESULAM M. Developmental learning disabilities of the right hemisphere: Emotional, interpersonal and cognitive components *Archives of Neurology*, 40: 463-468, 1983.
- WILSON B, COCKBURN J, and HALLIGAN PW. *Behavioural Inattention Test*. Suffolk, England: Thames Valley Test Company, 1987.
- WORTHINGTON AD. Cueing strategies in neglect-dyslexia. *Neuropsychological Rehabilitation*, 6: 1-17, 1996.
- YOUNG AWF, NEWCOMBE F, and ELLIS AW. Different impairments contribute to neglect dyslexia. *Cognitive Neuropsychology*, 8: 177–191, 1991.

Appendix A
Examples for NT's errors in reading aloud

Target (letter transliteration in upper case, phonetic in lower case)	Read (transcript)	Read in Hebrew	Target in Hebrew
XLV (xalav)	xala... what's xala?	חַלָּ... מה זה חַלָּ?	חלב
STL (shatal)	Shata	שַׁת	שתל
XYL (xayal)	Xayar...xayal?	חַיַּר...חַיַּל?	חיל
AMR (amar)	ama... don't know what this is	אַמַּ... לא יודע מה זה	אמר
KNF (kanaf)	Kana	קַנַּ	כנף
RSM (rasham)	Rasha...reshet (explains: Fishers' net)	רַשַׁ...רֶשֶׁת. רשת דייגים	רשמ
RCX (racax)	Raca	רַצַּ	רצח
BRX (barax)	Bara – I don't know what this is	בַּר – לא יודע מה זה	ברח
ARGZ (argaz)	Aragash ("I don't know" gesture)	אַרְגַּש – עשה פרצוף של "לא יודע" ומשך בכתפיו	ארגז
AXT (axat)	Axa	אַח	אחת
SFN (shafan)	Shafax (explains: spilt water)	שַׁפַּךְ. (שפך מים)	שפן

Figure 1. MRI scans of NT's brain at age 10;0. Axial T1 scans 5 mm thick, with 1mm gap. No focal lesion or brain abnormality were detected.

