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Typological effects on spelling development: a crosslinguistic study of Hebrew and Dutch*

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ABSTRACT

This study investigates the role of phonological and morphological information in children's developing orthographies in two languages with different linguistic typologies: Hebrew, a Semitic language with a highly synthetic morphology, and Dutch, a Germanic language with a sparse morphology.

192 Israeli and 192 Belgian monolingual schoolchildren in grades 1–6 (aged 6;0–12;0) were administered respective dictation tasks in which homophonous segments were the targets. In each language, these phonologically distinct segments are neutralized phonetically but are nevertheless represented orthographically. In both languages the target segments in the test words differed along two dimensions: (1) their morphological function as part of a stem or root versus as part of an affix; and (2) their morphophonological recoverability. The spelling tests in both languages consisted of four conditions which differed in the number and type of cues for retrieving the correct spelling of homophonous graphemes. The cues were of two types: morphological cues, which offer spellers clues to the correct spelling through consistent orthography/morphology mapping regularities; and

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morphophonological cues, which offer spellers clues to the correct spelling through the manipulation of orthography/morphophonology conversion procedures.

A central finding of this study is the differential treatment of morphological cues by Dutch and Hebrew spelling learners. When faced with neutralized segments with and without morphological function, Hebrew-speaking children find morphology an enormously helpful tool. Dutch-speaking children, in contrast, do not find morphology a good cue provider. The impact of typology on the interface between spoken and written language is invoked as an explanation of the main findings.

INTRODUCTION

The study discussed in this paper examines how children acquiring Hebrew and Dutch learn their respective orthographies, and in what ways their acquisition is constrained by the respective typologies of these two languages. In recent years linguists and psychologists have shown growing interest in the linguistic nature of alphabetic orthographic systems, in their psycholinguistic representation in adults (Derwing, 1992) and in their developmental history in children learning to read and write (Treiman, Cassar & Zukowski, 1994; Kemp & Bryant, 2003; Pacton & Fayol, 2004). In this paper we focus on the role of phonological and morphological information in children's developing orthographies in two languages with different linguistic typologies: Hebrew and Dutch. Hebrew is a Semitic language with a rich synthetic morphology and a 'deep' or opaque orthography. Dutch, in contrast, is a Germanic language with a sparse morphology and a relatively 'shallow' or transparent orthography. However, both have alphabetic orthographies based on the grapho-phonemic principle, requiring learners to plot out and map grapheme–phoneme pairs. Due to phonological neutralizations, both orthographies contain homophonous graphemes, which provide alternative spellings for the same phoneme and constitute sources for spelling errors. The paper investigates how children acquiring Hebrew and Dutch use morphological and morphophonological cues in learning to spell homophonous segments in their respective systems.

The development of written representations in schoolchildren is treated in this paper from two main perspectives. One focus is a crosslinguistic examination of the psycholinguistic factors which account for the way children learn to perceive, integrate and map linguistic information onto orthographic segments. We show that spelling development is linguistic in nature and involves learning and integrating a variety of linguistic units and constructs. Spelling is thus not a mere school-learned skill, but rather a problem-space children explore, an object of knowledge they have to

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conceptualize in the process of developing linguistic literacy (Karmiloff-Smith, 1992; Ravid & Tolchinsky, 2002). It consists of knowledge about the nature of the particular orthography as a notational system in a number of dimensions, integrating grapho-phonemic links, orthographic–internal consistencies, and aspects of morphological units encoded in the system (Ravid, 2001). These dimensions are discussed below.

A second focal point relates to the impact of typological features on spelling development. Recent crosslinguistic research has demonstrated the powerful impact of target-language typology on the process of acquisition from early preschool age in a range of domains, revealing that from very early on children are sensitive to the 'typological imperatives' of their language. That is, even very young children recognize 'where the action is at', so to speak, in the input language (Berman, 1986). Recently Slobin (2001: 441–442) has developed the idea of TYPOLOGICAL BOOTSTRAPPING in language acquisition, showing how competing forces in the history of each language brings about its particular typological character. Children exposed to input from a specific language develop in the natural course of language acquisition what Slobin calls 'explanatory systems' of their language system, which direct children inexorably towards typologically characteristic patterns of conceptual categorization and organization, lexicalization and grammaticization. The current paper carries the investigation of the typological imperative to the domain of written language as a notational system.

In this study we examine the impact of morphological typology on spelling acquisition and strategies in children learning Hebrew, a Semitic language with a highly synthetic morphology, and Dutch, a Germanic language with a sparse morphology. Both formal and functional aspects of morphology are encoded in the Hebrew and Dutch spelling systems, and need to be explored by young learners. It is reasonable to assume that Israeli and Belgian children will approach this task using different strategies and at differing paces.

Perspectives on the development of written representation

Far from being a mere technical skill, spelling is now perceived in the psychological and psycholinguistic literature as a window on what an individual knows about words, and the acquisition of spelling is regarded as a process of conceptual and linguistic learning (Templeton & Morris, 2000). It is now well established that spelling development does not start with formal school instruction: preschoolers already have concepts of print and theories about the nature of notational systems (Karmiloff-Smith, 1992). Many empirical studies document the emergence and consolidation of children's alphabetic systems (Ellis, 1994) in three major developmental

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stages: PRE-PHONETIC WRITING, involving logographic or symbolic writing, with early pre-phonetic attempts (Levin & Korat, 1993); PHONETIC WRITING, essentially breaking the grapho-phonemic code which associates graphemes with phonemes; and ALPHABETIC or ORTHOGRAPHIC WRITING, which involves incorporating morphological components into the spelling (Nunes, Bryant & Bindman, 1997; Ravid, 2001; Kemp & Bryant, 2003; Pacton & Fayol, 2004). The current study examines the developmental shift from stage II to stage III from the beginning to the end of gradeschool.

Studies in a variety of languages with diverse writing systems indicate that in its initial stages, phonetic and orthographic spelling develops alongside and in interaction with other facets of linguistic literacy, especially phonological and morphological awareness (Bryant, Nunes & Aidinis, 1999; Cheung, Chen, Lai, Wong & Hills, 2001). There is evidence that these skills both promote and are promoted by learning to read and write through the establishment of links between phonemes, syllables and morphemes and their written representations (Levin, Ravid & Rappaport, 2001). Morphological awareness contributes to success in the beginning phases of literacy instruction since morphology links together phonology and semantics (Sénéchal, 2000; Ravid, 2002). Children continue to gradually establish more systematic links between phonological and morphological constructs and their written representations in grade school (Gillis & De Schutter, 1996; Nunes *et al.*, 1997; Totereau, Thevenin & Fayol, 1997; Ravid, 2001). In subsequent stages of becoming efficient readers and writers, the most important morphological aptitude in English learners is the growing ability to segment, extract and discuss stems and affixes (Henry, 1993). By the age of 10;0 children are able to manipulate linguistic facets of spelling, such as rhymes, puns, phonology–orthography mismatches, morphological components and syntactic class (Ravid & Bar-On, 2005). In general, recent crosslinguistic and language-specific studies have shown that morphology is important in the development of reading and writing skills, though to differing degrees and in different ways in typologically different languages (Ku & Anderson, 2003; Ravid, 2005).

Knowledge domains in spelling development

Knowledge of alphabetical orthographic systems develops in four domains: mapping phonology onto graphemic segments; learning about internal conventions of the orthographic system; learning about morphological regularities in the spelling system; and mapping morphophonological segments onto written representation. In order to acquire mature knowledge of one's orthography, a learner has to be aware of these different orthographic domains, to construct their cognitive representations and be able to retrieve them at will, and to map this knowledge onto the specific orthography being

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learned. As we show below, developing spelling perception is mediated by typological traits of the language being learnt.

Phonology

Alphabetic orthographies require children to plot out and map grapheme–phoneme pairs. Mastering this principle is termed by Olson (1994: 263) 'an intellectual achievement' whereby the child construes the graphic model as a model of speech. According to this view, phonological representations do not exist explicitly in the child's mind before the onset of literacy: it is the interaction with an alphabetical notational system that creates such cognitive representations. Acquiring explicit phonological representations is a protracted process which involves the gradual extraction of abstract and discrete phonological segments from online continuous and co-articulated speech (Cheung *et al.*, 2001). Moreover, children's phonological representations are causally related to their progress in literacy development (Wagner, Torgesen & Rashotte, 1994).

Moreover, most orthographies are not entirely 'shallow', that is, they do not represent phonological information fully and accurately. Homophonous graphemes, which provide alternative spellings for the same sound (e.g. English ⟨ce⟩, ⟨s⟩, ⟨ss⟩ for [s]), frequently occur in many orthographies. Therefore, plotting out the spelling of specific words and learning to spell systematically also means learning to overcome opacity in mapping phonemes onto graphemes. The two languages investigated in this study differ in their 'orthographic depth', yet both have homophonous graphemes.

Hebrew. As a result of historical neutralizations, Modern Hebrew pronunciation does not bear a one-to-one relationship with its orthography. The latter has remained virtually unchanged for the last 2000 years, and reflects phonological consistencies in earlier historical periods (Ravid, 2005). There are two types of one-to-many relationships between current Hebrew phonology and its spelling system: a number of phonemes are each expressed by two graphemes, reflecting historically distinct segments.[1] For example, [t] is spelled as either Ŧ (Hebrew ט) or as T (ת). Conversely, three letters denote two distinct phonological segments, a stop and a spirant, e.g. the letter B (ב) indicates both [b] and [v].

Dutch. For Dutch native words, a similar observation can be made: a one-to-many relationship between segments and graphemes holds between, for instance, the segment [t] (underlying /t/ or /d/) and the graphemes ⟨t⟩ and ⟨d⟩. At the end of a word voiced segments are devoiced: /d/ and /t/

[1] To ensure readability, we will use both Hebrew letters and their Latin counterparts when discussing the Hebrew orthography. For example, the Hebrew letter ג (Gimel) will also be represented by the Latin character G. Note that we use 9 to represent the letter *ayin* ע, standing for the voiced pharyngeal fricative.

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are both pronounced as [t]), but the underlying phonological opposition /t/ – /d/ is retained in the orthography. This regularity holds for stops and fricatives. Regarding vowels, a one-to-many relationship holds, for instance, between the grapheme ⟨e⟩ and the segments [e], [ɛ] and [ə]: ⟨e⟩ stands for [e] and [ə] in ⟨schepen⟩ /sχepən/ 'ships', and for [ɛ] in ⟨schelp⟩ /sχɛlp/ 'shell'.

Internal orthographic conventions

Alphabetic orthographies are governed by internal principles and consistencies that have to be figured out by learners. Some of these, in the form of letter sequences such as English ⟨tion⟩ or ⟨ceive⟩, obviously have a privileged role in learning. There is evidence that children learning deep orthographies such as those of English and French make implicit use of such orthographic regularities (Pacton, Perruchet, Fayol & Cleeremans, 2001; Kemp & Bryant, 2003).

Orthographic consistencies are often linguistic in nature and include information about how and where to segment content and function words. For example, English and Dutch use capital letters to indicate both proper nouns and sentence boundaries (Treiman & Kessler, 2004), while German marks all nouns by capitals. Hebrew and Arabic, in contrast, indicate word boundaries by certain final versus medial letters. French articles are usually written separated from the noun they modify (e.g. ⟨la fille⟩), but in certain cases they are attached to it (e.g. ⟨l'eau⟩). In Hebrew, morphemic function letters include prefixes attached to the next word, as in the string [ve-ala] 'and-went up', spelled ⟨W9LH⟩ ועלה (Ravid, 2001, 2005). An important facet of alphabetical orthographies is the fact that they do not always assign the same weight to the representation of consonants and vowels (Coulmas, 1989).

Dutch. Dutch, like all languages using Latin and Cyrillic script, represents both consonants and vowels consistently by letters. Thus, in Dutch, /bɑnan/ 'banana' is written as ⟨banaan⟩. Moreover, the phonological opposition between long and short vowels is represented in the Dutch orthography as ⟨a⟩ versus ⟨aa⟩ (for some vowel-pairs, e.g. /ɪ/ and /i/, this is represented differently: ⟨i⟩ versus ⟨ie⟩), though not in a transparent way, since this phonological opposition is mediated by an autonomous spelling rule relying on orthographic open and closed syllables. Hence, long /a/ is written as ⟨a⟩ in an open syllable and as ⟨aa⟩ in a closed syllable.

Hebrew. Hebrew has two orthographic versions. One version, VOCALIZED orthography, represents both consonants and vowels. Consonants are represented by letters, vowels by both diacritic marks and letters. This 'transparent' version is restricted, however, to children's and new immigrants' texts, Biblical texts and poetry. A second and less transparent

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version, NON-VOCALIZED orthography, represents all consonants, while vowels are partially and ambiguously represented by the four letters ⟨AHWY⟩, Hebrew אהוי. For example, Hebrew spells /banana/ as ⟨BNNH⟩ בננה with only the final /a/ represented in writing. This orthography is the default version of written Hebrew, used across the board for most purposes (Share & Levin, 1999). While Israeli children's books are vocalized up to about 4th grade reading level, children themselves do not readily use vocalizing diacritics in their writing, and by 4th grade find them superfluous in reading as well (Ravid, 2005). The Hebrew spelling test used in this paper used non-vocalized spelling.

We now turn to two more orthographic aspects that relate formal and functional aspects of morphology to spelling.

Morphology

Morphological regularities are often expressed in alphabetic orthographies. For example, the English adjective suffix ⟨-ic⟩ has three different phonetic values in ⟨electric⟩, ⟨electricity⟩, and ⟨electrician⟩ ([k], [s], and [š] respectively), but is spelled consistently with the same letters ⟨ic⟩. Morphologically motivated orthographic sequences such as ⟨ic⟩, ⟨tion⟩ or ⟨ance⟩ can be assumed to exist in the linguistic cognition of mature spellers and to facilitate conventional spelling despite the disrupted phoneme-to-grapheme mapping (Templeton & Morris, 2000).

The role of morphological knowledge in spelling is related to the degree of morphological wealth in the language system, and to its prominence in the orthography (Bybee, 1995). Recent studies indicate an interaction between language typology and the use of spelling strategies (Ravid, 2001, 2002). For example, the novice English speller is not required to pay much attention to morphological information: the core everyday English lexicon which children acquire early on is largely mono-morphemic, with sparse inflectional morphology and little derivational morphology. Thus, complex patterns of letter co-occurrence guide early spelling in English (Kemp & Bryant, 2003). In early gradeschool, young English learners acquire the spelling of past-tense ⟨-ed⟩ in well-documented stages which take its grammatical function into account only towards the end of the process (Nunes *et al.*, 1997). In contrast, Russian first graders, learning a morphologically complex language, already spell homophonous segments indicating 1st declination nouns and nominatives flawlessly; while adults even deny the possibility of making spelling errors in such segments (Rusakova & Ceytlin, 1999).

French provides yet another example of the interface of morphosyntax with spelling, since it has a largely 'silent' plural morphology, sparsely represented in speech while being richly represented in the orthography. In

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a series of studies, Fayol and his associates have shown how French-speaking children who are not attuned to morphological distinctions when they start learning to spell learn the spelling patterns for marking plural nouns and verbs (Totereau *et al.*, 1997; Pacton & Fayol, 2004). Morphology is crucially important to the current study, since the two languages under investigation differ in the degree of their morphological syntheticity, which may affect spelling patterning in development.

Hebrew. The highly synthetic nature of Hebrew is reflected in its written form, which represents a variety of morphemes in fairly consistent ways. The central Semitic lexical-morphological unit, the consonantal root, has stable written representation despite surface phonological alternations. For example root *k-t-b* 'write' presents stop/spirant alternation in [mixtav] 'letter' (spelled ⟨MKTB⟩ **מכתב**), [ktav] 'writing' (⟨KTB⟩ **כתב**), and [ktuba] 'marriage contract' (⟨KTWBH⟩ **כתובה**). But the corresponding written letter ⟨K⟩ **כ** remains consistent, which helps learners in perceiving roots as morphemes despite the abstractness and unpronounceability of the spoken root (Ravid, 2002; Ravid & Bar-On, 2005).

The effect of morphology in Hebrew extends much beyond the root. Affix letters – inflectional, derivational and clitic morphemes – are all spelled regularly and consistently. For example, Hebrew [t] has two alternative spellings: ⟨T⟩ **ת** and ⟨Ŧ⟩ **ט**, representing a neutralized emphatic coronal stop. However, affixal [t], as in the past-tense first person singular suffix *-ti*, is always spelled ⟨T⟩ and never ⟨Ŧ⟩. Research has shown that Hebrew speakers make use of this information from early on, and that consequently affix letters are spelled correctly earlier than root letters in Hebrew (Ravid, 2001, 2005).

Dutch. The morphological structure of Dutch words is highly concatenative, i.e. consists of juxtaposed morphemes. Compounds and derivations are abundantly used in Dutch. Inflection is fairly restricted, and generally involves coronal obstruents or nasals and/or a schwa (De Schutter, 1994). As in Hebrew, a morphological principle guides the spelling of Dutch words. The 'principle of similarity' in the official 'Woordenlijst Nederlandse taal' states that 'a word, stem, prefix or affix is always written in the same way' (1997: 17), and 'the principle of resemblance' states that 'words that are formed in the same way are written in the same way' (p. 18).[2] For the first principle this means that ⟨goed⟩ 'good' is pronounced with a final [t], but it is spelled with a final ⟨d⟩ because of the ⟨d⟩ spelling in inflected and derived forms such as ⟨goedig⟩ or ⟨goede⟩. For the second principle this means that ⟨grootte⟩ 'size' is spelled with a geminate ⟨t⟩ despite phonological degemination, because the same morpheme ⟨te⟩ is

[2] The document that stipulates the principles of the spelling of Dutch words and lists the correct spelling of a representative number of word forms.

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added to the stem in words such as ⟨dikte⟩ 'thickness', ⟨hoogte⟩ 'height', ⟨breedte⟩ 'breadth'. In other words, Dutch orthography abstracts away from the effects of phonological rules such as final devoicing, voice assimilation, and other rules of connected speech, in order to preserve morpheme identity.

This results in morphologically transparent word forms in the orthography. For instance, the simple present, third person singular is formed by adding the suffix ⟨t⟩ to the stem of the verb (except when the stem ends with a ⟨t⟩). Thus 'he plays' is written in Dutch as ⟨hij speelt⟩ (⟨speel⟩ + ⟨t⟩); 'he answers' is spelled ⟨hij antwoordt⟩ (⟨antwoord⟩ + ⟨t⟩); and the exception is 'he eats', which is not written with a final geminate: ⟨hij eet⟩ (instead of ⟨hij eett⟩).

Although morphosyntactic rules such as these are simple and straightforward, Dutch-speaking children and adolescents (and even university students) find it extremely difficult to spell verb forms such as ⟨antwoordt⟩ correctly, while the word forms ⟨speelt⟩ and ⟨eet⟩ are hardly ever spelled incorrectly (Sandra, Frisson & Daems, 1999).

Morphophonology

In addition to encoding meaning-carrying morphemes, alphabetic orthographies also express morphophonological information in systematic ways. This information may be used to recover underlying phonological distinctions. For example, number distinction in French third person pronouns ⟨il⟩ versus ⟨ils⟩, like many morphological markings in French (Totereau *et al.*, 1997), is expressed in writing alone, but LIAISON with the initial vocal of the next word provides a clue to the existence of an underlying distinction (⟨il a⟩ vs. ⟨ils ont⟩). English geminates constitute another example: written gemination, which takes place under morphological operations (e.g. ⟨hopped⟩ versus ⟨hoped⟩) is associated with a short vowel rather than a diphthong in the free stem (e.g. ⟨hop⟩ versus ⟨hope⟩). This can be used to determine the spelling of the stem.

Hebrew. There are two main routes in Hebrew to recover neutralized phonological distinctions represented in the spelling, and both involve extracting morphophonological segments, analysing them and comparing morphologically related words. One has to do with comparing stop/spirant pairs. Modern Hebrew alternates stops [p, b, k] with their spirant counterparts [f, v, χ] as in [mixtav] 'letter'/[ktuba] 'marriage contract', root *k-t-b*. Some of these alternants are homophonous with other phonological segments. For example, [x] may derive from either a spirantized /k/, spelled ⟨K⟩ כ, or from /ħ/ (pharyngeal fricative) neutralized to [χ], spelled ⟨Ħ⟩ ח. Being able to juggle word forms in one's mind to see if the spirant in the word alternates with a stop may help in selecting the correct letter in

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spelling. Since [χ] in [miχtav] alternates with [k] in words sharing the same root such as [ktav] 'writing' or [ktovet] 'address', it can be assumed that it is spelled with ⟨K⟩. In contrast, the [χ] in [maχšev] 'computer' never alternates with [k] in any position in related words, e.g. [χišev] 'computed', [χašav] 'thought', [hitχšavut] 'consideration', therefore it should be spelled with ⟨Ħ⟩.

Another type of morphophonological clue in learning to spell Hebrew involves vowel lowering. Though pharyngeals and glottals are no longer pronounced in mainstream Israeli Hebrew, they nonetheless continue to operate at the morphophonological level, mainly by attracting low vowels in their environment. For example, [dereχ] 'road' and [keraχ] 'ice' share the same pattern *CéCeC* as well as a final segment [χ]. This segment derives from a spirantized /k/ in [dereχ], which accounts for the spelling ⟨DRK⟩ דרך; and from a neutralized pharyngeal fricative /ħ/ in [keraχ], which accounts for both the deviant phonological form *CéCaC* with the low vowel [a], as well as for the spelling ⟨QRĦ⟩ קרח. The association of low vowels, especially [a], with one of the possible letters may aid in choosing the correct spelling.

Dutch. One of the main morphophonological clues that can be used in Dutch involves 'undoing' the final devoicing of voiced segments at the end of a word: the voiced segment surfaces when it is pronounced in intervocalic position. For instance, the final devoiced [d] in [av∂nt], written as ⟨avond⟩ ('evening'), surfaces in the plural [av∂nd∂], and the final devoiced [d] in the verbform [ɑntwort] ⟨antwoord⟩ ('answer') surfaces in the simple past form [ɑntword∂].

Given this background, our study investigates the domain of spelling acquisition in two languages with differing typologies: Hebrew, a Semitic language with a rich morphology and a 'deep' orthography, and Dutch, a Germanic language with a sparse morphology and a 'shallow' orthography.

The phenomenon

Despite the typological and orthographic differences between Hebrew and Dutch, they share the same phenomenon: phonologically neutralized segments. We are interested in the ways Dutch- and Hebrew-speaking children employ morphological and morphophonological cues in order to spell homophonous graphemes representing phonologically neutralized segments.

For different reasons, certain phonological distinctions in both Dutch and Hebrew are neutralized, yet these segments are mapped onto distinct graphemes. Such 'deep' phonology-to-orthography mapping constitutes an obstacle to the acquisition of orthographic, or conventional, spelling. For example, Dutch ⟨arend⟩ (/arɛnt/, 'eagle') and ⟨agent⟩ (/ɑγɛnt/, 'officer')

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share a final [t] in speech due to final devoicing, however written Dutch retains the ⟨t⟩/⟨d⟩ distinction in the spelling. Similarly, although Hebrew [tarim] (/tarim/, 'lift, Imp') and [ta'im] (/ta'im/, 'tasty') share an initial [t] due to historical neutralization processes, written Hebrew makes a distinction between the spellings: ⟨TRYM⟩ תרים and ⟨Ŧ9YM⟩ טעים, following the historical phonological distinction.

As we have shown above, both morphology and morphophonology can provide learners with means for recovering the grapho-phonemic link in cases of opacity due to homophony. A useful clue might be the morphological distinction between root and affix letters in Hebrew and stems and affixes in Dutch. In principle, a homophonous root radical in Hebrew may be spelled by either one of the possible graphemes, e.g. root [χ] may be spelled by either ⟨H⟩ ח or ⟨K⟩ כ. Moreover, children may not always succeed in identifying a less transparent root link between words, as between [dereχ] 'road' and [darkon] 'passport' (Ravid, 2002). The large number of Hebrew roots, the differing degrees of semantic relatedness between words sharing the same root, and the frequent occurrence of homophonous letters in roots all make learning to spell roots correctly a long and arduous task which requires a large vocabulary and repetitious encounters with word-families sharing the same written root. In contrast, learning to spell function letters is a simpler matter. The number of homophonous function letters is small, each designates a fixed set of affixes and is mapped onto them transparently, consistently and regularly. A homophonous affix segment (e.g. the coordinator [ve-]) is always represented by only one of the two possible graphemes (in this case ⟨W⟩ ו). Therefore, Hebrew roots are predicted to be more difficult to spell than Hebrew affixes.

A similar prediction can be made for Dutch stems and affixes. Only a small set of letters are used as affixes – regular verb forms can only take ⟨t, d⟩ and ⟨te, de⟩ as affixes and other word classes can only be inflected with a limited number of suffixes, such as ⟨e⟩, ⟨en⟩ and ⟨s⟩, if inflected at all. Since the morphological rules are extremely simple and transparently reflected in the orthography, spelling inflected words should be much easier, as compared to spelling stems.

Another type of clue is morphophonological in nature and involves manipulating word structure so as to determine its spelling. As we explained above, accessing the written Dutch ⟨t/d⟩ distinction in devoiced [arɛnt] ⟨arend⟩ 'eagle' versus [αγɛnt] ⟨agent⟩ 'officer' can be done through pluralizing these nouns to ⟨arenden⟩ and ⟨agenten⟩ respectively. Similarly, one possible cue in retrieving the underlying distinction in Hebrew [dereχ] 'road' and [keraχ] 'ice' is to note the deviant vowel pattern in [keraχ] 'ice', which results from vowel lowering associated with the underlying pharyngeal segment spelled ⟨H⟩. Though these cues are rather complex to formulate explicitly, there is independent evidence that they exist in the

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linguistic cognition of mature spellers and are eventually accessed by children (Ravid, 2005).

Comparing Dutch and Hebrew spelling

Crosslinguistic comparisons of spoken language acquisition are well known in the literature, and constitute an essential tool for tracing universal versus language-specific developmental patterns as well as for empirically testing the validity of theoretical models of linguistic processing and representation. Such comparative studies focus on first-order cognitive and linguistic entities such as early distinctions between nouns and verbs, temporal and spatial notions, or encoding of transitivity values.

While comparing reading development in different languages is fairly straightforward, crosslinguistic comparisons of the development of spelling knowledge are still scarce (Bryant *et al.*, 1999). One major reason is that such studies involve a comparison of second-order linguistic phenomena, which is neither an obvious nor a straightforward task. Comparing different notational systems has to take into account the transformations involved in converting spoken into written entities, constrained by language typology, cultural systems, and historical change. For example, the non-vocalized Hebrew orthography reflects the highly synthetic nature of the spoken system; it is rather opaque, strictly traditional and has not changed in the last 1000 years (Ravid, 2005). In contrast, Dutch orthography is vocalized, and reflects the relatively impoverished inflectional morphology of the spoken language. Unlike Hebrew, it has undergone several drastic spelling reforms in the last century, in which phonological transparency has been one of the major guiding principles (Nunn, 1998).

Thus the phenomena compared in this study are similar, but not identical, and therefore a further transformation was called for. Our methodological design created identical conditions which made it possible to compare second-order linguistic phenomena in Hebrew and Dutch.

METHODOLOGY

The methodological core of this study is a dictation task for each of the two languages, comprised of four conditions, in which the presence of morphological and morphophonological cues was systematically monitored.

Participants

The study population consisted of 192 Israeli and 192 Belgian monolingual schoolchildren from grades 1–6 (in both countries children were aged

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6;0–7;0, 7;0–8;0, 8;0–9;0, 9;0–10;0, 10;0–11;0, and 11;0–12;0).[3] The children were all native speakers of Hebrew and Dutch respectively, from middle-high socio-economic background. They were tested in their classrooms in the north of Israel and in the Dutch-speaking part of Belgium. Educational backgrounds were comparable: Kindergartens in Israel and Belgium do not engage in explicit reading or writing instruction, though literacy-preparatory activities are part of the kindergarten curriculum. Many kindergarteners in both countries recognize alphabet letters in their respective languages, and they know how to write their own names and possibly some other words. In both countries, children are taught to read and write intensively from first grade onwards. Israeli children do not receive explicit instruction in spelling, though their teachers practice occasional spelling instruction when they feel the circumstances call for it. In Belgium, in contrast, it is common practice to have explicit spelling instruction and training in spelling-rules from third grade onwards. Instances of rule governed spelling involving morphosyntactic rules are listed among the compulsory attainment goals for primary schools. See Ravid & Gillis (2002) for more details on literacy practices in the two populations.

Procedure

Dictations were carried out in the full class forums in both countries. Participants received a response sheet on which the spelling test was printed and asked to spell the target words, presented in a sentential context to ensure clear and non-ambiguous understanding. Each carrier sentence contained one target word (containing one target grapheme). After the complete sentence had been read to them at a relatively slow pace by the experimenter, the participants filled in the blank spaces with the target word. The purpose was to give participants sufficient time to write down the spelling of each word without granting them too much verification time. After the final sentence was completed, the response sheets were immediately collected.[4] The whole process took between 45 minutes in the younger age groups to 20 minutes in the oldest age groups. The Dutch and the Hebrew spelling tests appear in the Appendix.

[3] Participants' ages were not available in either country because of privacy restrictions on minors participating in educational experimentation. However, we made sure in our respective discussions with class teachers that all participating children fell within the same comparable age ranges given in brackets in all classes.

[4] The Dutch version of the test was printed on two separate sheets, so that one item of each minimal pair was on the first page and the other on the second page. After dictating the last word of the first sheet, the response sheets were collected, so that comparison of the two items was impossible.

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Materials

Condition 1: Morphological and morphophonological cues. In both Hebrew and Dutch, Condition 1 of the spelling tests contained 8 homophonous target segments recoverable through both morphological and morphophonological cues. 'Recoverability' indicates the existence of conversion procedures whereby correct grapho-phonemic mapping is achieved.

In Dutch, Condition 1 consisted of pairs of verbs in present tense and in past participle ending with surface [t] due to final devoicing, e.g. /bə̂tovə̂rt/ spelled ⟨betovert⟩ 'bewitch, present tense'/⟨betoverd⟩ 'bewitch, past participle' with ⟨t⟩ and ⟨d⟩ respectively. There are two ways to recover the difference in the spelling: (1) through morphology, that is present tense spelled with ⟨t⟩, past participle spelled with ⟨d⟩; (2) through morphophonology, by converting the past participle forms to an adjective or to the simple past, [bə̂tovə̂rdə̂] both spelled ⟨betoverde⟩, thus recovering the ⟨d⟩ spelling.

In Hebrew, Condition 1 consisted of pairs of similar-sounding words containing the same segment [v] (neutralized /w/ and /b/) as a function or a root letter. This homophonous [v] may be spelled either by ⟨W⟩ ו or ⟨B⟩ ב, following the historical form of the word. For example, in the form [vair] 'and-city', [v] designates the coordinator 'and', spelled ⟨W⟩ ו. In [uvair] 'and-bright', [v] is a root letter (*cf*. root *b-h-r* 'bright') spelled ⟨B⟩ ב. There are two ways to recover the different spellings: (1) through morphology, since function [v] is always spelled ⟨W⟩ ו, whereas root [v] may take one of the two possible spellings (items balanced in the test). Thus, [vair] 'and-city' will be spelled with ⟨W⟩ ו. (2) Through morphophonology: ⟨W⟩ ו always represents a spirant, whereas ⟨B⟩ ב represents an alternating pair of stop and spirant, which can be detected by morphological conversions. For example, to retrieve the B spelling, [uvair] 'and-bright' may be converted into non-bound [bair] 'bright'. [5]

Condition 2: Morphophonological cues only. Condition 2 contained 8 homophonous items with a morphophonological, but not a morphological, conversion cue for each language.

In Dutch, Condition 2 consisted of pairs of nouns ending with surface [t] due to final devoicing, e.g. ⟨arend⟩ 'eagle'/⟨agent⟩ 'officer'. The final segment is part of the stem, with no separate morphological value, recoverable by pluralization: singular [arɛnt] 'eagle' is pluralized to [arɛndə̂(n)] 'eagles', spelled ⟨arenden⟩; whereas singular [aɣɛnt] 'officer' is pluralized to [aɣɛntə̂(n)] 'officers', spelled ⟨agenten⟩.[6]

[5] [bair] undergoes spirantization after the coordinator 'and', which is prefixed to it.

[6] The /n/, spelled as ⟨n⟩, at the end of a word can be silent after a schwa. Intervocallically /n/ is never silent, but at a word's ending it can be dropped after a schwa, though phonetically speaking there is considerable variation among speakers.

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In Hebrew, Condition 2 consisted of pairs of words in the same morphological pattern, containing a surface [χ] due to neutralization of /ħ/ and spirantized /k/. This identical segment is a root letter in both cases, and therefore morphology does not provide the Hebrew speller with a cue for recoverability; however a morphophonological clue is the low vowel associated with [χ] deriving from /ħ/, spelled ⟨Ħ⟩. This is how the different spellings of the final [χ] in [dereχ] 'road' and [keraχ] 'ice' are recoverable.

Condition 3: Morphological cues only. Condition 3 contained 8 homophonous items with a morphological, but not morphophonological, conversion cue for each language.

In Dutch, Condition 3 consisted of pairs of verbs containing a surface [t], spelled either as a single ⟨t⟩ or a geminate ⟨tt⟩. There is no morphophonological conversion rule, however the members of each pair have distinct morphological functions: [t] spelled as ⟨t⟩ occurs in adjectives, e.g. ⟨verplichte⟩'required, adjective', whereas [t] spelled as ⟨tt⟩ occurs in simple past, e.g. ⟨verplichtte⟩ 'required, simple past'.

In Hebrew, Condition 3 consisted of pairs of words containing a parallel segment [t] spelled as either ⟨T⟩ ת or ⟨Ŧ⟩ ט. There is no morphophonological conversion rule in Modern Hebrew to recover the neutralized /t/ and /t/[7] respectively, however the members of each pair have distinct morphological functions: [t] standing for a function letter is always spelled ⟨T⟩, whereas [t] standing for a root letter may be spelled as either ⟨T⟩ or ⟨Ŧ⟩ (balanced in the test). For example, [kašot] 'hard, Fm, Pl' is spelled ⟨QŠWT⟩ since -ot is a feminine plural suffix; while [mašot] 'oar' is spelled ⟨MŠWŦ⟩ with a final root letter ⟨Ŧ⟩ (root *š-ʊ-ŧ* 'sail').

Condition 4: No Cues. Condition 4 consisted of 8 homophonous segments with two possible spellings with no recoverability through either morphological or morphophonological cues.

In Dutch, the test items were pairs of words containing the diphthong [*ɛɪ*], spelled as either ⟨ij⟩ or ⟨ei⟩, for historical reasons, e.g. ⟨zwijnen⟩ 'pigs'/⟨treinen⟩ 'trains'. This is how minimal orthographic pairs like ⟨leiden⟩ 'guide' and ⟨lijden⟩ 'suffer' are created. Knowledge of the diachrony of Dutch is required in order to find out which of the two alternatives holds: the diphthong /*ɛɪ*/ is spelled as ⟨ei⟩ when it derives historically from Proto-Germanic /*ɑi*/ and as ⟨ij⟩ when it derives from long /i/.

In Hebrew, the test items were pairs of words containing the vowel [i], which may or may not either be spelled by ⟨Y⟩ י, e.g. [min] 'from' spelled ⟨MN⟩ מן compared with [min] 'gender' spelled ⟨MYN⟩ מין. The phonological conditions under which these two spellings occur are either arbitrary or available only to specialists in historical Hebrew phonology.

[7] Representing the historical emphatic coronal stop.

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TABLE 1. *Overview of conditions in the experiment*

Condition	Morphological function	Morphophonological recoverability
1	+	+
2	−	+
3	+	−
4	−	−

The four conditions of the research design were thus systematically varied according to the following scheme in Table 1.

Frequency and familiarity of the selected test items. Since no frequency data were available for Hebrew at the time the test was constructed, the frequency of individual test words was not a variable in the design of the test.[8] Test words were selected on the basis of the authors' intuitions about which words were (reasonably) familiar to primary school children. This selection of words was submitted to an independent ad hoc test.

In order to assess the familiarity of the test words, the following procedure was undertaken. For the Hebrew test words, 63 adults familiar with child language were asked to judge each word on a five-point scale, indicating how familiar they thought it to be for an 8-year-old. The average scores ranged from 3·45 for the words in condition 1, 4·26 in condition 2, 3·99 in condition 3, and 4·31 in condition 4. For Dutch the word list in Kohnstamm, Schaerlaekens, De Vries, Akkerhuis & Froonincksx (1981) was consulted. That list contains 6785 everyday words and provides for each word its familiarity for 6-year-olds. Each word was scored by 160 judges from the Netherlands and the Dutch-speaking part of Belgium. The judges were kindergarten teachers and primary school teachers. The percentages in the table in Kohnstamm *et al.* (1981) were converted to a similar scale as used for the Hebrew data. This yielded a familiarity score of 3·61 for the condition 1 words, 3·90 for the condition 2 words, 3·35 for the condition 3 words and 3·78 for the condition 4 words. The slightly lower percentages could be due to the younger age the judges had to keep in mind.

[8] For Dutch, frequency was included in the design: the CELEX frequency was counterbalanced in the test words. For instance, the words in Condition 1 such as ⟨betovert⟩ (⟨t⟩ item) – ⟨betoverd⟩ (⟨d⟩ item) were chosen in such a way that in two pairs the ⟨t⟩ item was at least twice as frequent as the ⟨d⟩ item according to CELEX, and in the other two pairs the ⟨d⟩ item was at least twice as frequent as the ⟨t⟩ item. In Condition 3, the ⟨t⟩-words were most frequent in three of the four pairs (⟨verwachtte⟩ – ⟨verwachte⟩ is the only pair in which the ⟨tt⟩ has a frequency superior to that of the ⟨t⟩ word: 1174 versus 292). But since there was not matching information about frequency in Hebrew, analyses will not be reported on the effect of frequency.

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The scores for Hebrew and Dutch were submitted to a Mann-Whitney U-test, which showed that there was no statistically significant difference between the scores for the two languages: $z = -1{\cdot}53$, $p < 0{\cdot}13$.

Predictions

Following from the background presented, we made two major predictions. Firstly, we expected that given a neutralized phonological distinction, the more motivated the relationship between phonology and orthography, the better participants' performance should be. 'Motivation' means here relying on two sources of information that can be used: (1) *Morphology*. The target segment may have a morphological function which can be used as a cue to get at the spelling. (2) *Morphophonology*. There may be a particular morphophonological conversion procedure that can be applied so as to figure out how to spell the target letters. Our prediction was that the more motivated the condition, the easier it is to learn, and the concomitant prediction was that the more arbitrary the condition, the more errors. The four test conditions can thus be ordered on an arbitrariness scale from condition 1, the most motivated condition with both morphological and morphophonological cues, through condition 2 and condition 3, each with one type of motivation[9], to arbitrary condition 4.

Secondly, we did not expect any major differences between the learning patterns of Dutch and Hebrew spelling, since children of the same age and schooling level can be assumed to have similar cognitive and linguistic resources, and the underlying phenomenon of spelling homophonous segments is the same in both languages.

Scoring

32 response sheets were randomly selected from each grade. Subsequently they were scored by the authors of this paper, each for her/his native language. Only the target letters within the target words were scored for their correctness. Illegible answers were discarded.

Each correctly spelled target letter received 1 point, and each incorrectly spelled one received 0 points. The number of data points: 12 288 written words by the children.

[9] We did not have solid a priori reasons for ordering Condition 2 vis-à-vis Condition 3: they both have one plus and one minus sign in Table 1.

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RESULTS

General overview of the results

Following our predictions, we compared the success patterns of both study populations on the four test conditions. Table 2 presents the data for Hebrew and for Dutch respectively.

To test our predictions, a (4) condition × (6) grade × (2) language ANOVA was performed on the pooled data, yielding a highly significant result: $F(47, 12\,240) = 50{\cdot}18$, $p < 0{\cdot}01$. The condition effect was significant ($F(3, 12\,284) = 61{\cdot}26$, $p < 0{\cdot}01$); the Grade effect was significant ($F(5, 12\,282) = 148{\cdot}28$, $p < 0{\cdot}01$), showing that on the whole, correct responses increased with age and schooling. The language effect was also significant ($F(1, 12\,286) = 224{\cdot}25$, $p < 0{\cdot}01$): judging from this test, Hebrew-speaking children spell better than Dutch-speaking children. A three-way interaction of grade × language × condition emerged ($F(15, 12\,272) = 3{\cdot}77$, $p < 0{\cdot}01$). Three significant two-way interactions emerged. One was a condition × grade interaction ($F(15, 12\,272) = 8{\cdot}61$, $p < 0{\cdot}01$), showing that condition differentially affects the results per grade. A second significant interaction emerged: language × grade ($F(5, 12\,282) = 6{\cdot}33$, $p < 0{\cdot}01$), which, pooled over the four test conditions, signifies that irrespective of the specific test conditions, children in the two languages perform differently in the spelling test. The third significant condition × language interaction ($F(3, 12\,284) = 330{\cdot}50$, $p < 0{\cdot}01$) which emerged (depicted in Figure 1) proved central to our investigation.[10]

Figure 1 shows that, contrary to our predictions, the four study conditions patterned differently in the two languages. In Hebrew, our predictions were confirmed: the most motivated condition, condition 1, with both morphological and morphophonological cues for spelling, is the easiest for Hebrew-speaking children, followed by condition 2 and condition 3, each with a single motivating cue for recoverability – either morphological or morphophonological. The most arbitrary or the least motivated condition 4 is the hardest. In all conditions, learning is going on and the number of spelling errors is decreasing. However for Dutch our predictions were not confirmed. The two conditions with no morphological cues – condition 4 and condition 2 – are the easiest to learn, and Dutch-speaking children attain close to 90% correct scores in second grade. In contrast, these high correct scores are not even attained in sixth grade in the two morphologically informative conditions, condition 1 and condition 3.

[10] Entering Familiarity into the analysis revealed that Familiarity is indeed a significant factor, however this did not change the significance of the effects reported in the main analysis.

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TABLE 2. *Percentage correct responses per condition* ($N=256$ *possible correct responses in each grade and condition*) *and per language, and the mean success score,* S.D. *and median score* (*on a maximum score of* 8) *averaged over* 32 *participants per grade*

	Condition 1				Condition 2				Condition 3				Condition 4			
	%	Mean	S.D.	Median	%	Mean	S.D.	Median	%	Mean	S.D.	Median	%	Mean	S.D.	Median
Hebrew																
Grade 1	72	5·8	1·5	6	54	4·3	0·9	4	71	5·7	1·1	6	48	3·8	0·9	4
Grade 2	82	6·6	1·2	7	62	4·9	1·1	5	75	6·0	0·8	6	55	4·4	1·2	4
Grade 3	93	7·4	0·8	8	78	6·3	1·4	6	85	6·8	0·9	7	64	5·1	1·2	5
Grade 4	93	7·4	0·8	8	81	6·5	1·5	6·5	81	6·5	1·2	7	74	5·9	1·4	6
Grade 5	96	7·7	0·5	8	90	7·2	1·1	8	91	7·3	0·8	7	87	6·9	1·2	7
Grade 6	98	7·9	0·4	8	91	7·3	1·1	8	90	7·2	0·9	7	89	7·1	1·2	7·5
Dutch																
Grade 1	47	3·8	0·8	4·0	50	4·0	0·9	4·0	45	3·6	0·6	4·0	60	4·8	1·4	4·5
Grade 2	50	4·0	1·0	4·0	80	6·4	1·0	6·0	48	3·8	0·4	4·0	84	6·8	1·2	7·0
Grade 3	50	4·0	1·3	4·0	88	7·0	1·0	7·0	49	3·9	0·4	4·0	88	7·0	1·0	7·0
Grade 4	50	4·0	1·0	4·0	95	7·6	0·6	8·0	53	4·3	0·7	4·0	90	7·2	0·9	7·0
Grade 5	52	4·2	1·1	4·0	95	7·6	0·7	8·0	56	4·5	1·0	4·0	95	7·6	0·8	8·0
Grade 6	59	4·7	1·3	4·0	92	7·4	0·9	8·0	66	5·3	1·3	5·0	96	7·7	0·7	8·0

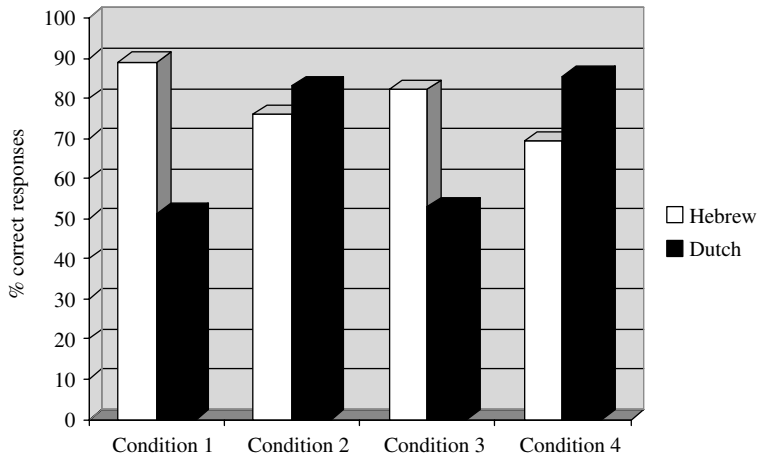


Fig. 1. Interaction of language and condition: percentage correct responses per condition and per language.

Morphological function

Our study contained two conditions with morphological cues: condition 1, doubly motivated by both morphology and morphophonology, and condition 3, by morphology alone. There were two other conditions that were not motivated morphologically: condition 2, with morphophonological cues for recoverability, and the arbitrary condition condition 4. We predicted that morphological function would affect participants from both languages in the same way. In order to do that, we compared the two morphologically motivated conditions with the two unmotivated conditions. Table 3 gives the percentage ($N = 512$/Grade) of correct scores relative to the morphological function of the target segments in Hebrew and Dutch.

To test our predictions, a (2) language × (2) morphological function ANOVA was performed and yielded a significant result: $F(3, 12\,284) = 418{\cdot}08$, $p < 0{\cdot}01$). Morphological function yielded a significant effect ($F(1, 12\,286) = 160{\cdot}24$, $p < 0{\cdot}01$); and there was a significant language × morphological function interaction ($F(1, 12\,286) = 886{\cdot}03$, $p < 0{\cdot}01$), depicted in Figure 2.

Figure 2 shows that again, counter to our predictions, Hebrew- and Dutch-speaking youngsters do not share the same learning patterns. Children learning to spell Hebrew do better when the target segments have a morphological function, and less well when they do not. But children learning to spell in Dutch show the opposite pattern: when the target segments do not have morphological function they score better. A *post hoc* analysis using the Tukey-Kramer HSD revealed that in both languages the

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TABLE 3. *Percentage correct responses per condition* ($N = 512$ *possible correct responses in each grade and in the two morphological conditions*) *and per language, and the mean success score,* S.D. *and median score* (*on a maximum score of* 16) *averaged over* 32 *participants per grade*

	Morphological function (Condition 1 and 3)				No morphological function (Condition 2 and 4)			
	%	Mean	S.D.	Median	%	Mean	S.D.	Median
Hebrew								
Grade 1	71	11·4	1·9	12·0	51	8·1	1·4	8·0
Grade 2	79	12·6	1·6	12·5	58	9·3	1·9	9·0
Grade 3	89	14·2	1·3	15·0	71	11·4	1·9	11·0
Grade 4	87	13·9	1·6	14·0	77	12·4	2·6	12·5
Grade 5	93	14·9	1·2	15·0	88	14·1	2·1	15·0
Grade 6	94	15·1	1·0	15·0	90	14·4	2·0	15·0
Dutch								
Grade 1	46	7·3	1·1	7·5	55	8·8	1·9	8·0
Grade 2	49	7·8	1·1	8·0	82	13·1	1·6	13·0
Grade 3	49	7·9	1·4	8·0	88	14·0	1·7	14·0
Grade 4	52	8·3	1·2	8·0	92	14·8	1·2	15·0
Grade 5	54	8·7	1·6	8·0	95	15·1	1·0	15·0
Grade 6	63	10·0	2·2	10·0	95	15·1	1·1	15·0

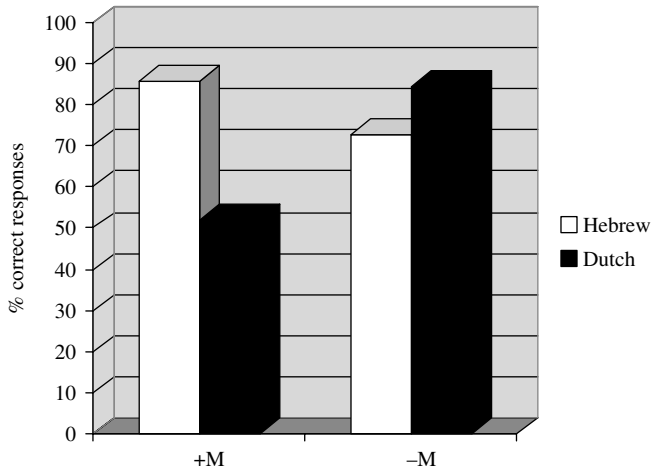


Fig. 2. Interaction of language and morphological function: ⟨+M⟩ stands for segments with a morphological function (condition 1 and 3), ⟨−M⟩ for segments without a morphological function (condition 2 and 4).

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TABLE 4. *Percentage* ($N = 256$/*Grade*) *correct responses in condition* 3 *for Dutch and Hebrew split out for stem/root versus affix letters, and the mean success score,* S.D. *and median score* (*on a maximum score of* 4) *averaged over* 32 *participants per grade*

	Stem/Root				Affix			
	%	Mean	S.D.	Median	%	Mean	S.D.	Median
Hebrew								
Grade 1	48	1·9	0·4	2·0	93	3·7	0·7	4·0
Grade 2	57	2·3	0·8	2·0	93	3·7	0·6	4·0
Grade 3	76	3·0	0·8	3·0	95	3·8	0·5	4·0
Grade 4	71	2·8	0·9	3·0	91	3·7	0·7	4·0
Grade 5	79	3·5	0·6	4·0	95	3·8	0·5	4·0
Grade 6	81	3·3	0·8	3·0	98	3·9	0·4	4·0
Dutch								
Grade 1	88	3·5	0·6	4·0	1	0·0	0·2	0·0
Grade 2	96	3·8	0·4	4·0	0	0·0	0·0	0·0
Grade 3	98	3·9	0·4	4·0	0	0·0	0·0	0·0
Grade 4	98	3·9	0·3	4·0	9	0·3	0·7	0·0
Grade 5	77	3·1	1·1	3·5	35	1·4	1·7	0·0
Grade 6	72	2·9	1·2	3·0	61	2·4	1·5	3·0

difference between segments with and without morphological functions is highly significant ($p < 0{\cdot}01$).

Morphological function or distinction: stems/roots vs. affixes

In order to examine the factor morphological function in greater depth, the results for the test items in condition 3 were further analysed. In the test material for both languages, condition 3 contains word pairs in which the same phonetic segment is spelled differently depending on its function. We hypothesized that in principle it would be easier to learn to spell the same target as an affix letter than as a root or stem letter, since root spelling is arbitrary while affix spelling follows clear spelling rules. Table 4 gives the percentage ($N = 256$/Grade) of correct scores relative to the morphological function (root/stem or affix letters) of the target segments in Hebrew and Dutch.

To test our hypothesis, a (2) language × (2) stem/root – affix ANOVA was performed and yielded a highly significant result for the whole model: $F(1, 3068) = 722{\cdot}81$, $p < 0{\cdot}01$). The effect stem/root – affix was significant, but more importantly, a significant interaction emerged between the morphological distinction and language ($F(1, 3070) = 1336{\cdot}41$, $p < 0{\cdot}01$), depicted in Figure 3.

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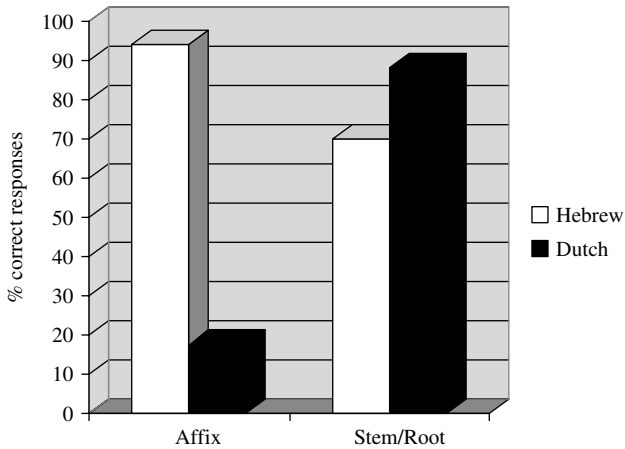


Fig. 3. Interaction of language and stem/root and affix (condition 3).

Figure 3 shows that our analysis yielded a crossover effect: for Hebrew indeed affix letters are significantly better spelled than root letters, as we hypothesized. While root letters start at chance level before learning begins, affix letters are spelled correctly almost from Grade 1 onwards. But for Dutch the opposite pattern emerges: Affix letters are poorly spelled, while the target stem graphemes have significantly better scores. Both letter types start at chance level, but affix letters more or less stay at that level, whereas stem letters show learning early on.

Morphophonological recoverability

Recall that in conditions 1 and 2, Dutch and Hebrew spellers were provided with morphophonological cues which could assist in retrieving the necessary spelling, for example through pluralization in Dutch or through checking for stop/spirant alternation in Hebrew. In conditions 3 and 4 no such clues were provided. Our predictions were that the more morphophonological motivation, the easier the spelling in both languages. Table 5 gives the percentage ($N = 512$/Grade) of correct scores relative to the morphophonological recoverability of the target segments in Hebrew and Dutch.

To test our predictions, a (2) language × (2) morphophonological recoverability ANOVA was performed: $F(3, 12\,284) = 77{\cdot}47$, $p < 0{\cdot}01$). The recoverability effect was significant ($F(1, 12\,286) = 9{\cdot}23$, $p < 0{\cdot}01$) as well as the language effect ($F(1, 12\,286) = 192{\cdot}27$, $p < 0{\cdot}01$) and the language × recoverability interaction ($F(1, 12\,286) = 30{\cdot}90$, $p < 0{\cdot}01$), depicted in Figure 4.

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TABLE 5. *Percentage* ($N = 512$/*Grade*) *of correct scores relative to the morphological recoverability of the target segments in Hebrew and Dutch, and the mean success score,* S.D. *and median score* (*on a maximum score of* 16) *averaged over* 32 *participants per grade*

	Recoverable (condition 1 and 2)				Unrecoverable (condition 3 and 4)			
	%	Mean	S.D.	Median	%	Mean	S.D.	Median
Hebrew								
Grade 1	63	10·1	1·8	10·0	59	9·5	1·2	10·0
Grade 2	72	11·5	1·7	11·5	65	10·4	1·7	10·0
Grade 3	85	13·7	1·9	14·0	75	11·9	1·8	12·0
Grade 4	87	13·9	2·0	14·0	78	12·4	2·4	12·5
Grade 5	93	14·9	1·5	15·5	89	14·2	1·9	15·0
Grade 6	95	15·2	1·3	16·0	89	14·3	1·8	15·0
Dutch								
Grade 1	48	7·8	1·3	8·0	52	8·3	1·5	8·0
Grade 2	65	10·4	1·2	11·0	66	10·6	1·3	11·0
Grade 3	69	11·0	1·8	11·0	68	10·9	1·2	11·0
Grade 4	72	11·6	1·2	11·5	72	11·5	1·1	12·0
Grade 5	73	11·7	1·2	12·0	75	12·1	1·3	12·0
Grade 6	76	12·1	1·5	12·0	81	13·0	1·6	13·0

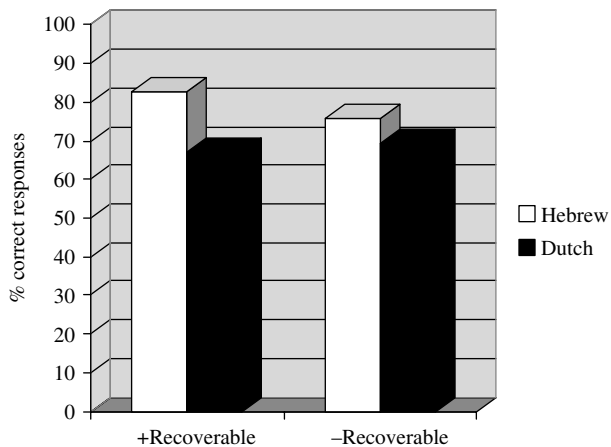


Fig. 4. Interaction of language and recoverability: ⟨+Recoverable⟩ stands for recoverable segments (condition 1 and 2), ⟨−Recoverable⟩ for segments without recoverability (condition 3 and 4).

According to Figure 4, the difference between recoverable and non-recoverable target items in Hebrew is highly significant, and the former are easier to spell than the latter. However, for Dutch the picture is different: the scores for the two types of target items are very close and they do not

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differ significantly. A *post hoc* analysis using the Tukey-Kramer HSD revealed that indeed, the difference between recoverable and non-recoverable items is not significant in Dutch ($p > 0{\cdot}05$), while the difference is highly significant ($p < 0{\cdot}01$) in the Hebrew data. In other words, recoverability leads in Hebrew to significantly better results than non-recoverability, while in Dutch non-recoverable items are slightly (consistently but not statistically significantly) better spelled than their recoverable counterparts.

Markedness

Following from our analysis of morphophonologically recoverable and non-recoverable items, we examined more closely the items within the recoverable condition 2, using only roots and stems and no affixes, so as to separate recoverability from morphological function. The target segments can be divided into marked and unmarked ones: unmarked segments are those for which the pronunciation coincides with the spelling; marked segments are the ones whose pronunciation is neutralized to that of the unmarked segments. Thus, for instance, the [t] in Dutch can be spelled as either ⟨t⟩ or ⟨d⟩ at the end of word. In [tart] (⟨taart⟩, 'cake'), [t] is pronounced and also written as ⟨t⟩. But in [part] (⟨paard⟩, 'horse'), the final segment is [t], which is written as ⟨d⟩. Hence, [t] written as ⟨t⟩ (as in [tart] – ⟨taart⟩) is unmarked ('what you hear is what you write') and [t] written as ⟨d⟩ (as in [part] – ⟨paard⟩) is marked. We predicted that unmarked segments would be more easily acquired than marked ones, because for the unmarked segments children can rely on straightforward sound to letter correspondences: when they hear [t] they write ⟨t⟩, when they hear [d] they write ⟨d⟩, while for the marked segments they cannot rely on those correspondences, like in ⟨paard⟩ where they hear a final [t] but nevertheless have to write ⟨d⟩. We also predicted that children learning to spell in the two languages would reveal the same behavioural patterns. Table 6 gives the percentage ($N = 256$/Grade) of correct scores relative to the markedness status of the target segments in Hebrew and Dutch.

The result of a (2) markedness × (2) language × (6) grade ANOVA was highly significant: $F(3, 3068) = 53{\cdot}68$, $p < 0{\cdot}01$). The main effect markedness was significant ($F(1, 3070) = 11{\cdot}75$, $p < 0{\cdot}01$) as well as the language effect ($F(1, 3070) = 33{\cdot}04$, $p < 0{\cdot}01$) and the grade effect ($F(5, 3070) = 63{\cdot}11$, $p < 0{\cdot}01$). Also the interactions language × markedness ($F(1, 3070) = 28{\cdot}33$, $p < 0{\cdot}01$), depicted in Figure 5, language × grade ($F(5, 3070) = 4{\cdot}32$, $p < 0{\cdot}01$) and markedness × grade ($F(5, 3070) = 11{\cdot}99$, $p < 0{\cdot}01$) were significant. Finally there was a significant interaction marked × grade × language ($F(5, 3070) = 31{\cdot}56$, $p < 0{\cdot}01$). Again we observe a crossover effect: marked items are better spelled in Hebrew than unmarked ones, while in Dutch the

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TABLE 6. *Percentage (N=256/Grade) of correct scores and the mean success score, S.D. and median score (on a maximum score of 4) averaged over 32 participants per grade, relative to the markedness of the target segments in Hebrew and Dutch (condition 2)*

	Marked				Unmarked			
	%	Mean	*S.D.*	Median	%	Mean	*S.D.*	Median
Hebrew								
Grade 1	74	3·0	1·0	3·0	34	1·3	1·2	1·0
Grade 2	86	3·4	0·8	4·0	38	1·5	1·1	1·5
Grade 3	88	3·5	0·8	4·0	68	2·7	1·1	3·0
Grade 4	91	3·6	0·6	4·0	71	2·8	1·3	3·0
Grade 5	91	3·7	0·7	4·0	88	3·5	0·8	4·0
Grade 6	95	3·8	0·6	4·0	87	3·5	0·9	4·0
Dutch								
Grade 1	9	0·4	0·7	0·0	90	3·6	0·6	4·0
Grade 2	76	3·0	1·0	3·0	84	3·3	0·9	4·0
Grade 3	88	3·5	0·7	4·0	87	3·5	0·8	4·0
Grade 4	94	3·8	0·5	4·0	95	3·8	0·5	4·0
Grade 5	92	3·7	0·6	4·0	97	3·9	0·3	4·0
Grade 6	94	3·8	0·6	4·0	91	3·6	0·5	4·0

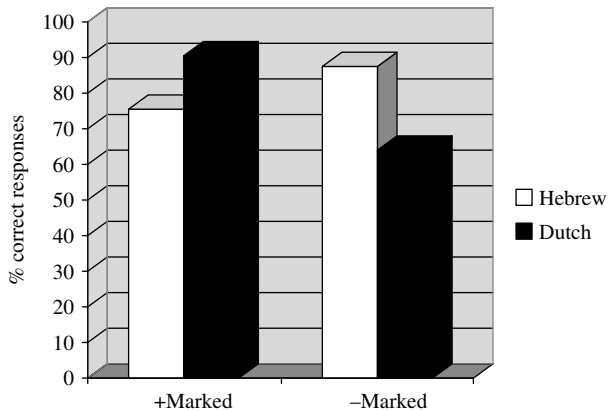


Fig. 5. Interaction of language and markedness of the target segments in condition 2, ⟨+M⟩ stands for marked segments, ⟨−M⟩ for unmarked segments.

opposite pattern occurs: unmarked items are better spelled than marked ones. Note that Dutch-speaking children spell unmarked items better than marked ones, though *post hoc* analyses reveal that the difference only reaches significance in first grade. These results are discussed below.

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DISCUSSION

This study compared learning patterns and strategies of spelling homophonous graphemes in Hebrew- and Dutch-speaking gradeschoolers. In order to create comparable data, the spelling tests each consisted of four conditions, which differed in the number and type of cues for retrieving the correct spelling of homophonous graphemes. The spelling cues were of two types: morphological cues, which offer spellers clues to the correct spelling through consistent orthography/morphology mapping patterns; and morphophonological cues, which offer spellers clues to the correct spelling through the manipulation of orthography/morphophonology conversion procedures. Our straightforward prediction was that the more cues to a condition, the less arbitrary its spelling; and that we could expect better results, that is, fewer spelling errors, in both languages in the more motivated or less arbitrary conditions with morphophonological and morphological cues. Moreover, we predicted the same learning patterns for Hebrew and Dutch learners facing the same problem-solving domain with the same phenomena.

These predictions were not confirmed, or at least not for both languages under consideration. In fact, they seemed to work very well for Hebrew and to predict the learning behaviour of Israeli children. In all test conditions, Hebrew spellers demonstrate learning curves and their correct scores grow steadily better from grade to grade. Indeed, for Hebrew, the morphologically motivated conditions appear to be easier to learn than those conditions which are not morphologically motivated; and when morphological cues are provided, Hebrew learners correctly spell function letters earlier than root letters, as predicted and as found in previous studies on the acquisition of Hebrew spelling (Ravid, 2001, 2005). Morphophonology is also a good cue provider for Hebrew speakers, and those items with phonological conversion procedures such as stop/spirant alternation and attention to vowel lowering are correctly spelled earlier than items with no conversion procedures. It was only in one domain that our predictions were not borne out for Hebrew, and that was the case of morphophonologically marked versus unmarked items. We predicted that unmarked graphemes, which hold a more systematic link with surface pronunciation, would be spelled more successfully. But Hebrew spellers find the marked grapheme ה, which is related to deviant morphophonological behaviour, easier to spell.

We did not find the same learning patterns nor the same confirmation of our predictions for Dutch. Firstly, counter to our predictions, for the morphological conditions even sixth graders perform rather poor, while the non-morphological conditions are mastered successfully early on. Again, counter to our predictions, stems are spelled correctly early on in Dutch, while affix letters, whose spelling rules are simple and transparent, stay at chance level almost up to sixth grade. Following the same pattern,

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morphophonological recoverability is not a good cue provider for young Dutch spellers. Both recoverable and non-recoverable items score similarly, with a slight advantage to non-recoverable items. Finally, the only domain where our predictions are confirmed for Dutch is the case of markedness. Indeed, Dutch learners find unmarked items, whose spelling is more systematically linked to surface representation, easier to spell.

Linguistic typology in spelling development

In order to explain these starkly contrasting results in Hebrew and Dutch, it is necessary to invoke the impact of typology and the interface of spoken and written language. As has been pointed out by Olson (1994), a reciprocal relationship holds between spoken and written language systems: learning to think about spoken language shapes and is shaped by thinking about written language. The type of spoken system children are exposed to from birth affects the way they think about their orthography – and as has been shown in other studies, written language perception shapes thinking about spoken language (Derwing, 1992). In fact, our study demonstrates how Slobin's (2001) typological bootstrapping works in written Hebrew and Dutch respectively: what children perceive as typical patterns of linguistic categorization in their oral language are transferred to the orthographies they learn, resulting in different 'explanatory systems' for these two orthographies.

The morphology/orthography interface

A central finding of this study is the differential treatment of morphological cues by Dutch and Hebrew learners, respectively. When faced with phonologically neutralized segments with and without morphological function, Hebrew-speaking children find morphology an enormously helpful tool. This is because this is the strategy they have been using in Hebrew acquisition all along. Put simply, this is where 'the action is' in Hebrew. Hebrew is a morphologically rich language in which even core lexical items – everyday familiar items – are morphologically constructed. Inflection is rich, obligatory and widespread, and derivation encodes a broad range of semantic notions onto a large number of morphological devices (Ravid, 2005).

Hebrew-speaking children rely on morphological cues in language acquisition from early on. They make early productive use of roots in both obligatory (e.g. novel verb coining) and non-obligatory contexts (e.g. innovative nouns and adjectives). Young Hebrew learners also display metalinguistic awareness of the root morpheme as early as in kindergarten (Ravid, 2002). As a result, Hebrew spellers look for morphological cues

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from their initial encounter with its orthography. This tendency is enhanced with the acquisition of literacy: written Hebrew is even more synthetic than its spoken version, due to optional high-register inflections and to spelling of some function words as part of the next written word (Ravid, 2005). The process of morphological analysis is natural to Hebrew spellers, as in many ways it is to French-speaking gradeschoolers (Pacton & Fayol, 2004).

Dutch children, in contrast, do not find morphology a good cue provider. Certainly, this is not 'where the action is' in acquiring Dutch, a morphologically sparse language. Unlike Hebrew-speaking children, Dutch-speaking children do not need morphological operations in order to construct words. The kind of operation they are acquainted with is the simple concatenation of mono-morphemes in the highly productive compounding. The inflectional system is very poor in Dutch, and in addition, inflected words sound very much like mono-morphemic ones: either inflection does not change the syllable structure of mono-morphemes (a coronal obstruent is added, as in the singular present tense of verbs or the /s/ plural of nouns); or if it does (as for the /ə(n)/ plural of nouns), the resulting form has a schwa in the final syllable, which is also a typical and frequent ending of mono-morphemes. Hence morphologically complex words are phonologically very much like simplex ones.

Much of the effort of Dutch-speaking children seems to be directed toward the acquisition of syntactic patterns such as word order (De Houwer & Gillis, 1998; Wijnen & Verrips, 1998). If this involves concomitant morphological operations, such as using the appropriate verb form depending on its placement in the sentence, children appear to be using phonological cues to solve the problem (De Haan, Frijn & De Haan, 1995).

Phonology, or even the phonetics of the word forms, appears to be much more predominant for Dutch-speaking children in their initial writing: they adhere to a 'what you hear is what you write' strategy much longer and much more profoundly than their Hebrew-speaking agemates. The morphological structure of the words to be written, no matter how transparent they are, acts more like a confound than as help. When morphological analysis is needed to determine spelling, Dutch-speaking children 'trust' their ears more than an analysis of the internal structure of words.

Our study indicates that morphological cues are largely ignored in the early stages of learning to spell in Dutch, and Dutch-speaking gradeschoolers seem to prefer morphophonological conversion cues or simply rote-learning to rule-learning. As a result, learning to overcome the few cases of homophonous morphologically-motivated spelling in Dutch is a protracted process which is not completed by the end of gradeschool (Sandra *et al.*, 1999).

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Spelling stems/roots versus affixes

An intriguing puzzle is why young Hebrew and Dutch spellers differ so radically in their treatment of stems (in Hebrew: Semitic roots) versus affixes. Stems were easier to spell than affixes in Dutch, while affixes proved easier to spell in Hebrew than roots. There were also different learning patterns for these two morphological components in the two languages under investigation. A tentative explanation we offer relates to different models of learning and representation of lexical and morphological knowledge. A dual-route model assumes the existence of two distinct processing systems to handle the two facets of morphology: abstract, symbolic rules and lexical memorization (Pinker & Ullman, 2002). A single-route model denies a split in processing mechanisms, and proposes to handle morphology by associative memory alone (McClelland & Patterson, 2002).

Explaining the Hebrew data is a straightforward affair for both models. Under a dual-route model, there is a spelling rule for affixes which assigns only ⟨T⟩ as a possible affix letter for the segment [t], while for roots there is no rule, and thus both ⟨T⟩ and ⟨ת⟩ are possible spellings of [t]. Under a single-route model, affixes are learnt earlier because their spelling is consistent and transparent, and because they have a low type and a high token frequency. Roots, in contrast, have a higher type and lower token frequency. Learning to spell roots is thus determined by complex factors such as the size of the morphological family and the degree of transparency of semantic and phonological relations among family members (De Jong, Schreuder & Baayen, 2000).

Explaining the Dutch data under the dual model is apparently more problematic. As in Hebrew, Dutch affixes should be easier to spell because they constitute an instance of rule-like behaviour. For example, in our test items, ⟨t⟩ signifies present tense, and ⟨d⟩ past participle. Stems should be harder to spell since there is no principled decision involved. There are some morphophonological conversion procedures to be applied here, such as pluralization. But it is already clear from the result summary that these conversion procedures do not appeal to Dutch gradeschoolers: overall recoverable and non-recoverable segments get the same success scores. Thus a dual-route model does not explain our results, because what should be easy – spelling rule-driven affixes – is apparently difficult for Dutch-speaking children, and what should be difficult – spelling stems with no rule guidance – appears to be easy for them.

A single-route model might offer a better explanatory option. Indeed, affixes in Dutch, as in Hebrew, are frequent and are consistently spelled. However, there is competition in the mental lexicon of Dutch between two forms such as ⟨bepaalt⟩ and ⟨bepaald⟩, which sound the same but are written differently. This presumably delays acquisition. Research by Sandra

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et al. (1999) indicates that spelling these homophones by teenagers is highly sensitive to frequency. As for stems (such as ⟨arend/agent⟩) under this single-route model, similar competition does not exist: while ⟨arend⟩ is co-listed with ⟨arenden⟩, no competing form with ⟨t⟩ is listed. Therefore, spelling a homophonous stem in Dutch is easier than a homophonous suffix.

While this study cannot determine the explanatory power of these two representational models on the basis of this phenomenon alone, it offers a promising path of investigation in the future along these lines.

The morphophonology/orthography interface

This pattern of differential attention to morphological information in the two study populations does not relate only to form–meaning relations, but also to morphophonology. This study has found that morphophonological information is meaningful to children learning to spell in Hebrew, and morphophonologically recoverability cues thus lead to earlier success in correct Hebrew spelling. Again, we believe that the availability of this strategy to young Hebrew spellers is a result of typological impact. Hebrew speakers are used from early on to dealing with allomorphic variations and to relating similar-meaning forms that differ in phonological shape. This is due to the fact that in addition to containing stop/spirant alternations, many frequent and familiar roots are defective. For example, root *b-w-?* shows up as a single radical [b] in [ba] 'came' and as [v] in [hevi] 'brought'. Moreover, a series of morphophonological phenomena such as segment deletion and alternation apply to Hebrew stems under linear morphological operations, e.g. singular [iparon] 'pencil' and plural [efronot] 'pencils'. Paying attention to such morphophonological alternations in spoken Hebrew, on the one hand, and mapping them onto consistent spelling patterns in written Hebrew, on the other, is reflected in our morphophonological results.

For children learning to spell in Dutch, this information gains significance only at the end of primary school. The morphologically complex verb forms such as ⟨betovert⟩ – ⟨betoverd⟩ 'bewitch(ed)' in condition 1 constitute a case in point. They consist of a prefix (⟨be⟩ and ⟨ver⟩) and a verb stem (⟨tover⟩) followed by the suffix ⟨t⟩ or ⟨d⟩. Thus target segments ⟨t⟩ and ⟨d⟩ in these items have morphological function and are morphophonologically recoverable. Error analysis revealed that in the very beginning of primary school children opt for a phonetic strategy: they write ⟨t⟩ when they hear [t], and thus, in Grade 1 almost all the verbs are written with ⟨t⟩, though half of them should have been written with ⟨d⟩. The frequency of ⟨d⟩ increases with age: children learn that some verb forms are written with a final ⟨t⟩ and others with a final ⟨d⟩. However the number of correct responses for condition I does not increase (see Table 2).

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It remains at around 50%, which suggests that although children learn that the verbs can have different endings, they have not yet mastered the correct regularity ('if present tense, write ⟨t⟩, and if participle, write ⟨d⟩) by Grade 6.

A further analysis of the responses shows that by the end of gradeschool, Dutch children seem to be working on the morphological structure of the verb forms. A simple tally of the responses relative to the prefix of the verb form (⟨be⟩ versus ⟨ver⟩) shows a growing tendency to write a ⟨d⟩ ending when the prefix is ⟨be⟩ and to write ⟨t⟩ when the prefix is ⟨ver⟩. Thus, the children in Grade 6 write 70% of the verb forms with the prefix ⟨be⟩ with a final ⟨d⟩ and almost 80% of the ⟨ver⟩ verb forms with a final ⟨t⟩. This implies that these children have started to analyse word forms and that they have started to connect morphological information with the orthographic representation of homophonous segments. Thus although they did not hit upon the correct rule, it appears that by the end of gradeschool they are on the right track for unravelling the morphology/orthography interface.

Spelling marked and unmarked segments

Clearly, children are guided by the interface of strategies appropriate to their spoken language systems as well as by universal factors in learning to spell (Bryant *et al.*, 1999; Templeton & Morris, 2000). The problem of markedness is a case in point. A marked segment is deviant in both languages: in Dutch it is the segment that is not spelled as it is pronounced, while in Hebrew it is the segment that attracts lower vowels and results in a deviant vocalic pattern. Dutch-speaking children take an essentially grapho-phonemic approach to the problem, and start out by seeking a one-to-one mapping between what they hear and what they write, homing in on the unmarked segment. Hebrew-speaking children, in contrast, do not assume only a grapho-phonemic link, but are also sensitive to the deviant, salient information produced by the marked segment. This difference should also be viewed in terms of the underpinnings of the specific language structure. Since Dutch-speaking children do not find morphophonological alternations good cue providers for spelling, their strategy is phonological in essence. But as Hebrew morphologically-governed phonological alternations are essential to a basic grasp of Hebrew form/function relations in word structure, young spellers focus on the marked, deviant pronunciation that signifies a change in spelling.

The influence of word frequency

A final comment is in order about the influence of frequency. In the literature, references are abundant of research showing that indeed

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frequency of exposure plays a crucial role in various types of psycholinguistic processes. For instance, Sandra *et al.* (1999) investigated the spelling of word forms such as the ⟨bepaald⟩ – ⟨bepaalt⟩ ('determined' – 'determines') pair, which is also used in the experiment reported in this paper. They found that Dutch adults (university students) tended to make quite a few errors in a dictation task and showed that these errors were not random: if an error occurred, the error reflected the frequency of the item (i.e. the frequency of the verb forms according to the CELEX lexical database). More specifically, ⟨bepaald⟩ is much more frequent in written Dutch than ⟨bepaalt⟩. The results of Sandra *et al.* show that if ⟨bepaalt⟩ was the target form, it was often written as ⟨bepaald⟩, but the reverse pattern (writing ⟨bepaalt⟩ instead of ⟨bepaald⟩) was infrequent. This shows that in adults' writings, frequency plays a role. However, when administering the same test with twelve- and thirteen-year-olds, they could not find this frequency effect. It might be the case that CELEX frequencies, extracted from adult written language, are not a good estimate of the frequencies relevant for those youngsters.

This opens up a relatively unexplored area of research that deserves closer scrutiny: when investigating an area such as spelling acquisition, which frequencies are relevant for children (of what age)? We believe that in order to further our understanding of how children learn how to write and spell correctly we need to investigate the following factors, as well as their interactions:

- What is the relevant MODALITY? Is it the frequency in written language that should be taken into consideration, or is it the frequency in spoken language that is relevant? When investigating homophones, for instance, this is a highly relevant question.
- What are the relevant SOURCES? It may well turn out that the relevant frequencies are not the frequencies in the adult language, but the children's own language. And this problem may well interact with the previous one: is it the frequency of words in the children's written language or in their spoken language?
- What is the relevant direction, INPUT or OUTPUT? It remains to be determined if it is the frequency of exposure that is important (how many times does the child encounter a particular word form?), or the frequency in the child's own output (how frequently has the child written a particular word form?) And, again, this problem may well interact with the two previous ones.

This leads us to the conclusion that in addition to the typological factors that have been scrutinized in the present paper, we are well aware of the fact that other psycholinguistic factors may play an important role in children's

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achievements. Frequency, which turns out to be a very complicated concept is one such factor, and it cannot simply be reduced to the frequencies mentioned in any lexical database. The corpora necessary for a lexical survey of language relevant to studies such as ours should consist of language spoken to children, written output of children, and written input to children. However, even for relatively well-studied languages such as Dutch and Hebrew, such corpora are very limited in size, and some of them are not in the public domain due to copyright restrictions, for example. Although this paper thus focused on typological characteristics and their implications for literacy, a major research effort should be invested in the future in collecting and making publicly available the kinds of corpora that are of prime importance in order to determine the influence of other psycholinguistic determinants on this process, and in particular the influence of frequency.

CONCLUSION

One of the clear conclusions that emerges from this study is that spelling development is not a mere technical skill of phoneme to grapheme conversion. We have shown that orthographic knowledge is linguistic in nature, and that learning to spell is a developmental process of attaining mastery in the domain of linguistic literacy (Ravid & Tolchinsky, 2002). It cannot be described and explained apart from the typology of the language whose orthography is learnt. Not only do children have to represent linguistic concepts in their oral language knowledge, they have to learn how these concepts are represented in the specific orthography they are learning (Slobin, 2001). The differential weight of information from different linguistic dimensions – phonology, morphophonology, morphology and morphosyntax – depends on the specific language typology and the particular way it interfaces with its orthographic system (Nunes *et al.*, 1997; Sénéchal, 2000; Kemp & Bryant, 2003; Pacton & Fayol, 2004; Treiman & Kessler, 2004).

We have demonstrated in this study that notions such as 'easy' and 'hard' in the acquisition of spelling are not straightforward. Dutch has a sparse inflectional morphology and a shallow spelling system which is easy to teach at school. Nevertheless, our Belgian gradeschoolers did not on the whole do as well as their Israeli peers faced with a deep non-vocalized orthography in a morphologically complex language. They also used different strategies at different time points en route to spelling correctly. Interestingly, a follow-up study of spelling awareness in Israeli and Belgian language teachers using the same test materials (Ravid & Gillis, 2002) revealed that these different patterns in spelling acquisition cannot be explained by differences in the quality of teaching instruction Dutch- and

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Hebrew-speaking children receive. Moreover, teachers in both languages were better able to explain exactly those spelling patterns where children performed less well, and provided poorer explanations where children performed well. This provides further support for our conclusion that learning to spell constitutes part of natural language acquisition, and is an inherently different task from being able to memorize spelling rules and explicitly analyse spelling patterns.

Our study is one more contribution to the growing number of studies that have investigated the impact of typology on language acquisition, showing that children's linguistic problem-solving is shaped by the spoken language system they have been learning.

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APPENDIX: THE SPELLING TESTS

Items are presented in pairs, as explained in the Materials section. The target sounds and corresponding graphemes are underlined.

CONDITION 1: MORPHOLOGICAL AND MORPHOPHONOLOGICAL CUES

Item	Spelling	Gloss
(i) Dutch		
1. b∂tov∂rt	betovert	'bewitches'
b∂tov∂rt	betoverd	'charmed'
2. v∂rsirt	versiert	'decorates'
v∂rsirt	versierd	'decorated'
3. b∂tek∂nt	betekent	'means'
b∂tek∂nt	betekend	'meant'
4. v∂rtont	vertoont	'shows'
v∂rtont	vertoond	'shown'
(ii) Hebrew		
1. ve-ala	W9LH, **ועלה**	'and-went up'
be-vehala	BBHLH, **בבהלה**	'in-fright'
2. ve-red	WRD, **ורד**	'and-go-down'
vered	WRD, **ורד**	'rose'
3. va-ir	W9YR, **ועיר**	'and-city'
u-vahir	WBHYR, **ובהיר**	'and-bright'
4. va-adaša	W9DŠH, **ועדשה**	'and-(a)-lens'
va'adat-kišut	W9DT-QYŠWŦ, **ועדת-קישוט**	'committee-(for) decoration'

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CONDITION 2: MORPHOPHONOLOGICAL CUES ONLY

Item	Spelling	Gloss
(i) Dutch		
1. aɣɛnt	agent	'policeman'
arɛnt	arend	'eagle'
2. tomat	tomaat	'tomato'
sirat	sieraad	'ornament'
3. fazant	fazant	'pheasant'
vərbant	verband	'bandage'
4. tart	taart	'cake'
part	paard	'horse'
(ii) Hebrew		
1. dereχ	DRK, דרך	'road'
keraχ	QRH, קרח	'ice'
2. holeχ	HWLK, הולך	'walks'
šoleaχ	ŠWLH, שולח	'sends'
3. oréχet	9WRKT, עורכת	'sets, Fm'
oraχat	AWRHT, אורחת	'guest, Fm'
4. niχšal	NKŠL, נכשל	'fails'
neχšav	NHŠB, נחשב	'is considered'

CONDITION 3: MORPHOLOGICAL CUES ONLY

Item	Spelling	Gloss
(i) Dutch		
1. vərplɪχtə	verplichte	'obligatory'
vərplɪχtə	verplichtte	'forced'
2. vərwaχtə	verwachte	'expected'
vərwaχtə	verwachtte	'expected'
3. vərustə	veroeste	'rusty'
rustə	roestte	'(got) rusty'
4. vərlɪχtə	verlichte	'lighted'
vərɪχtə	verlichtte	'(were) lit'
(ii) Hebrew		
1. tarim	TRYM, תרים	'lift, Imp'
ta'im	Ṭ9YM, טעים	'tasty'
2. kašot	QŠWT, קשות	'hard, Fm, Pl'
mašot	MŠWṬ, משוט	'oar'

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CONDITION 3: MORPHOLOGICAL CUES ONLY (*Cont.*)

Item	Spelling	Gloss
3. mehirut	MHYRWT, מהירות	'speed'
karut	KRWT, כרות	'is cut down'
4. tapil	TPYL, תפיל	'drop, Imp'
takin	TKYN, תקין	'in order'

CONDITION 4: NO CUES

Item	Spelling	Gloss
(i) Dutch		
1. krɛɪsə̲n	krijsen	'scream'
rɛɪzə̲n	reizen	'travel'
2. lɛɪnə̲n	lijnen	'lines'
klɛɪnə̲	kleine	'small (one)'
3. zwɛɪnə̲n	zwijnen	'pigs'
trɛɪnə̲n	treinen	'trains'
4. pɛɪn	pijn	'pain, hurts'
rə̲frɛɪn	refrein	'chorus'
(ii) Hebrew		
1. hirgiz	HRGYZ, הרגיז (first *i* should not be marked)	'annoyed'
hisbir	HSBYR, הסביר (second *i* should be marked by Y)	'explained'
2. min	MN, מן (*i* should not be marked)	'from'
min	MYN, מין (*i* should be marked by Y)	'gender'
3. lispor	LSPWR, לספור (*i* should not be marked)	'to count'
lipol	LYPWL, ליפול (*i* should be marked by Y)	'to fall'
4. migraš	MGRŠ, מגרש (*i* should not be marked)	'empty lot'
nigaš	NYGŠ, ניגש (*i* should be marked by Y)	'approached'

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