Reading and Writing: An Interdisciplinary Journal **17:** 801–821, 2004.

Expression of syntactic complexity in sentence comprehension: A comparison between dyslexic and regular readers

MARK LEIKIN and ORIT ASSAYAG-BOUSKILA
Faculty of Education, University of Haifa, Israel

Abstract. The present study was designed to investigate the influence of syntactic complexity on sentence comprehension in Hebrew. Participants were 40 native Hebrew-speaking 5th grade dyslexic and normally reading children aged 10–11 years. Children's syntactic abilities were tested by three experimental measures: syntactic judgment, a sentence-picture matching task, and a sentence correction task. Each task consisted of sentences composed of five syntactic constructions varying in the level of syntactic complexity (active, passive, conjoined, object-subject relative, and subject-object relative). The length of sentences and the number of propositions in the sentences were controlled. In addition, a wide range of the children's reading and general abilities (e.g., reading comprehension, phonological awareness, and working memory) was examined. The results indicated that dyslexic readers were less accurate and slower than good readers in all reading tasks and in the tasks on sentence comprehension. The findings suggest that the factor of syntactic complexity seems to be a relatively independent aspect of sentence comprehension. This aspect of sentence comprehension is probably not affected in dyslexic readers. Rather, processing deficit related to phonological and memory impairments of dyslexic children and their ability to process syntactic information is responsible for the difficulties in sentence comprehension.

Key words: Dyslexia, Hebrew, Sentence comprehension Syntactic Complexity,

It is now generally accepted that processing of written text is a language-based activity and depends on a variety of factors, which include not only phonological and orthographic processes but also refer to semantic and syntactic sources of information (Ferstl & Flores d'Arcais, 1999; Perfetti, 1999). Such a view suggests, among other things, regarding reading disabilities first of all as development language disorders (e.g., Kamhi & Catts, 1989), which may be characterized by lower order (primarily, phonological) processing impairment as well as higher order (e.g., semantic and syntactic) processing deficit. However, the relationships between specific skills required for two levels of language processing on the one hand, and for lexical and supra-lexical processes in reading on the other, seem to be different (Share & Leikin, 2004).

Semantic/syntactic deficits are only weakly related, if at all, to the characteristically modular word recognition processes involved in reading isolated words and pseudowords. At the same times, these language deficiencies are significantly associated with processes operating beyond the level of individual words when readers are required to read and understand connected text (Gough & Tunmer, 1986; Hoover & Gough, 1990).

The role of syntactic abilities in dyslexia has been extensively discussed in the last decade (e.g., Badian, Duffy, Als & McAnulty, 1991; Gottardo, Stanovich & Siegel, 1997; Tunmer & Hoover, 1992). This research has yielded considerable evidence of a link between syntactic processing and reading skills (Bentin, Deutsch, & Liberman, 1990; Bowey, 1986; Deutsch & Bentin, 1996; Tunmer & Hoover, 1992; Willows & Ryan, 1986). Compared with good readers, poor and dyslexic readers differ on a number of syntactic processing tasks: sentence correction, grammatical acceptability, sentence judgment, etc. (Badian et al., 1991; Bentin et al., 1990; Gottardo et al., 1997; Tunmer & Hoover, 1992). Weakness in the different syntactic areas has been found in a wide range of ages (starting from the infancy) in various syntactic tasks (e.g., judgment, matching, correction), and regarding different syntactic categories (e.g., relative clause and word order) (Deutsh & Bentin, 1996; Nation & Snowling, 2000; Scarborough, 1991; Smith, Shankweiler & Mann, 1984). Moreover, a certain linkage between spoken language competencies and reading ability has been confirmed empirically in numerous studies, which report significant correlations between various language abilities (including syntactic) at or before school entry and reading achievement in the early grades (for reviews see Scarborough, 1998; Snow, Burns & Griffin, 1998).

However, if the presence of some semantic-syntactic deficiencies in many diagnosed dyslexics and other with established reading problems is not in dispute, the interpretation of these data is controversial. One view is that children with reading difficulties lack basic syntactic abilities due to delayed development of language skills (Byrne, 1981; Fletcher, Satz & Scholes, 1981) or due to structural deficiencies in the language system (Badian et al., 1991; Stein, Cairns & Zurif, 1984). This view was also supported by several studies in which correlations between poor reading comprehension and weakness in syntactic awareness skills were found (e.g., Nation & Snowling, 2000; Perfetti, 1994). Particularly, it was suggested that deficient syntactic awareness that reflected general difficulties in language processing (mostly grammatical and semantic impairments) exceeds the difficulties in reading comprehension (Nation & Snowling, 2000).

An alternative view was formulated by Perfetti and Lesgold (1977), who hypothesized that low understanding resulted in dyslexia, mainly from working memory limitations. Indeed, more than one group of researchers have argued that the association between general language abilities and reading is an epiphenomenon of mediating factors such as phonological abilities, IQ or social background (Gottardo et al., 1997; Shankweiler, Crain, Brady & Macaruso, 1992; Shankweiler et al., 1995). For example, syntactic deficiency was indicated as not characteristic of reading disability and the deficient syntactic ability observed in reading-disabled children reflected a limitation of short-term memory (or working memory) caused by a basic difficulty in generating phonological codes (Fowler, 1988; Shankweiler et al., 1992). Shankweiler et al. (1995), in their study in which good and disabled readers (aged 7–9) performed tasks on judgment of complex syntactic structures and sentence–picture matching, found that under the condition of decreased requirements from working memory poor readers did not differ from good readers in the tasks on syntactic knowledge. Accordingly, it was suggested that reading-disabled children know the relevant grammatical structures, and status of syntactic abilities alone cannot distinguish these children from controls.

Finally, Deutsch and Bentin (1996) summarized primary findings and proposed that the two opposing views could be approximated by the assumption that the apparent syntactic weakness of reading-disabled children did not reflect the absence of basic syntactic knowledge, but a poor ability to use this knowledge proficiently (cf. the processing deficit hypothesis of Crain and Shankweiler, 1988). Thus, the researchers are not agreed upon the character of syntactic ability in dyslexia, its role in comprehension of oral and written modalities of language, and the origin of syntactic weakness (if any) in reading-disabled children.

Note, however, that the 'syntactic issue' is closely associated with complex character of syntactic knowledge (and syntactic ability) and with cognitive complexity of sentence processing (Clifton & Duffy, 2001; Friederici, 1999; Hagoort, Brown & Osterhout, 1999). In this context, two points of interest may be singled out: syntactic complexity and task dependence in syntactic comprehension.

Regarding syntactic complexity, it was found that dyslexic readers articulate less complex syntactic structures (e.g., subject-relative and object-relative constructions) and produce less complex and shorter sentences in their speech as compared with normal readers (Kontiola, Laaksonen, Solkava & Erkingontti, 1990; King & Just, 1991; Smith et al., 1984; Vogel, 1974). Generally, syntactic complexity is measured by number of verbs, number of thematic rules, sentence length (number

of words), and type of syntactic construction (Caplan, 1993). In this case, the number of verbs corresponds with the number of propositions, which is not exactly characteristic of syntactic complexity but is thought significantly to affect sentence comprehension (Norman, Kemper & Kynette, 1992; Rochon, Waters & Caplan, 1994). Increase in the number of propositions demands growth of resources of working memory in use (Caplan & Waters, 1999) and, conversely, weakness of working memory causes significant difficulties in sentence comprehension (Leikin & Aharon-Peretz, 1998; Norman et al., 1992; Rochon et al., 1994). Likewise, sentence length is also a significant variable influencing sentence processing due to increased demands short-term memory. However, also this sentence measure cannot be counted as primarily syntactic. Thus, only the number of thematic rules and the type of syntactic construction seem to be the most promising variables in the study of syntactic ability (Caplan, 1993; Kemper & Rash, 1988).

The task variable also appears to be significant for sentence comprehension (see Rochon et al., 1994 for review). The tasks on sentence comprehension (e.g., sentence-picture matching, syntactic judgment, sentence correction) are different from the viewpoint of non-language cognitive abilities (e.g., memory and attention abilities) that are required for successful performance. At least, they differ in the degree of involvement of these abilities in sentence processing (Fowler, 1988; Just & Carpenter, 1992; Smith et al., 1984). The differences between the tasks are also evident in the level of participants' activity (e.g., identification of incorrect sentence in Syntactic judgment task – low-level, and 'production' in Sentence correction task – high level of activity) that is demanded in each specific case (Rochon et al., 1994).

In turn, weakness or impairments in some of the noted non-linguistic abilities (e.g., working memory) is known to be characteristic of dyslexia (Stanovich, 1988). Accordingly, the factor of the task seems to impose additional restrictions on the examination of syntactic weakness in dyslexia.

A further remark is appropriate regarding the language factor. To date, the syntactic ability issue has mostly been studied in English or other European languages. Yet specific features (not only syntactic) of different languages may considerably affect the concrete expression of syntactic complexity in different languages (e.g., Hebrew) as well as the importance of this factor in sentence comprehension. Evidently, if this is the case it will have significant influence on the performance of dyslexic readers in comprehension of sentences with different syntactic structures. Conversely, if the role of syntactic complexity has a universal character it will allow generalization of findings obtained in one lan-

guage to other languages. However, the role of syntax in general and of syntactic complexity in particular, in Hebrew language comprehension has hardly been studied even in normal readers. So far, few studies have examined the relationships between syntactic abilities and dyslexia in Hebrew (Bentin et al., 1990; Deutsh & Bentin, 1996).

Hebrew in general is closer to languages with pragmatic word order, in contrast to English in which the syntactic order of the sentence components is usually constant (Berman, 1985). The most characteristically Semitic feature of Hebrew is its derivational morphology (Ephratt, 1985). Most content words can be further broken down into two basic components: *root* and *pattern*. The root, being the semantic core of a word, is an ordered sequence of consonants (usually three), while the pattern is a sequence of vowels, or vowels and consonants (e.g., GiBoR, 'hero').

The pattern of Hebrew verbs differs from the patterns of other content words. Verbs are formed according to seven patterns (*binyanim*, 'conjugations') while nouns and adjectives may occur in any of several dozen different patterns (*mishkalim*, 'declensions'). The verb patterns denote such predicate-argument relations as transitivity, voice, causativeness, reflectiveness, etc. The noun patterns specify lexical classes, for example, action nouns, agents and instruments. Usually the verb is inflected by tense, gender, number and (in all but present tense) person. The verb in Hebrew thus provides some information about the subject that may be critical from the grammatical point of view; hence a great deal of information that proves to be essential for sentence understanding. Nouns and adjectives are also inflected by number, and for a few other specific cases (e.g., for possession). In Hebrew, then recognition of the lexical-morphological characteristics of the words seems to make available important syntactic information.

The gender and number agreement rules in Hebrew have no effect on semantic processing, but they reflect the syntactic relation of the sentence constituents (Shanon, 1973). In addition, since the agreement rules are at the level of inflectional morphology, their violation does not cause changes in word class (Deutsch & Bentin, 1996). For example, in the sentence *Yeled* (subject) *yafeh* (attribute) *kotev* (predicate) ('A nice boy is writing'), the morphological unit *yeled* ('boy') contains information about gender and number (singular). Simple and essential agreement rules in Hebrew grammar are acquired at a very early age (Deutsch & Bentin, 1996). Finally, types of syntactic constructions (e.g., active, passive, conjunct) in Hebrew seem to be the same as in English (Rosen, 1977).

Starting from the above-mentioned considerations, we set out to examine the contribution of syntactic complexity to sentence compre-

hension in Hebrew-speaking dyslexic and normal readers. To this end, we proposed applying three types of tasks that are widely used in different studies. They are sentence-picture matching (e.g., Shankweiler et al., 1995), syntactic judgment (e.g., Shankweiler et al., 1995; Smith et al., 1984), and sentence correction (e.g., Deutsh & Bentin, 1996; Nation & Snowling, 2000). These tasks are not confounded by factors of sentence length and number of propositions. We anticipated that controlling the latter two variables would allow examination of syntactic ability of dyslexic children. However, considering that the selected tasks are different from the viewpoint of activity level (production vs. identification) or level of cognitive complexity, we expected to find pronounced differences in performance of these tasks (especially, in the dyslexic readers).

In this case, we suggested that dyslexic readers will demonstrate evident weakness in the auditory sentence comprehension. We hypothesized also that results in sentence comprehension would be closely associated with ability to process syntactic information. At the same time, it was predicted that syntactic complexity would appear as a relatively independent variable, which significantly contributed to processes of sentence comprehension. In addition, it was proposed that the processing deficits related to phonological and memory impairments of dyslexic children and their ability to process syntactic information would appear to be responsible for difficulties of dyslexic children in sentence comprehension.

Finally, we suggested that employment of additional cognitive and reading tasks (e.g., working memory and word recognition tasks) would enable us to test potential influence of non-syntactic factors on sentence processing.

Method

Participants

Participants in the study were 40 5th graders aged from 10 to11 years ($M = 10.5$, $SD = 0.3$), from middle class families: 20 dyslexic children and 20 chronologically-age matched normally reading children. The two groups of children were also matched on nonverbal IQ scores (Raven Standard Progressive Matrices, Raven & Court, 1976) and gender (see Table 1).

The dyslexic readers were drawn from an urban center for learning disabilities in Haifa, and were diagnosed as having reading disability. The regular 5th grade readers were drawn from regular mainstream

Table 1. Performance of dyslexic and regular readers on the cognitive and reading tasks, and syntactic comprehension task (M and SD).

Variables	Dyslexic readers (n = 20)	Regular readers (n = 20)	P
Gender	9/11[a]	10/10[a]	0.759
Age	10.5 (0.3)	10.6 (0.3)	0.863
Raven	41.8 (3.9)	39.6 (4.4)	0.267
Working memory	−0.2 (0.8)	0.2 (0.6)	0.006
Short-term memory	44.3 (2.9)	47.0 (2.3)	0.002
Text reading			
Rate (words in min)	29.9 (7.1)	70.0 (13.7)	0.001
Accuracy	70.0 (19.7)	6.8 (2.8)	0.001
Reading comprehension	5.5 (1.9)	7.7 (0.9)	0.001
Isolated word reading			
Rate (in s)	109.3 (51.8)	52.4 (17.5)	0.001
Accuracy	11.9 (3.3)	28.8 (1.5)	0.001
Pseudoword reading			
Rate (in s)	0.9 (0.4)	0.6 (0.2)	0.012
Accuracy	−1.44 (0.4)	1.4 (0.3)	0.001

[a]Male/female.

class placements at schools in the city of Haifa in northern Israel. All participants had cognitive scores within the normal range, had received adequate opportunities for reading instruction, had no history of language impairment, hearing loss, or neurological findings, and were monolingual native Hebrew speakers. All the subjects participated voluntarily and parental permission was obtained.

Measures

Experimental tasks

Three tests on sentence comprehension were used:

1. *Sentence-picture matching task*. This task contained 26 sentences. Internal consistency (coefficient α) was .61. Sentences were illustrated by drawings of four sets of characters. For each sentence, four pictures were presented: a picture was provided to illustrate the right activity in the clause and three pictures were presented to illustrate the possible interpretations of the clause. The children

were instructed to listen to the sentence and to identify one picture that was apt for the sentence.

2. *Syntactic judgment task*. This task consisted of 30 sentences ($\alpha = 0.68$) which were divided into two categories: 10 syntactically correct sentences and 20 syntactically incorrect sentences. Four types of grammatical (syntactic/morphological) violations were used: 1. Violations of the *gender* agreement between subject and predicate. 2. Violations of the *number* agreement between subject and predicate. 3. Violations of both *gender and number* agreement between subject and predicate. 4. Violations of *time/tense* agreement between subject and predicate.

In this task the participants were asked to judge and say "correct" if the spoken sentence was syntactically correct and "incorrect" if it was syntactically incorrect (included grammatical violation).

3. *Sentence correction task*. This task consisted of 30 sentences which were divided into two categories identically to the division in the syntactic judgment task. Internal consistency (α) was 0.72. Some of the sentences were correct ($n = 10$) and some were incorrect ($n = 20$) and contained one or two grammatical (syntactic/morphologic) violations. The target written sentence was presented to the subject, and in parallel it was also spoken to the child (to prevent a burden on working memory). The children were instructed to find and correct orally the violation or violations (syntactic/morphological) in the written and spoken sentence if it was incorrect. Alternatively, if the written and spoken sentence was correct (without grammatical violation), the children were instructed to say "correct". After subject's answer, the examiner lowered the paper one line down to the next target sentence.

Each task included sentences that composed of five syntactic structures varying in the level of syntactic complexity (active, passive, conjoined, object-subject relative, subject-object relative). All the sentences included two propositions only and sentence length (number of words) was from five to ten words ($M = 7.68$).

The majority of the sentences were composed of three semantic categories, which are simple and frequent in the language: 1. human beings (mother, father, baby, sister, man, woman etc.), 2. jobs (policeman, wetter, doctor, teacher etc.), 3. animals (cat, dog, mouse, cow, snake, horse etc.).

Sentence order in each task was scrambled randomly. Responses to the sentences were scored as correct or incorrect. The number of correct

and incorrect responses of each sentence type was calculated along with the reaction time.

A composite measure of *Sentence comprehension* was also created by averaging standardized scores for all three sentence comprehension tasks: sentence-picture matching, syntactic judgment, and sentence correction. As expected, the first principal component also explained most of the variance in this set (80%), with similar weights for each of the individual variables (0.856, 0.887, 0.938, respectively). Internal consistency (α) was 0.87.

Additional measures

I. Three measures of basic abilities were used:

1. *IQ*. General ability was assessed by the Raven Standard Progressive Matrices (Raven & Court, 1976), a nonverbal test to measure the IQs, in which the stimuli are 60 black-and-white patterns, with one section missing. Participants were required to select the missing section from a series of six options.
2. *Working memory*. In the test on Sequence repetition on antonyms (Shany & Ben Dror, 1998; Shany, Zayber & Ben-Dror, 1997), the participants were asked to listen to series of words of increasing length and then to repeat the opposite words in the same order (i.e., ''white, fat'' – ''black, thin''). No repetitions were allowed.
3. *Short-term working memory*. This ability was assessed by the Recalling Sentences (RS) Woodcock Johnson III (Woodcock, McGrew, Mather & Schrank, 2001). The test required verbatim repetition of sentences of increasing length and linguistic complexity. No repetitions by the examiner were allowed.

II. Three measures of reading abilities were used:

1. *Pseudoword reading*. The Decoding Skills Test (DST) (Deutsch, 1994) provides information about the subject's ability to apply phonic and structural analysis skills for the decoding of printed pseudowords, which were structured to comply with the Hebrew morpho-phonemic rules. This test contained a set of 24 meaningless three or four letter strings presented with vowel marks. The DST score represents the total number of accurately read pseudowords ($n = 24$).
2. *Isolated word recognition*. Word recognition was assessed by the Real Words Reading Test (Breznitz, 1997, second list). Each child was asked to read aloud a list of 32 words as accurately as they

could. The test score represented the total number of accurately read real monosyllabic and polysyllabic words ($n = 32$).

3. *Reading accuracy, rate, and comprehension of connected text*. In the Reading Comprehension Test of Ministry of Education (Breznitz, 1997), children read a short passage (228 words) aloud and were then asked questions to assess literal and inferential understanding. Each child received an overall reading rate score, an accuracy score, and a reading comprehension score.

Results

Table 1 presents the background bio-social characteristics for the dyslexic and regular readers and their performance on the cognitive and reading tasks. The dyslectic group is seen to have been well matched with the control group on such background characteristics as gender, age and IQ.

At the same time, dyslexic readers differed significantly from regular readers in all reading measures and in working memory and short-term memory tasks. They were less accurate and slower than regular readers in pseudoword and isolated word reading, as well as in text reading (accuracy, rate, and comprehension). These findings confirm the applicability of groups' designation.

Results of two groups of participants in sentence comprehension tasks are presented in Table 2. Compared with regular readers, the dyslexic readers made significantly more mistakes in all tasks on sentence comprehension and were significantly slower in the performance of these tasks (besides sentence–picture matching task). That is, the results in Table 2 show that the dyslexic readers experience significant difficulties in auditory comprehension of sentences with different syntactic structure in different experimental tasks.

In order to examine the significance of the difference between two groups of participants in experimental tasks, a repeated measures analysis of variance (GLM) with group variable (dyslexic readers vs. controls) as between-subject factor and task type (three task types) variable as within-subject factor was carried out. Results of analysis revealed a significant group effect in experimental measures for performance accuracy ($F(1,0) = 60.65$, $P < 0.001$) but not for performance time ($F(1, 0) = 0.64$, $P = 0.429$). That is, only performance accuracy factor was found to distinguish between dyslexic and regular readers in sentence comprehension tasks. At the same time the task effects both for perfor-

Table 2. Raw score (M and SD) differences between dyslexic and regular readers in syntactic comprehension tasks (accuracy and reaction time[a]).

Variables	Dyslexic readers (n = 20)	Regular readers (n = 20)	P (2-tailed)
Sentence–picture matching (production)[b]	20.2 (3.1)	24.5 (2.2)	0.001
Reaction time	2.3 (0.7)	1.9 (0.6)	0.073
Syntactic judgment (identification)[b]	23.8 (2.6)	27.4 (1.8)	0.001
Reaction time	0.4 (0.3)	0.2 (0.07)	0.025
Sentence correction (production)[b]	18.5 (1.6)	23.8 (1.8)	0.001
Reaction time	1.1 (0.6)	0.6 (0.5)	0.005
Production (total)	19.3 (2.0)	24.1 (1.8)	0.001
Reaction time	1.7 (0.4)	1.3 (0.5)	0.003
Sentence comprehension (total)	20.8 (2.0)	25.2 (1.6)	0.001
Reaction time	1.3 (0.4)	0.9 (0.3)	0.002

[a]Per sentence.
[b]In parentheses, the type (level) of participants' activity in performance of sentence comprehension tasks is depicted.

mance accuracy ($F(2,0) = 116.96$, $P < 0.001$) and for performance time ($F(2,0) = 228.55$, $P = 0.429$) were revealed. In addition, a repeated measures ANOVA revealed significant group by task type interactions both for performance accuracy ($F(2,0) = 4.77$, $P < 0.01$) and performance time ($F(2,0) = 5.36$, $P < 0.009$).

Thus, the results showed that sentence comprehension of the participants was significantly affected by the task type variable. In this case, significant differences between dyslexic and regular readers were found too (see also Table 2).

With the object to examine the hypothesis about the different levels of activity required for performance of different tasks on sentence comprehension (Fowler, 1988; Just & Carpenter, 1992; Rochon et al., 1994; Smith et al., 1984), the new variable dichotomy – production (high level of activity: sentence–picture matching and sentence correction tasks) vs. identification (low-level of activity: syntactic judgment task) – was created (see Table 2). In examination of differences between groups of participants with respect to level of activity required for task performance (identification vs. production), level of activity was found to influence on performance accuracy ($F(1,0) = 213.01$, $P < 0.001$) and performance

time ($F(1,0) = 238.76$, $P < 0.001$). Inspection of Table 2 show that dyslexic readers were less accurate and slower in the tasks (sentence–picture matching and correction tasks) required more complex level of performance activity (production) than in the sentence judgment task (identification). Production/identification contrast was also found to be the factor that enables to distinguish between dyslexic and control groups with very significant group effect ($F(1,0) = 60.65$, $P < 0.001$). In addition, a repeated measures ANOVA revealed significant interactions of group effect with effect of level of performance activity (production vs. identification) both for performance accuracy ($F(1,0) = 26.82$, $P < 0.001$) and performance time ($F(1,0) = 12.91$, $P < 0.001$). This may also be well illustrated by the data from Table 2. The higher the activity level was, the stronger were the differences between dyslexic and regular readers.

The groups' performance in the tasks on sentence comprehension in accordance with syntactic construction type is presented in Table 3. Results showed that differences between two groups in comprehension of sentences of all five syntactic types were highly significant. Also, syntactic constructions almost uniformly varied in respect of relative difficulties for comprehension in both groups of participants (Figure 1).

A repeated measures ANOVA (GLM) revealed a significant main effect of syntactic complexity (type of syntactic constructions) in accu-

Table 3. Raw score (M and SD) differences between dyslexic and regular readers in comprehension (accuracy and reaction time[a]) of different syntactic constructions.

Syntactic structures	Dyslexic readers (n = 20)	Regular readers (n = 20)	F
Active	0.8 (0.1)	0.9 (0.1)	26.796*
Reaction time	2.4. (1.0)	1.5 (0.4)	19.451*
Passive	0.7 (0.1)	0.8 (0.1)	21.346*
Reaction time	2.3 (0.5)	1.9 (0.9)	9.130**
Conjunct	0.7 (0.1)	0.9 (0.1)	15.917*
Reaction time	3.8 (1.3)	2.76 (0.9)	7.855**
Object relative	0.6 (0.1)	0.8 (0.1)	44.916*
Reaction time	2.8 (0.8)	2.4 (1.0)	3.705 n.s.
Subject relative	0.6 (0.1)	0.8 (0.1)	24.919*
Reaction time	3.1 (1.4)	2.4 (1.0)	4.465***

*PPPaPer sentence.

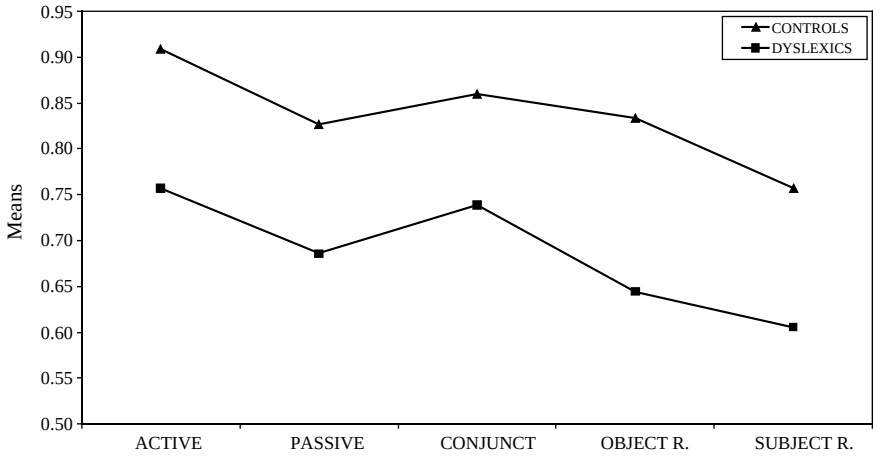

Figure 1. Variations of difficulties of different syntactic construction in two groups of participants.

racy ($F(4,0) = 21.96$, $P < 0.001$) and reaction time ($F(4,0) = 24.85$, $P < 0.001$) measures of performance. In this case, a significant group effects in performance accuracy ($F(1,0) = 61.92$, $P < 0.001$) and reaction time ($F(1,0) = 9.68$, $P < 0.003$) were also yielded. That is, the factor of syntactic complexity appears to influence significantly on participants' performance, and results of performance in the presence of syntactic complexity factor may distinguish between dyslexic and control groups. At the same time, no significant interaction of syntactic complexity (five types of syntactic constructions) with group (dyslexics vs. controls) was revealed for accuracy ($F(4, 0) = 1.16$, $P < 0.440$) and reaction time ($F(4, 0) = 1.09$, $P < 0.370$). In other words, the patterns of participants' performance in accordance with type of syntactic construction were not significantly different in the two groups.

Since the size of our sample did not enable us to perform a 5×3 (5 sentence types $\times$ 3 task types) repeated measures ANOVA, the syntactic complexity variable was compared with task type variable (for accuracy measure only) using Friedman's (nonparametric) test for K related samples. The results of Friedman's test on the task and syntactic complexity effects revealed only partial interactions of these two effects (see Table 4). Syntactic complexity effect was significant on the picture matching and Correction tasks but not on the judgment task. The internal order of the syntactic construction within each task was not consistent. For example, subject relative was the highest on correction tasks and the lowest on sentence–picture matching task (Figure 2). Note that this model was relatively consistent in both groups of participants.

Table 4. Results of Friedman's test on the task and syntactic complexity effects.

Tasks	Mean ranks of syntactic constructions[a]					χ^2	df	*P*
	A	P	C	Or	Sr			
Matching	4.16	3.49	2.71	2.79	1.85	57.721	4	0.000
Judgment	3.17	2.67	3.40	3.01	2.74	8.076	4	0.089
Correction	3.58	2.17	3.58	2.06	3.61	46.473	4	0.000

[a]A – Active, P – passive, C – conjunct, Or – object relative, Sr – subject relative.

In addition, in order to examine interactions of obtained effects (i.e., task type and syntactic complexity effects) with background characteristics and cognitive and reading variables, a repeated measures ANOVA (GLM) was carried out (for accuracy measures only). Results demonstrated no significant interaction of syntactic complexity effect with age ($F(4,0) = 2.561$, $P = 0.056$), gender ($F(4, 0) = 1.853$, $P = 0.141$), working memory ($F(4,0) = 1.800$, $p = 0.151$), isolated word reading ($F(4,0) = 1.265$, $P = 0.302$), and pseudoword reading ($F(4, 0) = 0.948$, $P = 0.448$). Only two significant interactions were revealed: with general ability ($F(4, 0) = 3.483$, $P = 0.017$) and slightly with short-term memory ($F(4,0) = 2.647$, $P = 0.050$). Thus, these findings are in line with above reported results: a lack of interaction of syntactic complexity effect with group variable.

Also computation of a repeated measure ANOVA revealed significant interaction (for accuracy measures) of task effect with isolated

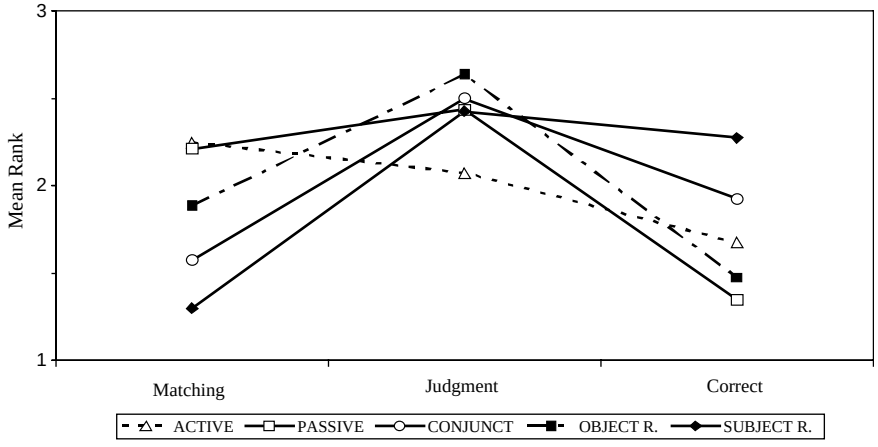

Figure 2. Interactions between syntactic complexity and task effects.

word reading ($F(2,0) = 6.029$, $P = 0.005$) and pseudoword reading ($F(2,0) = 4.493$, $P = 0.018$), and no significant interactions with age ($F(2,0) = 0.231$, $P = 0.795$), gender ($F(2,0) = 1.371$, $P = 0.266$), general ability ($F(2,0) = 0.320$, $P = 0.266$), working memory ($F(2,0) = 0.60$, $P = 0.554$), and short-term memory ($F(2,0) = 0.42$, $P = 0.663$). Since, decoding skills are viewed to be critical for definition of dyslexia (e.g., Siegel, 1999; Stanovich, 1988), obtained results confirm the above reported interaction of task effect with group variable.

Discussion

The focus of the present study was to examine the independent contribution of syntactic complexity to sentence comprehension in dyslexic and regular 5th grade Hebrew-speaking readers. Actually, an examination of this central topic suggested considering two different issues: the status of syntactic abilities in dyslexic readers and the contribution of a special component of syntactic structure – syntactic complexity – to sentence comprehension in Hebrew. We expected dyslexic readers to demonstrate evident weakness not only in reading-related tasks but also in the auditory sentence comprehension. Also, we suggested that the level of sentence comprehension would be closely associated with ability to process syntactic information. Finally, we predicted that syntactic complexity would appear as a relatively independent variable, which significantly contributed to processes of sentence comprehension. Overall, the results provided considerable support for these three assumptions.

Children classified as dyslexic readers and well matched with control children on age, gender, and non-verbal IQ experienced notable difficulties in all reading tasks. Compared with controls, they were significantly less accurate and slower in word and pseudoword reading, contextualized reading and reading comprehension. Also, the dyslexic children demonstrated a clear decline in working memory. Thus, the marked deficiency in decoding and working memory abilities found in this group confirmed the previous diagnosis of these children as dyslexic readers (Siegel, 1999; Stanovich, 1988).

At the same time, the dyslexic children experienced marked difficulties in all tasks on sentence comprehension: they were significantly slower and less accurate than controls. Sentence comprehension difficulties (or syntactic weakness) in reading impairment has been a subject of debate in contemporary literature on dyslexia (Badian et al., 1991; Bentin et al., 1990; Gottardo et al., 1997; Tunmer & Hoover, 1992). Previ-

ous experimental data indicated that poor readers differed from normal readers on a number of syntactic processing tasks such as sentence correction (e.g., Bentin et al., 1990; Deutsch & Bentin, 1996), sentence-picture matching (e.g., Glass & Perna, 1986), and sentence judgment (e.g., Bentin et al., 1990), namely the same types of task as in the present study. Accordingly, differences between dyslexic and regular readers obtained in the study were fully expected and were in line with existing data. Note, however, that our findings indicate not only statistically significant but also prominently expressed differences. Moreover, these differences were robust across three different types of sentence comprehension tasks and five types of syntactic constructions.

According to the objective of the study, the syntactic abilities of the participants were measured by their level of competence in syntactic complexity, that is, their ability to handle sentences with different syntactic construction (to comprehend them). In this case, the dyslexic children proved considerably weaker than the controls. However, the very significant main effect of syntactic complexity obtained in the study did not interact with the group variable. Seemingly, this last finding may be deemed evidence of the inherent value of syntactic complexity for sentence comprehension (Caplan, 1993), which does not depend on the group of participants. This assumption is confirmed by the absence of any interactions between the syntactic complexity effect and such variables as short-term and working memory and decoding skills.

Decoding skills (phonological abilities) along with working memory capacity are thought to be one of the central characteristics of dyslexia (Gough & Tunmer, 1986; Siegel, 1999; Stanovich, 1988). However, the findings demonstrated that these abilities contributed differently to performance on the sentence comprehension tasks. While the decoding variable very significantly interacted with the main effect of the task, there were no significant interactions with working and short-term memory. These differences may be due to the relative value of decoding skills and working memory in dyslexia, and they may also be explained by differences in the relative difficulty of the tasks used in the study for assessing decoding and memory abilities. In any event, our results suggest that the dyslexic children were characterized primarily by a prominent decoding deficit. At the same time, decoding skills largely reflect a reader's phonological ability, which is thought to be the source of dyslexics' difficulties in syntactic comprehension (Fowler, 1988, Shankweiler et al., 1992). Likewise, memory abilities (principally short-term memory) are known as relevant and very important for the sentence comprehension tasks (Caplan & Waters, 1999). Weakness of short-term memory capacity in

reading disabilities is noted in the literature (Perfetti & Lesgold, 1977; Siegel, 1999; Stanovich, 1988) and was also found in the present study.

However, while statistical analysis identified significant relationships of performance on the sentence comprehension tasks with at least decoding ability, neither of decoding and memory variables (nor the group variable) interacted with the syntactic complexity effect. Seemingly, this fact makes it possible to differentiate two notions: syntactic comprehension and sentence comprehension (or more exactly syntactic competence and sentence processing). In this context, it may be suggested that the syntactic competence of dyslexic children does not significantly differ from that of regular readers. Accordingly, the origin of sentence comprehension difficulties may be sought in a processing deficit of reading impaired children, which seems to include sentence processing weakness (Breznitz & Leikin, 2000; Deutsch & Bentin, 1996). In turn, sentence processing is complex and depends on a variety of factors (Ferstl & Flores d'Arcais, 1999; Perfetti, 1999). These include phonological processing and memory resources. However, dyslexic readers are characterized by a deficit just in these two fields.

In this context, the relationships of sentence complexity to task type must be considered too. The results showed that significant differences between the three tasks on sentence comprehension were evident in the general sample as well as dyslexic group. These findings are in line with available literature data that indicate important differences between the three task types in the specific cognitive abilities required for their performance (e.g., Rochon et al., 1994). In particular, this seems to be associated with the character of the task performance (i.e., with the level of participants' activity during the task performance). For example, syntactic judgment task requires only identifying a presence of any incorrectness in the sentence (low-level of activity), whereas picture matching and correction task imply carrying out of a few more complex operations (high level of activity).

The results of our study showed that, compared with controls, the difficulties of dyslexic children increased more significantly, when passing from the tasks required a low activity level (identification: syntactic judgment task) to tasks required a high activity level (production: picture matching and correction tasks). An interaction of syntactic complexity with task was also found only in production tasks. That is, the higher was the level of activity required by the task, the highest was the level of cognitive complexity of the task and the stronger was the influence of type task effect on the performance.

Dyslexic children were characterized by a deficiency in at least a few abilities necessary for the performance of production tasks, for exam-

ple, short-term memory, working memory, and attention (e.g., Fowler, 1988; Just & Carpenter, 1992). Two of these abilities (i.e., short-term and working memory) were tested in our study and were found to be significantly impaired in the dyslexic children. These findings may explain the significant interaction of task and group effects.

At the same time, the main effect of the task interacted only partly with the main effect of syntactic complexity. That is, the syntactic complexity effect appeared hardly affected by the task effect (except the syntactic judgment task – identification, i.e., low-level of activity). Accordingly, two suggestions may be put forward. First, the factor of syntactic complexity seems to be a relatively independent aspect of sentence comprehension. Second, the various tasks in sentence comprehension differ in cognitive complexity (and the level of required activity) and may (but do not necessarily) interact with the syntactic complexity effect.

To summarize, the factor of syntactic complexity seems to be a relatively independent aspect of sentence comprehension. This factor significantly influences on performance in the tasks on sentence comprehension and does not correlate significantly with the group of participants. Probably, this aspect of sentence comprehension is not affected in dyslexic readers. Rather, the processing deficits related to phonological and memory impairments of dyslexic children and their ability to process syntactic information are responsible for their difficulties in sentence comprehension.

References

Badian, N.A., Duffy, F.H., Als, H. & McAnulty, G.B. (1991). Linguistic profiles of dyslexic and good readers. *Annals of Dyslexia*, *41*, 221–245.

Bentin, S., Deutsch, A. & Liberman, I.Y. (1990). Syntactic competence and reading ability in children. *Journal of Experimental Child Psychology*, *48*, 147–172.

Berman, R. (1985). The acquisition of Hebrew. In D. Slobin (Ed.), *The Crosslinguistic Study of Language Acquisition* (vol. 1, pp. 255–371). Hillsdale, NJ: Erlbaum.

Bowey, J.A. (1986). Syntactic awareness and verbal performance from preschool to fifth grade. *Journal of Psycholinguistic Research*, *15*, 285–308.

Breznitz, Z. (1997). *Text for oral reading*. Ministry of Education, Culture and Sport. Jerusalem [in Hebrew].

Breznitz, Z. & Leikin, M. (2000). Syntactic processing of Hebrew sentences in normal and dyslexic readers: Electrophysiological evidence. *The Journal of Genetic Psychology*, *161* (3), 359–380.

Byrne, B. (1981). Deficient syntactic control in poor readers: Is a weak phonetic memory code responsible? *Applied Psycholinguistics*, *2*, 210–212.

Caplan, D. (1993). *Language: structure, processing, and disorder*. cambridge, MA: MIT Press.

Caplan, D. & Waters, G. (1999). Verbal working memory and sentence comprehension. *Behavioral and Brain Sciences*, *22*, 77–126.

Clifton, C.J. & Duffy, S.A. (2001). Sentence and text comprehension: Roles of linguistic structure. *Annual Review of Psychology*, *52*, 167–196.

Crain, S. & Shankweiler, D. (1988). Syntactic complexity and reading acquisition. In A. Davison & G.M. Green (Eds.), *Linguistic Complexity and Text Comprehension: Readability Issues Reconsidered* (pp. 167–192). Hillsdale , NJ: Erlbaum.

Deutsch, A. (1994). *Operating of attention systems in the field of the syntax in children with severe reading disabilities. Doctoral thesis*. The Hebrew University, Jerusalem [in Hebrew].

Deutsch, A. & Bentin, S. (1996). Attention factors mediating syntactic deficiency in reading-disabled children. *Journal of Experimental Child Psychology*, *63*, 386–415.

Ephratt, M. (1985). *Root–pattern array: Main tool for hebrew word formation*. Doctoral thesis. Jerusalem: The Hebrew University [in Hebrew].

Ferstl, E.C. & Flores d'Arcais, G. (1999). The reading of words and sentences. In A.D. Friederici (Ed.), *Language comprehension: A biological perspective* (pp. 175–210). Berlin: Springer.

Fletcher, J.M., Satz, P. & Scholes, R.J. (1981). Developmental changes in the linguistic performance correlates of reading achievement. *Brain and Language*, *13*, 78–90.

Fowler, A.E. (1988). Grammaticality judgments and reading skill in grade 2. *Annals of Dyslexia*, *38*, 73–94.

Friederici, A.D. (1999). The neurobiology of language comprehension. In A.D. Friederici (Ed.), *Language comprehension: A biological perspective* (pp. 265–304). Berlin: Springer-Verlag.

Glass, A.L. & Perna, J. (1986). The role of syntax in reading disability. *Journal of Learning Disabilities, 19*, 354–359.

Gottardo, A., Stanovich, K.E., & Siegel, L.S. (1997). The relationships between phonological sensitivity, syntactic processing, and verbal working memory in the reading performance of third-grade children. *Journal of Experimental Child Psychology*, *63*, 563–582.

Gough, P. & Tunmer, W. (1986). Decoding, reading, and reading disability. *Remedial and Special Education*, *7*, 6–10.

Hagoort, P., Brown, C.M. & Osterhout, L. (1999). The neurocognition of syntactic processing. In M. Brown & C.M. Hagoort (Eds.), *The Neurocognition of language* (pp. 273–318). Oxford: Oxford University Press.

Hoover, W.A. & Gough, P.B. (1990). The simple view of reading. *Reading and Writing: An Interdisciplinary Journal*, *2*, 127–160.

Just, M.A. & Carpenter, P.A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review*, *99*, 122–149.

Kamhi, A. G. & Catts, H.W. (1989). *Reading disabilities: A developmental language perspective*. Boston: Little Brown.

Kemper, S. & Rash, S. (1988). Speech and writing across the life span. In M.M. Gruneberg, P.E. Morris & R.N. Sykes (Eds.), *Practical aspects of memory: current research and issues* (pp. 107–112). Chichester: Wiley

King, J. & Just, M.A. (1991). Individual differences in syntactic processing. *Journal of Memory and Language*, *30*, 580–602.

Kontiola, P., Laaksonen, R., Solkava, R. & Erkingontti, T. (1990). Pattern of language impairment is different in Alzheimer's disease and multi-infarct dementia. *Brain and Language*, *38*, 364–383.

Leikin, M. & Aharon-Peretz, J. (1998). An aspect of auditory word and sentence comprehension in Alzheimer's disease. *Journal of Medical Speech-Language Pathology*, *6*, 115–122.

Nation, K. & Snowling, M.J. (2000). Factors influencing syntactic awareness skills in normal readers and poor comprehenders. *Applied Psycholinguistics*, *21*, 229–241.

Norman, S., Kemper, S. & Kynette, D. (1992). Adults' reading comprehension: Effects of syntactic complexity and working memory. *Journal of Gerontology: Psychological Sciences*, *47*, 258–265.

Perfetti, C.A. (1994). Psycholinguistics and reading ability. In C.A. Perfetti (Ed.), *Handbook of psycholinguistics* (pp. 849–894). New York: Academic Press.

Perfetti, C.A. (1999). Comprehending written language: A blueprint of the reader. In A.D. Frederici (Ed.), *Language comprehension: A biological perspective* (pp. 167–208). Berlin: Springer-Verlag.

Perfetti, C.A. & Lesgold, A.M. (1977). Discourse comprehension and sources of individual differences. In P.A. Carpenter & M.A. Just (Eds.), *Cognitive processes in comprehension* (pp. 141–183). Hillsdale, NJ: Erlbaum.

Raven, J. & Court, J. (1976). *Raven's progressive matrices*. Oxford: J.C. Raven Ltd., Oxford Psychologists Press.

Rochon, E., Waters, C.S. & Caplan, D. (1994). Sentence comprehension in patients with Alzheimer's disease. *Brain and Language*, *46*, 329–349.

Rosen, H.B. (1977). *Contemporary Hebrew*. The Hague: Mouton.

Scarborough, H.S. (1991). Early syntactic development of dyslexic children. *Annals of Dyslexia*, *41*, 207–220.

Scarborough, H.S. (1998). Early identification of children at risk for reading disabilities: phonological awareness and some other promising predictors. In B.K. Shapiro, P.J. Accardo & A.J. Capute (Eds.), *Specific reading disability: A view of the spectrum* (pp. 77–121). Timonium, MD: York Press.

Shankweiler, D., Crain, S., Brady, S. & Macaruso, P. (1992). Identifying the causes of reading disability. In P.B. Gough, L.C. Ehri, et al., *Reading acquisition* (pp. 275–305). Hillsdale, NJ: Erlbaum.

Shankweiler, D., Crain, S., Katz, L., Fowler, A.E., Liberman, A.M., Brady, S.A., Thornton, R., Lundquist, E., Dreyer, L., Fletcher, J.M., Stuebing, K.K., Shaywitz, S.E. & Shaywitz, B.A. (1995). Cognitive profiles of reading disabled children: Comprehension of language skills in phonology, morphology, and syntax. *Psychological Science*, *6*, 149–156.

Shanon, B. (1973). Interpretation of ungrammatical sentences. *Journal of Verbal Learning and Verbal Behavior*, *12*, 389–400.

Shany, M. & Ben Dror, I. (1998) *Test of Working Memory*. Unpublished test. University of Haifa [in Hebrew].

Shany, M., Zayber, T. & Ben-Dror, A. (1997). *Diagnostic Tools: Reading and writing*. Internal report of the Unit of Research and Assessment, Bet-Berl College [in Hebrew].

Share, D. & Leikin, M. (2004). Language impairment at school entry and later reading disability: Connections at lexical versus supra-lexical levels of reading. *Scientific Studies of Reading, 8*, 87–110.

Siegel, L.S. (1999). Issues in the definition and diagnosis of learning disabilities: A perspective on Guckenberger v. Boston University. *Journal of Learning Disabilities, 32* , 304–320.

Smith, S.T., Shankweiler, D. & Mann, V.A. (1984). The association between comprehension of spoken sentences and early reading ability: the role of phonetic representation. *Journal of Child Language*, *11*, 627–643.

Snow, C. E., Burns, M. S. & Griffin, P. (1998). *Preventing reading difficulties in young children*. Washington, DC: National Research Council.

Stanovich, K.E. (1988). The dyslexic and garden variety poor reader: The phonological core variable difference model. *Journal of Learning Disabilities*, *21*, 590–604.

Stein, C.L., Cairns, J.S. & Zurif, E.B. (1984). Sentence comprehension limitations related to syntactic deficits in reading-disabled children. *Applied Psycholinguistics*, *5*, 305–322.

Tunmer, W.E. & Hoover, W. (1992). Cognitive linguistic factors in learning to read. In P.B. Gough, L.C. Ehri & R. Treiman (Eds.), *Reading acquisition* (pp. 175–214). Hillsdale, NJ: Erlbaum.

Vogel, S.A. (1974). *Syntactic abilities in normal and dyslexic children*. Baltimore, MD: University Park Press.

Willows, D.M. & Ryan, E.B. (1986). The development of grammatical sensitivity and its relationship to early reading achievement. *Reading Research Quarterly*, *21*, 253–266.

Woodcock, R.W., McGrew, K.S., Mather, N. & Schrank, F.A. (2001). *Woodcock Johnson III*. Chicago: Riverside Publishing.

Address for correspondence: Dr. Mark Leikin, Faculty of Education, University of Haifa, Mount Carmel, Haifa 31905 Israel.
Tel: +972-4-8249381; Fax: +972-04-8240911; E-mail: markl@construct.haifa.ac.il