Morphological processing in Hebrew-speaking reading-disabled students

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Abstract

Marking number/gender agreement on Hebrew adjectives is a case in point: it is a challenging task requiring lexical and grammatical insight, a well-known source of processing errors in Hebrew usage. The current study examined impaired processing of noun and adjective inflection in adult speakers of Hebrew with dyslexia. 30 normally reading university students, 30 dyslexic university students, and 30 normally reading 6th grade students were administered a production task on noun-adjective pluralization. Accuracy of noun form and adjective agreement were measured, as well as reaction time to producing the whole plural noun phrase. Of interest was the contrast between forms involving a stem change, and forms taking a predictable (regular) vs. idiosyncratic (irregular) suffix. The study found that dyslexic individuals tended to be slower and less accurate overall, though the extent of this impairment was somewhat more pronounced for irregular forms and forms involving a stem change. Performance was also compared to younger controls (sixth graders) and indicated ways in which these deficits could vs. could not be explained by their relative reading experience.

INTRODUCTION

Inflectional morphology involves both lexicon and grammar, and is especially problematic in populations with demonstrated language difficulties. Marking number/gender agreement on Hebrew adjectives is a case in point: it is a challenging task requiring lexical and grammatical insight, a well-known source of processing errors in Hebrew usage. The present study investigates knowledge of Hebrew plural adjective agreement as a window on the linguistic facets of reading disability.

Inflectional morphology has two major functions: marking inherent grammatical features on lexical elements (e.g., plural marking on nouns); and spreading these features onto other lexical items by the process of *agreement* – e.g., adjective agreement with nouns in terms of number and gender. Inflectional systems are characterized by high token frequency, general and obligatory applicability (Bybee, 1985; Dressler, 1989), and they are therefore prominent in language usage (Bybee, 2006). Semantically, inflection exhibits transparency, regularity, and predictability. These aspects render inflection highly salient by facilitating the initial mapping of meaning or function onto linguistic segments (Brown, 1973), so that inflection emerges early on in child language. At the same time, many inflectional systems are fraught with morphological and morpho-phonological complexity and inconsistency. Gaining command of these *structural* aspects of inflection is therefore a protracted developmental process that may continue across the school years (Laaha et al., 2006; Ravid, 1995). This also renders inflectional marking a serious challenge to individuals suffering from linguistic disabilities, such as Specific Language Impairment (Montgomery & Leonard, 2006) or Developmental Dyslexia (Berninger, 2001**;** Joanisse, Manis, Keating & Seidenberg, 2000; Scarborough, 1991).

While Specific Language Impairment has long been in the limelight as a clearly linguistic disability, less attention has been directed to systematically investigating Developmental Dyslexia (or Specific Reading Disability = henceforth **DD**) in psycholinguistic terms (Casalis, Colé & Sopo, 2004; Egan & Pring, 2004; Goulandris, Snowling & Walker, 2000; Rispens, Roeleven & Koster, 2004). DD is diagnosed in normally developing children when their reading skills are substantially below the expected level of their chronological age, measured intelligence, and educational opportunities (Curtin, Manis & Seidenberg, 2001; Stanovitch, 1989; Vellutino, Fletcher, Snowling & Scanlon, 2004). Individuals with DD typically exhibit poor performance in recognizing printed words, as well as in spelling and reading comprehension (Lyon, 1995; Rack, Snowling & Olson, 1992; Schiff & Raveh, 2006; Stanovitch, 1991). And this relatively low reading performance typically persists into adulthood (Bruck, 1992; Elbro, Nielsen & Peterson, 1994; Gallagher, Laxon, Armstrong & Frith, 1996; Raveh & Schiff, 2008; Snowling et al, 1997).

Ample evidence indicates that the core problem in DD involves inadequate representation and use of phonological information (Joanisse et al, 2000; Morris et al., 1998; Serniclaes, Sprenger-Charolles, Carré & Demonet, 2001). This phonological deficit may be responsible for failure to achieve high lexical quality in word representation, resulting in degraded reading comprehension (Perfetti, 2007). Recent studies indicate that dyslexics have difficulties at higher levels of general language development and experience syntactic processing limitations (Smith, Macaruso, Shankweiler & Crain, 1989). While these limitations might be the outcome of a lesser exposure to written language in children with DD (Bryant, 1995), longitudinal studies of preschool children at genetic risk for dyslexia reveal slower

development in lexicon and syntax (Lyytinen et al., 2001; Scarborough, 1991; Snowling, Gallagher & Frith, 2003) – suggesting an underlying linguistic impairment.

These problems are particularly apparent at the interface of literacy and morphological processing (Hauerwas & Walker, 2003; Leong, 1999; Nippold, 2002). As morphological units such as roots and affixes are typically represented in orthographic systems (Derwing, 1992; Ravid, 2005), morphology plays a crucial role in school age lexical and literacy development (Carlisle, 1995; Nagy, Berninger & Abbot, 2006). Recent cross-linguistic work suggests that morphological knowledge bootstraps reading processes, while reading ability promotes and enhances the efficiency of morphological analysis (Kuo & Anderson, 2006). The importance of morphological knowledge for reading increases throughout the school years side by side with the growth of the literate lexicon (Carlisle, 2000; Shankweiler, et al., 1995; Singson, Mahony & Mann, 2000;), and the increase in multi-morphemic words necessitating morphological analysis (Anglin, 1993; Mann, 2000). Bishop & Snowling (2004) in fact claim that the relationship between language impairment and dyslexia can be captured in a single model encompassing phonological, morphological, semantic and syntactic processes.

Processing morpho-syntactic information such as verb-subject agreement has been shown to be problematic for children suffering from DD, attributed to deficient syntactic processing resulting inter alia from limitations on verbal working memory (Rispens et al, 2004). This situation may be exacerbated in a highly synthetic language such as Hebrew (Bolozky, 1999; Ravid, 2003; Schwarzwald, 2002), where language users need to seek meaning within the word and to relate words via

morphological components (Gillis & Ravid, 2006; Ravid & Schiff, 2006; Schiff, Raveh & Kahta, 2008). The rich inflectional system of Hebrew assigns values for gender and number on nouns and adjectives (together with person and tense marked on verbs, person, number and gender inflections on prepositions, and optional morphology marking on nouns and verbs). Structurally, this system exhibits varied and complex stem and suffix allomorphy (e.g., *lev / levav-ot* 'heart / s'), which extend the morpho-phonological distance between free and bound forms (Levin et al, 2001; Ravid & Schiff, 2009, in press).

Several studies have noted poorer morphological abilities in Hebrew-speaking dyslexic adults. In a study of dyslexic and normal readers' perception of vowel letters in different morphological contexts, Schiff and Ravid (2004) found that dyslexics did less well and took more on accurate lexical decisions, with some deviant patterns indicating that they could not make use of written morphological cues available to normal readers. In a study using a morphological analogy task, Schiff and Ravid (2007) showed that dyslexic adults performed on par with 4th graders, and had more associative responses than they did - testifying to the reduced morphological abilities of dyslexics. Two priming studies (Raveh & Schiff, 2008; Schiff & Raveh, 2006) examined whether dyslexic adults compared with chronological and reading age controls were able to extract and represent morphemic units, showing that the dyslexic group responded well to auditory morphological stimuli but not to visual ones during word recognition. A morphological study by Ben-Dror, Frost and Bentin (1995) found a group of Hebrew-speaking grade school children with severe reading problems to be inferior to both age-control and reading-control groups.

Taken together, these findings strongly indicate that investigating the quality of morphological processes in Hebrew-speaking individuals with dyslexia is of considerable interest both theoretically and methodologically. If dyslexia does indeed involve impairment at the word-form level, it is important to specify the effect of this impairment on processing performed at higher levels of the lexical system, such as extraction of morpho-phonological information at both the written and spoken modality (see Ravid, 2012, for the detailed conceptualization of spoken and written Hebrew morphology on which this study is based). The current study aims to address this issue by investigating plural noun inflection and plural adjective agreement in dyslexic adult University students, compared with normally reading peers, on the one hand, and typically developing 6th graders, on the other.

NOUN AND ADJECTIVE PLURALS

As an inflectional system, plural marking is characterized by high token frequency, general and obligatory applicability (Bybee, 1985; Dressler, 1989), and they are therefore prominent in language usage, “a constant presence” in both speech and writing (Bybee, 2006). Semantically, plural inflection exhibits transparency, regularity, and predictability. At the same time, plural systems are fraught with morphological and morpho-phonological complexity, inconsistency and irregularity, which challenge processing.

Hebrew noun plurals too demonstrate the semantics / structure dichotomy. Pluralizing Hebrew nouns is a linear process of stem suffixation, with plural suffixes incorporating information about number and gender. Plural formation is determined by two factors – (i) the inherent gender and (ii) the phonological marking of the

singular noun. Singular masculine nouns end with a consonant, e.g., *tik* 'bag', *séfer* 'book', or with a final stressed *–e*, as in *mixse* 'lid'[i]. Singular feminine nouns are phonologically marked by stressed –a, e.g., *mita* 'bed', or by suffixes ending in *–t*[ii], such as *xanut* 'shop'. Regular plural suffixation takes note of both noun gender and phonology. Thus, masculine nouns take the plural suffix *–im*, e.g. *pil* / *pilim* 'elephant/s', while feminine nouns take the plural suffix *–ot*, as in *pila* / *pilot* 'elephant/s,Fm'.

One complicating factor in pluralizing Hebrew nouns is irregular number/gender suffixation. Thus, some masculine nouns take the feminine suffix *-ot*, e.g., *kir* / *kirot* 'wall/s', *sulam* / *sulamot* 'ladder/s', *rexov* / *rexovot* 'street/s', instead of the expected but incorrect *kirim*, *sulamim*, and *rexovim* respectively. In the same way, some feminine nouns take masculine plural *-im*, e.g., *beytsa* / *beytsim* 'egg/s', *mila* / *milim* 'word/s', *shana* / *shanim* 'year/s', instead of the regular, and incorrect, *beycot*, *milot*, *shanot* respectively. In some other cases, irregular suffixation results from a clash between noun gender and noun phonology, as in the case of *tsipor / tsiporim* 'bird/s' or *xatser* / *xatserot* 'courtyard/s'. Both these feminine nouns end with a consonant, like masculine nouns, but Hebrew speakers have to apply irregular masculine *-im* to the former and regular feminine *–ot* to the latter. Such lexical exceptions and misleading phonology constitute stumbling blocks to young children acquiring Hebrew pluralization (Berman, 1981; Ravid, 1995; Ravid & Schiff, in press).

A second complicating factor is the fact that plural inflection may trigger stem change. Plural suffixation, like all linear nominal operations in Hebrew, shifts noun stress to the final syllable created by the conjunction of the suffix and the final

consonant of the stem, as in *tik* / *tikím* ‘bag/s’, *dégel* / *dgalím* ‘flag/s’. Many stems in the Hebrew lexicon remain unchanged under suffixation, as in the cases of *rexov* / *rexovot* ‘street/s’, *xut* / *xutim* ‘thread/s’. However, morpho-phonological stem changes may apply in plural nouns, such as vowel reduction, deletion, or change, stop / spirant alternation, and *t* omission. For example, singular *rakévet* ‘train' drops the final *t* before attaching the plural suffix, to yield plural *rakavot*. In some cases, nouns may both change stem structure and take irregular suffixation. For example, masculine *iparon* / *efronot* 'pencil / s' has an irregular feminine suffix, and in addition, it demonstrates three stem changes: vowel change (*i* → *e*), vowel deletion (*a* → Ø), and stop-spirant alternation (*p* → *f*).

Plural marking on adjectives

A second plural category investigated in this study is marking attributive Hebrew adjectives for plural agreement with nouns in the noun phrase, which follow the head noun and agree with it in number and gender. Adjectives are relational terms which characterize the attributes, properties or states of nouns (Lyons, 1977). In many languages, adjectives agree with the noun they modify in number and gender; and, in other languages (e.g., French, Latin, Hebrew), also in additional values such as definiteness or case. When gender marking on nouns is not transparent learning adjective agreement is difficult for both L2 adults (Kempe & Brooks, 2001) and monolingual children (Kempe & Brooks, 2003).

The less robust psycholinguistic nature of adjectives (Markman, 1989) and the fact that they represent non-essential information is mirrored in their slower emergence and acquisition (Blackwell, 2005; Mintz & Gleitman, 2002; Waxman & Klibanoff,

2000). Adjectives also constitute an extremely low-frequency class when compared to other content words in children's early lexicons in various languages (Mintz, Newport & Bever, 2002; Sandhofer, Smith & Luo, 2000).

Hebrew adjectives[1] share structural features with both nouns and verbs (Berman, 1988; Ravid & Levie, 2010). They appear in two major syntactic positions – as NP modifiers and as sentential predicates. In their attributive function, NP-modifying adjectives follow the head noun and obligatorily agree with it in gender, number, and definiteness, e.g., *ha-sirot ha-levan*ot 'the-boats,Fm the-white,Pl,Fm' = the white boats'. In their predicative function, adjectives agree with the subject noun in gender and number, but not in definiteness, e.g., *ha-sirot hayu levanot* 'the-boats,Fm were white,Pl,Fm'.

Marking plural agreement on Hebrew adjectives is an obligatory inflectional process that is part of the core morphology (Schwarzwald, 2002). At the same time, this is a challenging operation requiring command of complex morpho-phonological and syntactic variables. These features of the domain designate plural adjective agreement with nouns as a rich arena for an investigation of morphological knowledge and processing in individuals with dyslexia, with the view to determine to what extent dyslexia involves linguistic and / or processing impairment.

When the inherent grammatical gender of the noun matches its plural suffix, marking plural agreement on the adjective is straightforward. Thus, for masculine *sir* 'pot' and adjective *gadol* 'white', the plural NP 'big pots' would be *sirim gdolim* 'pots

[1] Focus here is on *lexical* rather than *grammatical* adjectives. The latter denote modal functions (.e.g., *asur* 'forbidden'), occur only as predicates in constructions lacking overt NP subjects, and do not carry any agreement marking.

big,Pl'; for feminine *sira* 'boat' the plural phrase would be *sirot gdolot* 'boats,Fm big,Pl,Fm'. But in case of clash between the plural noun suffix and its grammatical gender, adjective agreement follows noun grammar rather than the formal suffix. For example, masculine *kir* 'wall' takes an irregular feminine plural suffix –*ot* to yield *kirot*, but the adjective would take its plural agreement from the inherent gender of the noun. The plural phrase 'white walls' would then be *kirot levanim* 'walls,Fm big,Pl,Masc', with conflicting suffixes on the noun and on the adjective. Observation shows that it is not only children who often mark such adjectives erroneously, following the surface noun suffix (Berman, 1985), but also adults in casual conversation and even in writing. Partially predictable suffixes, which display misleading formal cues (e.g., feminine *kos* 'glass', which lacks feminine marking), have been shown to be even more difficult for young children and to continue to challenge Hebrew speakers throughout adolescence (Ravid & Schiff, in press; Ravid et al., 2008). Moreover, Hebrew nouns often undergo stem changes when inflected (or derived), as in *rakévet / rakavot* 'train / s' or *ish / anash-im* 'person / Pl' (Ravid, 2006; Schiff, Ravid & Levy-Shimon, 2011).

Against this background, we hypothesize that opaque noun morphology will hinder correct assignment and slow down adjective agreement in individuals with dyslexia. We assume that individuals with DD suffer from impaired phonological and morpho-syntactic processing which become apparent when demands are made on verbal working memory (Crain & Shankweiler, 1990), as in our adjective agreement task. We hypothesize that such demands will be exacerbated by the morpho-phonological structure of the head noun with which the adjective agrees. Two kinds of problems

are foreseen in this context, with different implications for the studied populations: The first is suffix irregularity, a lexical feature that needs to be learned from exposure to (mainly) written language (Ravid & Schiff, in press) – where individuals with dyslexia may be hindered by reduced exposure to written texts, and thus exhibit delay in morphological ability. A second issue is attention to stem change in the pluralized noun, which is not always apparent in the non-voweled orthography, and may thus represent inherent phonological problems unrelated to degree of exposure to written language, in fact, a deficiency (Rack, Snowling & Olson, 1992).

Our study design targets these issues by comparing the dyslexic University students to two control groups: (i) matched by chronological age to normally reading peers and (ii) matched by reading level to a group of normally developing 6th graders. Previous studies focusing on grade schoolers' ability to perform morphological tasks such as solving root and pattern analogies (Ravid & Schiff, 2006) showed that by 6th grade, typically developing children performed almost at ceiling. In contrast, dyslexic university students showed lower morphological abilities than their peers on the same tasks (Schiff & Ravid, 2007). Thus, we could make the following predictions. In comparison to their chronological peers, the dyslexics are predicted to score lower in accuracy on both nouns and adjectives, and take more time in reacting to the full plural phrase. Moreover, where performance requires reading ability and exposure to written language, as in choice of suffix, we predict that dyslexic adult students should perform at least like normally developing 6th graders, matched by reading levels; and where performance hinges on phonological abilities mostly unrelated to

written language exposure, that is, stem change, we predict that they do worse than the 6th graders.

METHOD

Participants

The study population consisted of 90 participants in three groups: 30 normally reading university students, 30 dyslexic university students, and 30 normally reading 6th grade students. Participants were all native, monolingual speakers of Hebrew from middle-high SES background. The 6th graders (mean age: 12;4; SD: 3.2) had no diagnosed language, reading or learning disabilities. They were matched to the dyslexic students by reading level on a word-reading task (Schiff & Kakhta, 2006). The dyslexic University students were randomly selected from a group of undergraduate students involved in a learning disabilities support group, whose members had been assessed as having reading disabilities within three years prior to attending university or while attending university, to verify dyslexia. The normally reading comparison group consisted of volunteer participants, all undergraduates who were accepted into the control group if they perceived themselves as average readers, with no history of learning or reading problems, who were not taking any medication, and had not repeated a grade. There was an equal number of males and females in the three groups, and the age range of adult participants was 20–26 (Israeli students are typically older than their American and European peers, in view

of the fact that they only start University after a military service of 2–3 years). Mean age was 23;5, SD=1.83.

Materials

Noun Selection. The task consisted of 32 singular noun-adjective pairs, e.g., *tof gadol* 'drum big = big drum', or *isha tova* 'woman good,Fm = good woman'. Nouns were classified into four categories by suffix type (regular and irregular) and by stem type (non-changing and changing). Half of the nouns were masculine, and half – feminine. Nouns were selected by the following process: 30 teachers were asked grade a list of 50 nouns taken from grade school texts on a scale of 1-5 in terms of familiarity to grade school children. We discarded nouns considered by the teachers as completely unfamiliar and very familiar, and ended up with a list of nouns which had received the rank of 3-3.5 out of 5 on the scale. The full list on task nouns appears in Appendix I.

Adjective Selection. Only four adjectives were used in conjunction with the nouns – *gadol* 'big', *lavan* 'white', tov 'good', *shaket* 'quiet', all well-known, everyday adjectives familiar to children. Since Hebrew adjectives may also undergo stem change, we made sure that the target adjectives either had non-changing stems (*tov / tovim* 'good / Pl') or else shared *a*-deletion, as demonstrated in the plural forms of *gadol* / *gdolot* 'big / Pl.Fm', *lavan* / *levanim* 'white / Pl', and *shaket/ shketot* 'quiet / Pl,Fm'. This type of stem change is a very early acquisition in Hebrew-speaking children (Ravid, 1995; Ravid & Shlesinger, 2001). When tested on the task items, all of the participants from both SES backgrounds made the correct stem change on the three *a*-deleting adjectives.

Procedure

Participants were tested orally and individually in the spring (that is, 3 months before the end of the school year) in a quiet room at their school or at the university. Administration was computerized, as follows. Each participant was presented with a set of four training noun-adjective pairs, two masculine and two feminine, two with regular suffixes and two with irregular suffixes, two with non-changing and two with changing stems. These pairs were presented in auditory form in singular and subsequently in plural form by the computer software, e.g., *ner lavan* 'candle white', many *nerot levanim* 'candles white,Pl'. After training, the actual experiment started. Participants heard 32 singular noun-adjective pairs as stimuli. Each stimulus singular NP was read aloud by the computer software, and the participant was asked to say it aloud in plural form. For example, given the stimulus *olam gadol* 'world big = big world', participants were expected to say *olamot gdolim* 'worlds big,Pl = big worlds', that is, to pluralize the noun and to mark plural agreement on the adjective. Each response was audio-taped and transcribed by attending investigators (MA students majoring in Education). The computer software marked the onset of the participant's response. Presentation of the stimulus and the online recording of the responses were controlled by the SuperLab software program. Table 1 presents the structure of the Plural Noun-Adjective Task.

INSERT TABLE 1 ABOUT HERE

Scoring. Noun plurals were scored on correctness (accuracy) of stem and plural suffix. Adjectives were scored on accuracy of suffix, as related to noun stem and suffix. In addition, we measured reaction time to correctly producing the whole

plural noun phrase. Only full responses were analyzed. All scores were converted to percentages. When 15% of the recorded responses were checked by two different judges to ensure reliability, virtually all were found correctly coded (α = .92).

RESULTS

We present results in three sections. First, we report the results on accuracy of noun plurals. This is followed by the results on accuracy in applying plural agreement to adjectives; and finally we report reaction time to producing the whole plural noun phrase. Where interactions are described, we report only results significant at the .05 level following Bonferroni post-hoc pairwise comparisons.

Noun plurals: Accuracy

Table 2 presents **correct** responses on the four categories of noun plurals in the three populations.

INSERT TABLE 2 ABOUT HERE

We conducted a three-way ANOVA of Population (3) x Stem type (2) x Suffix type (2) on the data in Table 2. Population was significant ($F(2,87)=14.58$, $p<.001$, $\eta_p^2=.25$), and the Bonferroni post-hoc analyses showed that normally reading students did the best (M=99.74%), while the two other groups did significantly worse, and did not differ from each other (Reading Disabled University Students M=96.58%, Normally Reading 6th Graders 97.08%). Stem Type was marginally significant ($F(1,87)=3.92$, $p=.051$, $\eta_p^2=.04$): Nonchanging stems scored higher (M=98.13) than changing stems (M=97.47). Suffix Type was significant ($F(1,87)=28.56$, $p<.001$, $\eta_p^2=.25$): Regular suffixes scored higher (M=98.84%) than irregular suffixes (M=96.76%). All two-way interactions were significant –Stem x Population ($F(2,87)=3.63$, $p<.04$, $\eta_p^2=.08$), Suffix

x Population ($F(2,87)=6.37$, $p<.004$, $\eta_p^2=.13$), depicted in Figures 1 and 2, and 3 respectively. Stem x Suffix also interacted ($F(1,87)=13.59$, $p<.001$, $\eta_p^2=.14$), showing that the locus of difficulty was in the changing-stem irregular suffix category. The three-way interaction was not significant.

PLEASE INSERT FIGURES 1 & 2

According to Figure 1, 6th graders and dyslexic University students did less well than normally reading students on both types of stems; but the crucial point is that while 6th graders had similar scores on both stem types, the reading disabled students did less well on changing stems.

According to Figure 2, 6th graders and dyslexic University students did less well than normally reading students on both types of suffixes; but here, both 6th graders and reading disabled students did less well on irregular than on regular suffixes.

Adjective agreement: Accuracy

Table 3 presents **correct** responses on plural adjective agreement according to the four categories of noun plurals in the three populations.

INSERT TABLE 3 ABOUT HERE

We conducted a three-way ANOVA of Population (3) x Stem type (2) x Suffix type (2) on the data in Table 3. Population was significant ($F(2,87)=18.27$, $p<.001$, $\eta_p^2=.3$), and the Bonferroni post-hoc analyses showed that all three groups differed from each other: Normally reading students did the best (M=98.75%), followed by Normally Reading 6th Graders 95.63%, and finally Reading Disabled University Students with M=91.04%. Stem Type of the noun plural form was significant ($F(1,87)=9.32$, $p<.004$,

η_p^2=.1): adjectives in agreement with nouns having nonchanging stems scored higher (M=96.04%) than changing stems (M=94.24%). Suffix Type was significant (F(1,87)=42.42, p<.001, η_p^2=.33): adjectives in agreement with nouns having regular suffixes scored higher (M=98.47%) than irregular suffixes (M=91.81%). Suffix interacted with population (F(2,87)=6.13, p<.004, η_p^2=.12), as depicted in Figure 3. As before, Stem interacted with Suffix (F(1,87)=17.1, p<.001, η_p^2=.16), showing again in adjective agreement that the locus of difficulty was in the changing-stem irregular suffix category. There were no other interactions.

PLEASE INSERT FIGURE 3 ABOUT HERE

According to Figure 3, 6th graders and dyslexic University students did as well as normally reading students on adjectives agreeing with nouns carrying regular suffixes; however, 6th graders did less well on adjectives in agreement with irregular than regular suffixes, and in the reading disabled students this difference is even more pronounced.

Reaction Time

Table 4 presents RTs to **correct** responses on production of the full plural noun phrase according to the four categories of noun plurals in the three populations.

INSERT TABLE 4 ABOUT HERE

We conducted a three-way ANOVA of Population (3) x Stem type (2) x Suffix type (2) on the data in Table 4. Population was significant (F(2,87)=16.5, p<.001, η_p^2=.28), with the post-hoc Bonferroni showing that the three populations differed significantly from each other as follows: Normally reading University students took the least time to produce a correct plural phrase (M=754.61), followed by 6th grade

normal readers (M=970.05), and Reading disabled University students took the most time (M=1221.57). Stem Type was significant ($F(1,87)=4.75$, $p<.04$, $\eta_p^2=.05$): Plural phrases based on nouns with nonchanging stems took less time to produce (M=955.02) than did phrases with changing stems (M=1009.14). Suffix Type was not significant, however both the Population x Stem and Population x Suffix interactions were significant ($F(2,87)=12.1$, $p<.001$, $\eta_p^2=.22$ and $F(2,87)=5.69$, $p<.006$, $\eta_p^2=.12$ respectively. Most important, the Population x Stem x Suffix interaction was significant ($F(2,87)=4.35$, $p<.02$, $\eta_p^2=.09$), as shown in Figure 4.

INSERT FIGURE 4 ABOUT HERE

According to Figure 4, the normally reading students, on the one hand, and the 6th graders, on the other, do not show differences among the four noun categories. However, not only do the reading disabled students have longer RTs than bothother populations, they show differences between the two most difficult noun categories carrying irregular suffixes, and this difference is especially marked in the category with changing stems and irregular suffixes.

Discussion

The current study compares morpho-syntactic abilities in three groups of participants – normally reading University students, reading disabled University students, and a group of 6th graders matched to the reading disabled students on reading ability. On all three measures – accuracy of noun plurals, accuracy of adjective agreement, and RT – the reading disabled University students did significantly worse than their normally reading peers. These results confirm our main hypothesis regarding the diminished morpho-syntactic abilities of our adult dyslexic population. Moreover, the dyslexic adults did significantly worse than the 6th graders

on accuracy of adjective agreement – that is, on knowledge of irregular suffixation, and they took significantly longer than 6th graders in pluralizing the full NP, a task that requires attention to stem changes and the ability to relate morphologically distant stems. These results thus point to problems in domains related to morphology, i.e., both lexicon and phonology. Based on the interactions found in noun plurals, adjective plurals and reaction time to the whole phrase, we elaborate these findings below.

In making required stem changes in plural nouns, the reading disabled students did less well than even 6th graders. Recall that stem changes are learned across the school years (Ravid & Schiff, 2009, in press; Schiff, Ravid & Levy-Shimon, 2011). Thus the dyslexic adults seem to be deficient rather than delayed on the important structural facet of morphology, i.e., its interface with phonology (Ravid, in press) at two levels. First, they have problems at representing the individual phonological distinctions that underlie morpho-phonological stem changes. For example, the *i* in the free stem *dli* 'bucket' changes to *a* in its bound plural form *dlay-im*, while *misgéret* / *misgar-ot* 'frame/s' requires attention to both change in vowels from *e* to *a* as well as to *t* deletion. These conclusions are corroborated by independent new findings on deficient phonological abilities in Hebrew-speaking dyslexic populations (Schiff, Ravid & Halabi, 2011), while reflecting the insight that, across many different languages, development ushers in the perception of smaller and finer phonological distinctions (Demont & Gombert, 1996; Durgunoglu & Oney, 1999; Harris & Giannouli, 1999; Siok & Fletcher, 2001). At the same time these finding indicate a problem at a higher, more integrative level, where adults dyslexics are less able than both age-matched and reading-matched peers to relate the free and bound forms of

stem-changing noun plurals. That is, in a language where lexical quality involves creating many robust pairings of morpho-phonologically related allomorphs, dyslexic individuals have less coherent and stable lexical representations than even their much younger reading peers.

The analysis of irregular suffixation in noun plurals contributes to this interpretation of a less coherently organized lexicon in dyslexics. Our findings indicate that the dyslexic adults did less well than age-matched typically reading students on irregular suffixation, and in that dimension they did not differ from the 6th graders, that is, typically developing younger and dyslexic older participants are less able to retrieve the irregular plural forms of nouns. This finding is significant both at the level of representing individual nouns in the lexicon, as well as deriving generalizations from such irregularities which might create dense architectures across the lexicon. To illustrate this point, consider the fact that all *CiCaCon* and *CiCCon* masculine nouns take irregular feminine suffixation, as reflected in the *iparon / efronot* 'pencil / s' item in our task. The more words in this pattern in an individual's lexicon, the greater her ability to draw a generalization and inflect the next *CiCaCon* noun correctly despite its irregularity. This less efficient lexical ability probably derives from less exposure to written language on the part of younger, typically developing children who will go on to construct a robust lexicon based on literacy experience with age and schooling, but which apparently cannot be expected in the dyslexic university students who must laboriously make their knowledge gains at the face of lexical deficiency.

The results on marking plural agreement on adjectives and on reaction time to the whole plural phrase contribute another perspective to the accumulated evidence regarding reduced linguistic processing abilities and lesser performance efficiency in reading disabled adults. For one thing, adjectives agreeing with nouns bearing irregular plural suffixes achieve lowest scores in the dyslexic population, less than in the reading-matched 6th graders. This reflects a lower processing ability in the adult dyslexics, since irregular suffixes require the simultaneous retrieval of the singular noun form in order to determine its inherent gender so as to correctly inflect the adjective in agreement with it. But in addition, the dyslexic adults not only take the most time on responding to the whole plural phrase, much slower than their younger reading peers, they also have the highest RTs on the changing stem and irregular suffix category - analyzed and discussed in length in Ravid & Schiff (in press) and Schiff & Ravid (2011). This category contains nouns such as feminine *ir* / *ar-im* 'city / s', where adjective inflection depends crucially on the ability to carry out a chain of checking activities. These consist of pairing the stem-changed plural allomorph with its free singular noun form so as to determine lemma identity and consequently with its inherent gender despite opposite marking on the plural noun, culminating in the assignment of the agreement suffix to the adjective. For example, producing the phrase *kcavot xadim* 'sharp edges' involves pairing the bound plural form *kcav-* to its singular form *kace* ending with masculine *–e,* thus determining that the adjective should take the masculine plural suffix *–im* despite the obvious mismatch with the irregular noun plural suffix *–ot.* Such an operation of identifying and promoting one type of suffix at the expense of conflicting information takes

time, especially when working with a less coherent lexical and morpho-phonological structure.

In general, we found that adult students with DD performed more poorly on both regular and irregular nouns, with irregulars (in the sense of irregular suffixes and stem changes) being the most challenging for them and for the younger controls. In some ways, it seems like the dyslexic group was generally similar to younger controls in some ways (e.g., regularity effects in adjectives and nouns), but not in others (noun stem effects). Likewise they tended to show slower RTs than both control groups. The obvious difference between the two groups is the fact that the younger controls are on a typical path of development (e.g., gaining mastery over stem changes) and are thus expected to reach the level of the adult controls, while the adult DDs are not expected to show a further developmental trajectory. Our results may thus tentatively point to deviance in the DD students' morphological abilities in the sense of not having made the expected developmental gains by adulthood.

One reservation that needs to be noted regarding our results is the fact that while were able to control the familiarity score of the test items, we could not assure that the irregular forms were closely matched to the regular forms on a full range of psycholinguistic variables such as token frequency, imageability; orthographic or phonological complexity. This is because noun plurals with irregular suffixes and / or changing stems follow gender-specific patterns, with each sub-category in the list of possible items having special characteristics (Ravid & Schiff, in press). We followed these patterns rigorously in our choice of items, nevertheless this is one limitation of our study that needs to be taken into account.

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Stem type	**Nonchanging stem**		**Changing stem**	
Stem gender	**Masculine**	**Feminine**	**Masculine**	**Feminine**
Regular suffix	*tik* 'bag' *tik-im* 'bags'	*matana* 'present' *matan-ot* 'presents'	*tof* 'drum' *tup-im* 'drums'	*dim'a* 'tear' *dma'-ot* 'tears'
Irregular suffix	*kinor* 'violin' *kinor-ot* 'violins'	*beyca* 'egg' *beyc-im* 'eggs'	*kace* 'edge' *kcav-ot* 'edges'	*ir* 'city' *ar-im* 'cities'

Table 1. Structure of the four noun categories in the noun-adjective task

Group	No-change Stem Regular suffix	Changing Stem Regular suffix	No-change Stem Irregular suffix	Changing Stem Irregular suffix
Normally Reading 6th graders	99.84 (0.85)	98.02 (4.06)	95.78 (5.91)	94.69 (5.98)
Normally Reading University students	99.79 (1.14)	100 (0)	100 (0)	99.17 (2.16)
Reading Disabled University students	97.66 (3.04)	97.71 (3.28)	97.29 (4.51)	93.65 (6.06)

Table 2. Mean correct percentages and standard deviations on the formation of noun plurals, by noun category (stem and suffix type) and population

Group	No-change Stem Regular suffix	Changing Stem Regular suffix	No-change Stem Irregular suffix	Changing Stem Irregular suffix
Normally Reading 6th graders	99.58 (2.28)	98.75 (3.81)	93.75 (13.43)	90.42 (13.0)
Normally Reading University students	99.58 (2.28)	100 (0)	99.17 (3.17)	96.25 (7.45)
Reading Disabled University students	97.5 (5.06)	95.42 (6.13)	88.75 (8.9)	82.5 (13.37)

Table 3. Mean correct percentages and standard deviations on the formation of adjective plural agreement, by noun category (stem and suffix type) and population

Group	No-change Stem Regular suffix	Changing Stem Regular suffix	No-change Stem Irregular suffix	Changing Stem Irregular suffix
Normally Reading 6th graders	910.75 (357.16)	993.82 (344.51)	959.43 (400.44)	1016.21 (450.66)
Normally Reading University students	758.68 (240.3)	744.28 (211.08)	738.62 (185.41)	776.86 (306.94)
Reading Disabled University students	1098.64 (347.34)	1124.12 (403.8)	1217.62 (460.82)	1445.92 (492.92)

Table 4. Mean reaction times (in milliseconds) and standard deviations to correct responses on the formation of the full noun phrase, by noun category (stem and suffix type), population, and grade

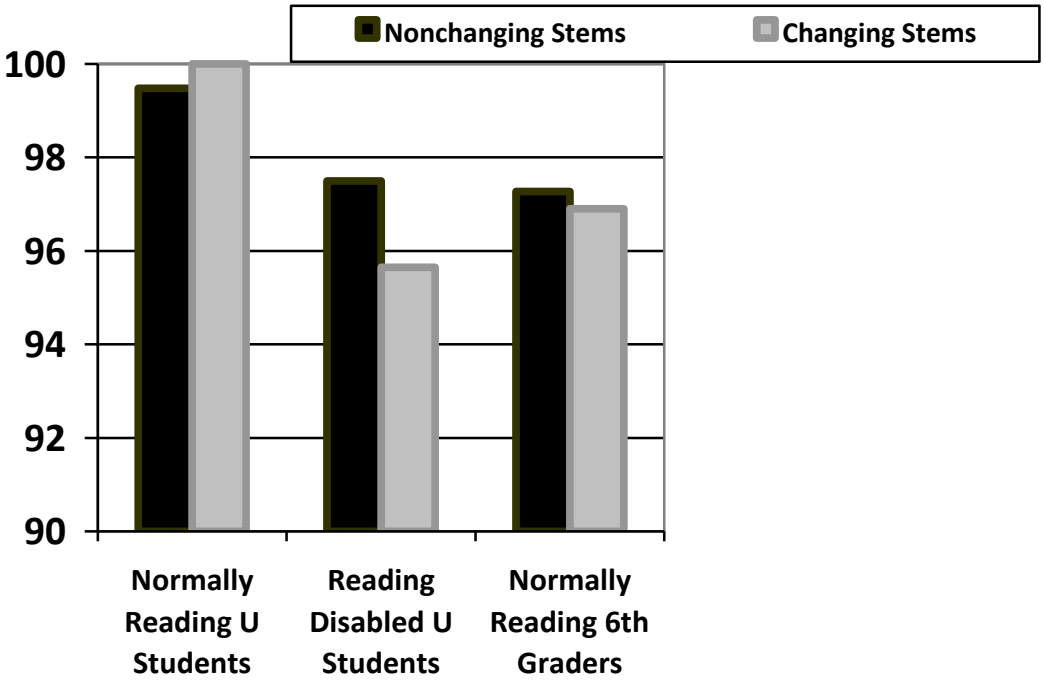

Figure 1. Interaction of Stem and Population in noun plurals

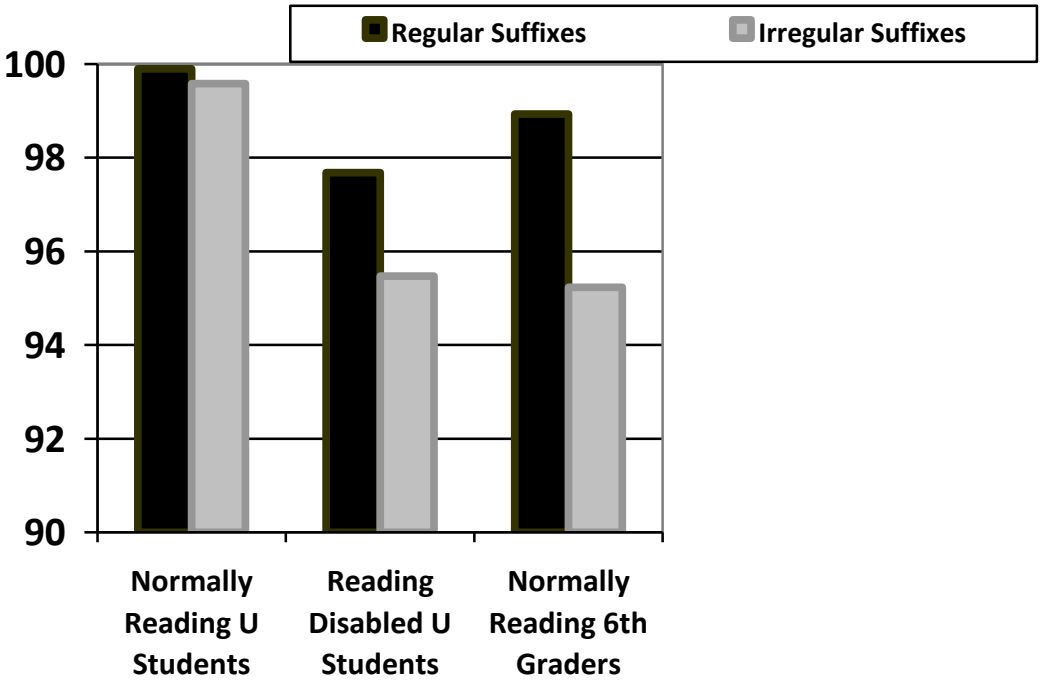

Figure 2. Interaction of Suffix and Population in noun plurals

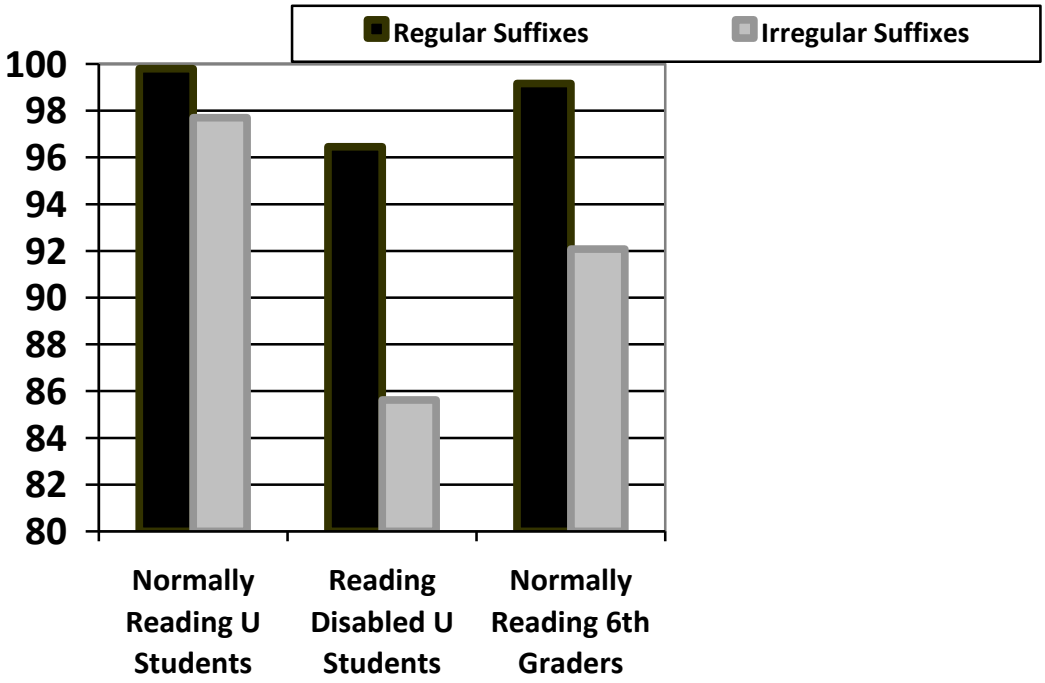

Figure 3. Interaction of Suffix and Population in adjective agreement with noun plurals

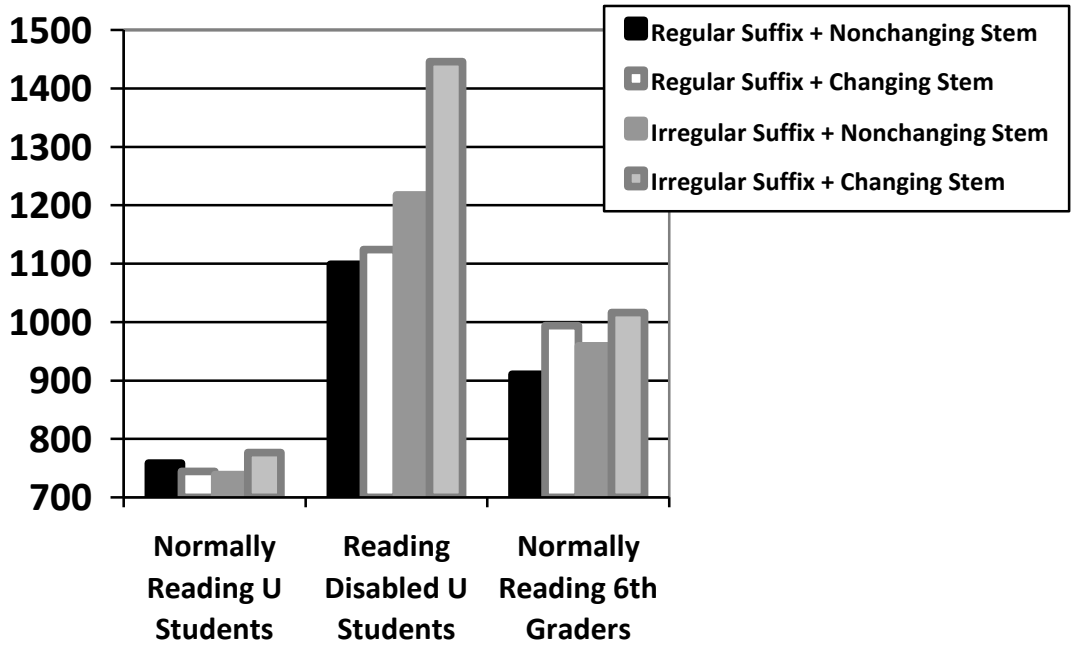

Figure 4. Interaction of Population, Stem and Suffix in Reaction Time to the full phrase

APPENDIX

32 Target Nouns (singular / plural forms, gloss in singular)

Nonchanging stem, regular suffix, masculine

pil / *pil-im* 'elephant', *xatul* / *xatul-im* 'cat', *tik* / *tik-im* 'bag', *agas* / *agas-im* 'pear'

Nonchanging stem, regular suffix, feminine

xulca / xulc-ot 'shirt', *matana* / *matan-ot* 'present', *smixa* / *smix-ot* 'blanket', *sira* / *sir-ot* 'boat'

Nonchanging stem, irregular suffix, masculine

kinor / kinor-ot 'violin', *olam* / *olam-ot* 'world', *sulam* / *su*lam-*ot* 'ladder', *sade* / *sad-ot* 'field'

Nonchanging stem, irregular suffix, feminine

beyca / *beyc-im* 'egg', *shana* / *shan-im* 'year', *pnina* / *pnin-im* 'pearl', *nemala* / *nemal-im* 'ant'

Changing stem, regular suffix, masculine

tof / *tup-im* 'drum', *cel* / *clal-im* 'shadow', *dli* / *dlay-im* 'bucket', *shor* / *shvar-im* 'bull'

Changing stem, regular suffix, feminine

ta'ut / ta'uy-ot 'error', *kalétet* / *kalat-ot* 'cassette', *dim'a / dma'-ot* 'tear', *misgéret* / *misgar-ot* 'frame'

Changing stem, irregular suffix, masculine

lev / *levav-ot* 'heart', *kace* / *kcav-ot* 'edge', *iparon* / *efron-ot* 'pencil', *régesh* / *regash-ot* 'feeling'

Changing stem, irregular suffix, feminine

tola'at / *tola'-im* 'worm', *dérex* / *drax-im* 'way', *ir* / *ar-im* 'city', *isha* / *nash*-im 'woman'

4 Target Adjectives (masculine singular / plural / feminine plural)

tov / *tovim* / *tovot* 'good'; *gadol* / *gdolim* / *gdolot* 'big'; *lavan* / *levanim* / *levanot* 'white'; *shaket* / *shketim* / *shketot* 'quiet'

[i] Stress is unmarked except in penultimate position, as final stress is default in Hebrew (Segall, Nir-Sagiv, Kishon-Rabin & Ravid, 2008).

[ii] This refers only to non-root *–t* spelled ת (Ravid, 2005).