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Does brief exposure to a written text affect spelling performance in a second language?

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Abstract

Because both spelling and reading abilities tap orthographic knowledge, improvements in one ability may lead to improvements in the other. Here, we test whether spelling performance in a second-language (L2) can be improved by a short L2 reading task, as brief exposure to an L2 can increase the activation of L2 representations, making orthographic conventions more available. Participants were 89 adult native Hebrew speakers who were advanced learners of English as an L2. They performed a dictation task on 80 English words, before and after a brief exposure phase. In the Reading Aloud condition participants orally read two stories during the exposure phase, whereas in the Reading while Listening condition, participants silently read the same stories while listening to a recorded narration of the text. Of relevance, words targeted in the dictation task did not appear in the text, such that exposure effects could not be the result of item-specific learning. Results showed better spelling performance post-exposure than pre-exposure in the Reading Aloud condition. Further, analysis of spelling errors revealed that participants in the Reading while Listening condition preserved the phonology of the spelled words, more so post-exposure than pre-exposure. Critically, participants in a control nonlinguistic condition, who were not exposed to English during the exposure phase, did not show such spelling gains. Together, the findings reveal that spelling performance may be dynamically modulated by brief language exposure and suggest that brief reading experience may affect subsequent access to orthographic knowledge required for spelling.

Keywords Spelling · Read aloud · Read while listen · Reading · Language similarity

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Introduction

Reading entails the activation of associated mental representations of the printed words, including semantic, orthographic, phonological and morphological information (Akamatsu, 1999). Notably, these same mental linguistic representations are also engaged during spelling, such that in order to accurately spell a word, one needs to access these different types of information (Ehri, 1997; Fender, 2008; Russak & Kahn-Horwitz, 2015). As such, spelling performance can serve as a window to the mental linguistic representations that subserve reading performance. Further, given the overlap in these underlying representations (Holmes & Carruthers, 1998), reading and spelling are tightly linked, and thus improvements in one process may lead to improvements in the other. In the current study we seek to test this relationship, focusing on whether brief targeted exposure to reading in a second language (L2) can serve to improve learners' L2 spelling performance.

Reading and spelling

According to the *Lexical Quality Hypothesis* (Perfetti & Hart, 2002), rich and accurate semantic, orthographic and phonological knowledge of words serves as building blocks for efficient reading comprehension (see also the *Reading Systems Framework*, Perfetti & Stafura, 2014). Thus, orthographic knowledge provides an important foundation for higher level reading comprehension processes. Further, improving orthographic knowledge, by way of learning to spell, can support efficient reading. For instance, Ouellette et al. (2017) showed that among adults, improvements in spelling of individual words led to faster reading of the same words. Thus, gains in spelling can be translated to gains in reading. Of interest, such orthographic knowledge is not only important for reading, but it also develops while reading (Conrad et al., 2019; Share, 1995; Share, 1999). The *Self-Teaching Hypothesis* (Share, 1995, 2008) proposes that the decoding of letter strings that happens while reading enables the reader to attend to orthographic details, such as print to sound relationships, letter identity and general orthographic conventions such as commonly used spelling patterns (e.g., digraphs) (Shahar-Yames & Share, 1995, 2008). Implicit learning of orthographic knowledge through reading is also consistent with the statistical learning view of spelling (Treiman & Kessler, 2022), by which children extract untaught patterns as they encounter written language. Thus, to the extent that reading and spelling share orthographic representations (Holmes & Carruthers, 1998; Houghton, 2018; Shahar-Yames & Share, 2008), and that reading may improve orthographic knowledge, improvements in reading should result in spelling improvements, just as improvements in spelling result in reading gains (Ouellette et al., 2017).

Of relevance, most previous research on how reading supports spelling examined long-term experience with reading to ask whether and how such accumulated reading experience promotes spelling (e.g., Burt, 2006; Mol & Bus, 2011). For instance, Burt (2006) observed that reading experience as measured by the Author Recognition Test (ART) significantly predicted spelling abilities among young adults, after

controlling for additional measures including phonological sensitivity, phonological coding, and orthographic processing abilities. Here, we go beyond these important long-term relationships to test whether a brief and targeted phase in which L2 users read a short text under different conditions can result in spelling gains following exposure.

Long-term and short-term experience

As alluded to earlier, the relation between reading and spelling rests on the assumption that reading serves to strengthen orthographic knowledge, which in turn supports accurate spelling (e.g., Burt, 2006). Interestingly, recent work on word retrieval suggests that both accumulated long-term experience with a language, as well as short-term language exposure can affect subsequent performance. For instance, Kreiner and Degani (2015) found that Russian-Hebrew bilinguals experienced less difficulty in Hebrew (L2) lexical retrieval if they had been using the language extensively for more years. Thus, early Russian-Hebrew bilinguals experienced fewer tip-of-the-tongue incidences in a Hebrew picture naming task compared to later Russian-Hebrew bilinguals (consistent with the *Frequency Lag Hypothesis,* Gollan et al., 2011, and its precursor the *Weaker Links Hypothesis,* Gollan et al., 2008). Interestingly, this long-term accumulated experience with the language was complemented by effects of brief language exposure. Specifically, these same bilingual groups experienced more lexical retrieval difficulty following briefly watching a 10-min movie in Russian relative to their performance before the movie, suggesting that brief exposure to Russian served to change the activation balance of their two languages, hindering Hebrew (L2) lexical retrieval (see also Degani et al., 2020; Stasenko & Gollan, 2019). The authors suggested that brief exposure changes the activation balance of the languages of multilingual speakers, increasing the activation of one language at the expense of the other. Following this logic, spelling performance in the L2 may be subject to change as a result of both long-term experience with the languages in question as well as short term language exposure. Specifically, both long-term and short-term changes in activation balance of the languages may change the availability of orthographic information, such that enhanced activation should facilitate retrieval of known spelling patterns in the target language.

In contrast to the previous brief exposure effects described above (Degani et al., 2020; Kreiner & Degani, 2015; Stasenko & Gollan, 2019) in which exposure to the first-language (L1) hindered subsequent performance in the L2, here we test whether brief exposure to the L2 can *facilitate* processing of the L2. Further, going beyond word retrieval, we test whether brief reading exposure affects spelling performance. We reason that brief exposure to the L2 should enhance activation of all relevant L2 representations, including orthographic knowledge and spelling patterns, and thus support more accurate spelling post-exposure.

Some indirect evidence for this possibility comes from a line of studies focusing on the S*elf-Teaching Hypothesis*. Specifically, Share (1995) observed that reading aloud short texts containing pseudoword targets led to improved spelling performance on these targets three days following exposure among second graders. Thus,

brief reading exposure provided an opportunity to learn to spell unknown (pseudo) words. Of relevance, this and related studies (for review see Share, 2008) framed their effects in the context of learning, suggesting that participants learn the spelling of *specific* challenging items during reading, and later exemplify this newly acquired information in a spelling task. Here, in contrast, we propose that exposure to the L2 may improve spelling performance more globally, generalizing to items that have not been included during the exposure phase. This more global effect may operate in two ways. First, a brief reading task in the L2 can serve to globally increase the activation of that language, making its orthographic representations more accessible post exposure. Indeed, findings of better spelling performance for words that are more frequent in the language (Chua & Rickard Liow, 2014) suggest that availability of representations may facilitate spelling. For instance, encountering a word like 'grapheme' in the text may increase the availability of the bigraph 'ph' such that this convention is more activated when later needed to spell a word like 'phenomena'. Second, extending the underlying assumption of the *Self-Teaching Hypothesis* (Share, 2008), a brief reading task can serve as a teaching episode not only of particular items, but also of more general grapheme-to-phoneme conventions (GPC) exemplified in items that are not themselves included in the text. For advanced learners of the type tested here, the brief reading task is unlikely to serve as the first encounter with the particular GPC, but may nonetheless help to strengthen learning of conventions that have not been fully internalized. Indeed, Treiman and Kessler (2022) summarize studies to show that incidental extraction of functional patterns linking formal (visual) aspects with other units of the language (sound) is a slow and difficult process which may require time. As noted, in the current study specific items were not repeated, such that item-specific learning is not a viable mechanism, but the same common GPCs were naturally present during the reading and dictation tasks, and thus mastering challenging GPCs during reading may facilitate performance on the subsequent dictation task.

Regardless of whether the reading task increases the activation and availability of L2 representations or whether it facilitates learning of general GPC rules, we expect brief exposure to a reading task in the L2 to result in improved L2 spelling post-exposure. Further, we test whether different types of reading exposure influence post-exposure spelling differently.

Reading aloud versus reading while listening

Under the assumption that reading may serve to strengthen the availability of orthographic conventions (i.e., common spelling patterns), or provide a learning opportunity for these conventions, different reading conditions may do this in different ways. In the current study we compare the effects of reading aloud vs. silently reading while hearing a narration of the text. In the Reading Aloud condition (i.e., oral reading), speakers engage in the conversion of graphemes to phonemes in order to produce the phonological form of the word. This active conversion task may draw speakers' attention to the mapping of orthographic and phonological representations as it requires explicit linking of the two. Indeed, Rosenthal and Ehri (2011) observed that orally pronouncing to-be-learned words during silent reading improved

learners' ability to later spell the words, more so than learners who did not orally produce the words. In contrast, in the Reading while Listening condition, speakers receive the phonological form through the auditory channel, and have the option to map the auditory input onto the orthographic information presented visually. To the extent that readers indeed follow along by silently reading the text, such a condition may similarly serve to strengthen the mapping of phonological and orthographic representations. Both the Reading Aloud and the Reading while Listening conditions engage the linkage between orthography and phonology and may thus facilitate spelling performance.

The two conditions differ, however, in at least two key features. First, the correct phonological form is provided in the Reading while Listening condition but not necessarily in the Reading Aloud condition, in which readers may improperly convert the graphemes into phonemes, producing an inaccurate phonological form of the word. This in turn may lead readers in the Reading Aloud condition to create inaccurate mappings and extract the wrong conversion rules. Thus, Reading Aloud may lead to weaker spelling gains than the Reading while Listening condition. On the other hand, the Reading Aloud condition is a more demanding process, which may focus readers' attention on the relevant orthographic conventions, whereas the Reading while Listening condition can be performed passively. Thus, much like other production and comprehension tasks, the two tasks differ in the level of engagement they require from the speaker (see Gollan et al., 2011 for production comprehension comparisons). As such, their impact on post-exposure spelling performance may differ, with the active Reading Aloud condition resulting in greater spelling gains. Relatedly, the Reading Aloud condition biases readers to pay attention to each and every word in the text, whereas skipping of more difficult words or reliance on the provided phonological form may be possible in the Reading while Listening condition. Again, these considerations would suggest that the Reading Aloud condition may be a more effective condition for post-exposure spelling performance.

In previous research, reading aloud (oral reading) has typically been compared to silent reading, rather than to silent reading while listening to a narration (as is employed here). These studies have mostly been conducted in the context of reading comprehension (Prior et al., 2011), but some studies examined how these conditions affect spelling performance (for review see Share, 2008). For instance, De Jong and Share (2007) had third grade Dutch children read short texts including specific challenging items in both an oral and a silent condition, and tested their spelling performance on these items three days later using an orthographic choice task, a spelling task and a naming task. Their results showed superior naming following the oral reading condition but comparable orthographic choice and spelling performance following both conditions. De Jong et al. (2009) further demonstrated that both silent and oral reading allow for phonological recoding, which in turn supports orthographic learning. Thus, both types of exposure appear to support orthographic learning of specific items, but it remains to be examined to what extent they support generalization to non-presented items, and how they fare in the case of L2 spelling.

Comparing Reading Aloud vs. Reading while Listening, the current study will elucidate whether one or both of these conditions indeed facilitate L2 spelling. Such

findings may be of practical educational relevance, as both routines can be incorporated in L2 literacy pedagogy.

L2 spelling performance across different orthographic systems

Although variance in spelling performance may be traced to reading experience (Burt, 2006; Mol & Bus, 2011; Share, 2008), spelling abilities in the L2 may develop in part due to transfer of skills from the native language (Martin, 2017; Sparks, 2012; Sparks et al., 2008) as bilinguals can transfer literacy related skills from one language to another (Bialystok et al., 2005; Jared et al., 2011; Leikin et al., 2010; Schwartz et al., 2008; Wang et al., 2006) and may experience difficulty in processing spelling conventions that are incongruent across their languages (Allaith & Joshi, 2011; Iniesta et al., 2021; Kahn-Horwitz et al., 2014; Russak & Kahn-Horwitz, 2015; Saiegh-Haddad, 2007; Saiegh-Haddad & Joshi, 2014). Of relevance, languages that are less similar to each other afford greater opportunity for unique L2 spelling abilities to develop. Thus, to the extent that a particular orthographic convention does not exist in learner's L1, his or her experience with the L2 can more directly predict acquisition of this L2 convention.

Following this rationale, in the current study we focus on two languages that differ in script. Specifically, Hebrew, the L1, is a Semitic abjad language whereas English, the L2,[1] is a Germanic-Indo-European alphabetic system (for a recent description comparing the two writing systems see Kuperman et al., 2021). Both Hebrew and English incorporate a principle of phonetic segments that are represented by graphemes (Bialystok et al., 2005), but there is no orthographic overlap across the languages, and the two languages differ in their phoneme to grapheme consistency. In terms of orthographic depth (Katz & Frost, 1992; for recent discussion see Schmalz et al., 2015), English is considered a deep orthography in that the level of reliability of the speech to symbol correspondence is low. A highly reliable correspondence would be one that is simple, consistent, and complete (Katz & Frost, 1992), whereas in English this correspondence is complex, for instance because many vowel sounds and several consonants are represented by digraphs (e.g., 'ou', 'ee', 'sh', 'th'). Further, English can be inconsistent with some sub-lexical units being insufficient to determine pronunciation (e.g., 'ough' has several possible pronunciations) and some phonemes may be represented by multiple alternative graphemes (e.g., /k/ represented by 'k' or 'c'). Finally, English may be incomplete when a given orthographic representation is insufficient to allow retrieval of the appropriate meaning (e.g., wind).

Hebrew, on the other hand, has two orthographic forms that differ in their respective orthographic depth. One form provides complete phonological information via diacritics that represent vowel information (i.e., pointed Hebrew), and one form

[1] We use the term L2 here when referring to English, to reflect the pattern of proficiency dominance in the tested population—namely Hebrew as the most proficient language, and English as the second most proficient language, rather than to differentiate ESL (English as a second-language) from EFL (English as a foreign-language) terminology (for the complexity in using these terms see e.g., Nayar, 1997).

creates opaque mappings (i.e., unpointed Hebrew, Ravid, 2011, for discussion see also Russak, 2019) as no diacritics are provided. Although native Hebrew speakers learn to read using the voweled transparent form, the opaque unpointed script is much more commonly in use for adult readers. In this form most vowel information is not explicitly available in the text and needs to be derived during reading from context or orthographic, morphological and phonological knowledge. Critically for spelling, Hebrew is also inconsistent in that some Hebrew phonemes (e.g., /t/) may be represented by more than one alternative grapheme ('ת' or 'ט'), creating ambiguity.

As these two languages differ in their guiding orthographic principles, and there are no shared graphemes across languages, spelling in English for L1 Hebrew readers may entail difficulty stemming from the inconsistent GPC in English, as well as from differences in orthographic principles in their respective languages. Indeed, previous work on spelling abilities in English as the L2 identified particular orthographic conventions that are a source of difficulty for L1 Hebrew speakers. Specifically, Martin (2017) examined adult L2 English learners with various L1s (Hebrew, Chinese, and French) on a spelling discrimination task. Focusing on item-specific orthographic knowledge, she compared sensitivity to spelling errors that involved consonants to those that involved vowels. Her results revealed that although all L1 groups were more sensitive to spelling errors involving consonantal change, the L1 Hebrew speakers experienced an exceptional difficulty with vowel spelling (see also Martin et al., 2020). Presumably, as vowel information is not explicitly represented in the abjad L1 script, acquisition of these types of spelling conventions may need to be acquired independently in the L2. Thus, spelling performance in English (L2) for L1 Hebrew speakers is expected to be heavily influenced by specific literacy experience in English.

Relatedly, additional orthographic conventions may be novel for L2 learners and pose particular difficulty in spelling tasks. For instance, in a study of children learning English as a foreign language, Schwartz et al. (2016) identified orthographic conventions that are of particular difficulty for L1 Hebrew speakers (see also Kahn-Horwitz, 2020; Russak & Kahn-Horwitz, 2015). These include long vowels represented by vowel digraphs <ee> and <oo> as well as silent <e>, and consonant digraphs that do not exist in Hebrew (e.g., <th>). Results of a pseudoword spelling task revealed that Hebrew speaking children experienced more difficulty on these conventions compared to native Arabic speakers (with the exception of silent <e>), because Arabic does include long vowels and /th/ (for additional direct comparisons of Hebrew and Arabic speaking children learning English spelling see Russak, 2019, 2020). Similarly, Kahn-Horwitz (2020) recently identified eight challenging orthographic conventions by beginning learners of English who are L1 speakers of Hebrew (e.g., <au>, <ew>, <ou>, <th>, consonant doubling, <le> as in candle, <k> before the vowel graphemes <e> and <i> as in kettle and skin), in a study testing the role of explicit spelling instruction. Thus, although the words targeted in the current study were initially composed to target specific challenging orthographic conventions as identified in Martin (2017), additional orthographic challenges (as described by Kahn-Horwitz, 2020) were included as these are real and common English words. Further, as these challenging orthographic conventions are

frequently occurring orthographic patterns in English, they naturally appear in English texts, such that brief exposure to reading of an English text is expected to affect the availability of such patterns, and influence native Hebrew speakers' spelling performance on a list of different English words.

Lexical and sublexical spelling

The classic dual-route model of reading (Coltheart, 1978) postulated that skilled readers can rely on a lexical semantic route by which the word is processed in its entirety such that its orthographic representation serves to search the lexicon for meaning, and a sublexical route in which a letter-to-sound rule procedure allows oral reading without consulting the lexicon. The model postulated that skilled reading entails a transition from reliance on the sublexical route to reliance on the direct lexical-semantic route. The *Self-Teaching Hypothesis* (Share, 2008) extended this framework to suggest that each and every word may undergo this transition process of unfamiliar-to-familiar, such that its processing starts out by phonological decoding (i.e., converting each grapheme to phoneme—sublexical route) and gradually becomes lexicalized (lexical route). A similar conceptualization is relevant in the case of spelling (Kreiner & Gough, 1990; see Tainturier, 2019 for similar assumptions for bilingual spelling with cross-language orthographic overlap). A word may be spelled correctly either because each phoneme is converted to its graphemic representation by way of language specific phoneme-to-grapheme conversion (PGC) rules, or its orthographic representation may be retrieved from long term memory. When a word is spelled correctly, the two routes are indistinguishable. To dissociate the two procedures, and elucidate phonological sublexical spelling skills, researchers often incorporate nonwords in the dictation task, as spelling of these items can only follow the sublexical route (e.g., Johansson-Malmeling et al., 2021). Here, we focus on analysis of spelling errors of real words as a way to tap sublexical procedures and reveal incremental changes in spelling and orthographic knowledge (Martin et al., 2020; Masterson & Apel, 2010; Zhang et al., 2021). In particular, spelling errors may retain the phonological form of the word (e.g., *ade* for *aid*) indicating that the phoneme-to-grapheme (PGC) mechanism was operative, but that the idiosyncratic spelling of the particular lexical item has not been internalized. In contrast, a spelling error that violates the phonological form of the word (e.g., *giled* for *jail*) reveals difficulties with the basic phoneme to grapheme relation in the language in question, or with relevant phonological contrasts in the target language (e.g., Martin, 2017). Put differently, to the degree that the phonological form of the word is preserved in the (incorrectly) spelled word, we may deduce the presence of at least partial knowledge of general orthographic knowledge via other PGCs, even in the absence of word specific orthographic representations (for discussion of the contribution of word specific and general orthographic knowledge to spelling see Zarić et al., 2021). Therefore, in the current study we examine both spelling accuracy and the preservation of phonological information in the case of spelling errors to reveal incremental changes in spelling performance.

The current study

To test whether short-term L2 exposure can facilitate L2 spelling performance, the current study focused on L1 Hebrew speakers who are moderately proficient in English. Such moderate proficiency was targeted because in order for brief exposure to enhance the availability of orthographic knowledge in English, sufficient previous learning of the language had to have taken place. Specifically, for learners who have not yet acquired English-specific orthographic knowledge (e.g., do not know that the phoneme /θ/ as in *think*, which is novel for Hebrew speakers, is represented by the digraph /th/), brief exposure cannot act to enhance activation of available representations. However, if such knowledge has already been learned, dynamic changes may be evident due to brief language exposure. Here, participants performed a spelling to dictation task on a set of individual words including common challenging English orthographic conventions (taken from Martin, 2017). Of note, the targeted words were medium to high frequency words (see Method section below) rather than pseudowords which have typically been used in previous studies (Share, 2008). This is because available evidence for the effect of brief language exposure centers on word retrieval, and thus existing lexical items may be more susceptible to short-term changes in language activation. Critically, the spelling task was performed before and after brief exposure to a reading task in English in one of two conditions. In the Reading Aloud condition participants were instructed to read a given text out loud, whereas in the Reading while Listening condition they were instructed to silently read the same text while listening to a narration of the story. Finally, a third group of participants performed the same pre- and post-exposure spelling task, but instead of a reading task in English they performed a nonlinguistic control (color drawing) task. This control group was included to account for the possibility that the mere effort involved in the pre-exposure spelling task would affect spelling performance post-exposure.

To the extent that short exposure to English can serve to strengthen the availability of relevant and challenging orthographic conventions, or provide a critical learning episode of these conventions, we expected spelling performance to be higher post-exposure to English reading. Further, we tested whether reading aloud or reading while listening to a narration more strongly affects performance. In addition to examining overall spelling accuracy pre- and post-exposure, we further examined the type of spelling errors produced. Specifically, we tested to what extent errors maintained the phonological form of the original word. We reasoned that such scoring would reveal knowledge of general orthographic conventions even when speakers have poor lexical quality of the particular word in question, and are unable to spell it correctly. For instance, spelling 'sneak' as 'sneeck' implies that the conversion of phonemes to graphemes was largely in place, but that idiosyncratic knowledge of the specific word 'sneak' was lacking. Thus, considering spelling accuracy and phonological preservation in errors, we hoped to elucidate dynamic changes in spelling performance. Finally, following previous research (e.g., Burt, 2006), we expected individuals with higher English proficiency and use to perform better in the spelling task

than those with lower experience. We further tested if such long-term accumulated language experience modulated the brief language exposure effect (Degani et al., 2020).

Method

Participants

Participants were 89 native Hebrew speakers (ages 18–35) with normal hearing and vision and with no learning disability. They were either current students or recent graduates from higher education institutions, recruited through word of mouth. Participants had studied English (L2) as a foreign language in a formal setting since elementary school (self-reported 11 years on average), and had no more than one year of immersion experience in an English-speaking environment. Nonetheless, English is constantly present in the environment through the media and used widely in educational and business settings. As such, native Hebrew speakers in Israel tend to reach at least moderate proficiency in English. Moreover, as all participants were current or recent graduates from higher education institutions, their English proficiency was sufficient for academic admission. Data from seven additional participants were excluded because they were native speakers of an additional language (other than Hebrew). Participants' characteristics based on a language history questionnaire (adapted from the LEAP-Q, Marian et al., 2007) are summarized in Table 1. Years of English study are self-reported years of learning. Overall Hebrew and English proficiencies are the averaged self-ratings of proficiency in reading, writing, conversation and speech comprehension, on a scale of 0 to 10, with 0 indicating the lowest level of ability and 10 indicating the highest level of ability. Overall Hebrew and English use are the averaged self-rated use in speaking, writing, reading, listening to music, watching movies and TV, and using the internet, on a scale of 0 to 10, with 0 indicating the lowest level of use and 10 indicating the highest level of use. English proficiency and use are also separately provided for the reading and writing scales. Current English exposure is a self-reported percentage, such that the sum of all languages is 100%. Preference to read in English is a self-reported estimate of the percentage of time the participant would choose to read in English if the text is available in all languages, such that the sum of all languages is 100%.

There were no significant differences in participants' background characteristics across the three conditions. We note that in the first phase of participant recruitment, participants were randomly assigned to the two English reading exposure conditions (*Reading Aloud* and *Reading while Listening*). In the second phase, additional participants were recruited and tested in the *Non-linguistic Control* condition. Across the three conditions, participants volunteered to participate, and some were compensated with 40 NIS (~$10) for their time. All had signed an informed consent following the Ethics' guidelines of the University.

Table 1 Participant characteristics

Characteristics	Brief exposure condition			
	Reading aloud	Reading while listening	Non-linguistic control	*F*
Number of participants	29 (18F,11 M)	30 (17F, 13 M)	30 (16F,14 M)	–
Age	24.80 (3.63)	27.03 (3.91)	26.07 (4.53)	2.17
Age began English study	8.24 (1.50)	8.10 (2.04)	7.78 (1.65)	0.53
Years of English study	10.21 (3.65)	11.83 (4.43)	12.76 (4.04)	2.94
Overall Hebrew proficiency	9.46 (0.52)	9.26 (0.62)	9.36 (0.60)	0.88
Overall Hebrew use	7.66 (1.22)	7.67 (1.09)	7.37 (1.32)	0.56
Overall English proficiency	6.77 (1.24)	6.76 (1.34)	7.10 (1.08)	0.75
English Reading Proficiency	6.69 (1.78)	7.33 (1.42)	7.24 (1.35)	1.52
English Writing Proficiency	5.72 (1.51)	5.63 (1.96)	6.44 (1.53)	2.65
Overall English Use	5.81 (1.59)	6.06 (1.56)	6.16 (1.71)	0.34
English Reading Use	6.10 (2.43)	5.93 (2.34)	6.07 (2.33)	0.08
English Writing Use	3.39 (2.11)	3.73 (2.42)	4.00 (2.65)	0.46
Current English exposure (%)	16.10 (12.48)	14.93 (10.91)	17.57 (10.55)	0.41
Preference to Read in English (%)	13.76 (20.27)	11.67 (18.46)	20.33 (27.16)	1.23

Standard deviations appear in parenthesis

There were no significant differences among the groups at $p < .05$ based on a one-way ANOVA with Bonferroni corrections for multiple comparisons

Materials

Dictation task

Eighty mono-syllabic English words that were selected from a previous study tapping spelling performance in English as a foreign language (Martin, 2017) served as stimuli for the dictation task. In that original study, Martin (2017) verified that none of the words overlapped in phonological form with Hebrew words. Fourteen of the words used in Martin (2017) were replaced to avoid repetition of words in the exposure stories (see "Appendix 1"). Critically, words were selected in the Martin (2017) to include challenging orthographic conventions such as consonant digraphs (<th>, <gh>), vowel digraphs (<ee>, <oo>, <ou>, <ea>, <ai>, <ie>), or silent <e>. Notably, whereas in Martin (2017) pseudoword pairs were created to specifically misspell vowel or consonant segments (e.g., discriminate 'blow/bloe'), many of the words could include misspellings in both vowels and consonants in a dictation task (e.g., 'klame' for 'claim').

The results of Martin (2017) suggest that adult native Hebrew speakers are likely familiar with these words, as a group of 67 adult native Hebrew speakers reached a 90% discrimination accuracy on these items. In addition, in the current study normative data were collected from a new group of 24 native Hebrew

Table 2 Lexical characteristics as a function of list

Measure	List A	List B	*t*
Number of items	40	40	–
Number of syllables	1	1	–
Number of letters	4.35 (0.80)	4.38 (0.70)	.15
Number of phonemes	3.18 (0.50)	3.28 (0.55)	.85
Written Word Frequency (Log SUBTLEX)	3.26 (0.66)	3.32 (0.52)	.48
Orthographic neighborhood	6.95 (5.14)	8.08 (4.90)	1.00
Phonological neighborhood	20.03 (11.55)	16.45 (8.44)	− 1.58
Bigram Frequency	1407.28 (761.07)	1315.96 (582.94)	− .60

Standard deviations appear in parenthesis

There were no differences between the two lists at $p < 0.05$ based on independent samples *t* tests

speakers (who did not take part in the main experiment), who marked less than five percent of the words as unfamiliar.[2]

Words were divided into two lists of 40 words each, to be counterbalanced between the pre- and post-exposure blocks of the dictation task. Words in the two lists were matched ($ps > 0.05$) on English length (in letters and phonemes), English frequency (log SubtLex written frequency), orthographic and phonological neighborhood size, part of speech and bigram frequency (see Table 2), all derived from the Elexicon database (Balota et al., 2007). The order of words within each list was initially randomized, and then kept constant for all participants.

Exposure task

Two short stories were selected for the brief exposure task. These were selected to be comprehendible and engaging enough for adult readers. The length of the text was selected as such in an effort to create a few minutes of exposure, as previous research suggested that 3–10 min of exposure may be sufficient to shift the activation balance of bilinguals' languages (Degani et al., 2020; Kreiner & Degani, 2015). The stories included "The Cookie Thief" by Valerie Cox (299 words, "Appendix 2") and the short folk tale "The Stone Soup" (605 words, "Appendix 2"). Critically, the target words from the dictation task did not appear in these stories but the stories did naturally include other words that incorporate many of the same challenging orthographic conventions (e.g., consonant and vowel digraphs, silent <e>). For the exposure conditions (Reading Aloud and Reading while Listening conditions), the stories were typed on an A4 paper in a Times New Roman font (size 12) with 1.5 line spacing. For the Reading while Listening condition, the stories were narrated by a female English-Hebrew bilingual

[2] Based on these norms, 8 words were identified as unfamiliar by 2 or more participants (neat, quote, blade, cop, clay, nod, toll, deem). Analyses were therefore performed with and without these items.

speaker in Audacity version 2.0.6. For the non-linguistic control Color Drawing condition, a mandala coloring figure was used.

Procedure

Participants were tested individually in a quiet room, either at a designated space in a university lab, or at the participant's home, at their convenience. Participants completed an informed consent and received written instructions in Hebrew, and subsequently all communication was carried out with a Hebrew-English bilingual experimenter in English, so as not to introduce a change in language from English to Hebrew in between the two dictation tasks. Participants first completed the English dictation task on one list of 40 items, during which they heard a recording of each target English word (embedded in a Power-Point presentation) and were required to write down the word in a designated table on a paper (i.e., responses were written, not typed). No time limit was employed, and the experimenter advanced through the words once the participant had finished writing down the word. Recordings were not repeated, such that each word was presented once, in isolation (with no carrier phrase). Participants were encouraged to guess when they were unsure of the correct spelling. Next, participants performed the exposure task in one of three conditions (see below). Then, they completed the dictation task again, following the same protocol, on a different list of 40 words. List order was counterbalanced across participants in each condition. Finally, all participants completed a detailed language history questionnaire in Hebrew providing information regarding their language proficiency and use (adapted from the LEAP-Q, Marian et al., 2007).

In the *Reading Aloud* condition, participants were instructed to read out loud two stories presented to them on a sheet of paper. Their productions were recorded anonymously using a digital recorder (analysis of these recordings is beyond the scope of the current paper). No time limit was imposed, but productions lasted less than 10 min ($M = 8.45$; $SD = 1.19$). The order of the two stories ("The Cookie Thief" and the "The Stone soup") was kept constant for all participants.

In the *Reading while Listening* condition, participants were instructed to listen to a recorded narration of the stories, and to follow the audio by silently reading along. They were presented with the same two stories as in the Reading Aloud condition, in the same order on a piece of paper. The recorded narration of the two stories lasted a total of 6 min and 55 s.

In the *Non-linguistic Control* condition, participants were presented with a black-and-white mandala figure, and were instructed to silently color the figure using colored pencils (as in Degani et al., 2020) for 10 min (as in Kreiner & Degani, 2015).

Results

Coding

Words were coded as accurately spelled only if the produced spelling was identical to the correct spelling of the word. For three words we accepted two alternative

Table 3 Mean percentage (and SE) of spelling accuracy (top) and phonological preservation in errors (bottom) as a function of time and condition (n = 89)

Time	Condition		
	Reading aloud	Reading while listening	Nonlinguistic control
% Accuracy			
Pre-Exposure	0.71 (0.02)	0.73 (0.02)	0.70 (0.02)
Post-Exposure	0.74 (0.02)	0.75 (0.2)	0.71 (0.02)
% Phonological preservation in errors			
Pre-Exposure	0.73 (0.01)	0.73 (0.02)	0.70 (0.02)
Post-Exposure	0.74 (0.02)	0.76 (0.02)	0.71 (0.02)

SE calculated over all data points taking into account the presence of the within-participant Time variable following (Morey, 2008). To this end, we used the function described by Change, W. http://www.cookbook-r.com/Graphs/Plotting_means_and_error_bars_(ggplot2)

spellings because upon reexamination, we realized the word was homophonic (Eight—accepted 'ate' as well), or the particular recording included a mispronounced vowel (Toll—accepted 'tall' as well; Cop—accepted 'cup' as well).[3]

To identify incremental orthographic knowledge, and the degree to which knowledge of PGC rules was exemplified despite lack of word specific orthographic knowledge, an error analysis was conducted. Specifically, errors were coded by a native English speaker according to the percentage of phonemes of the target word that were maintained in the produced spelling. To this end, and following Masterson and Apel (2010), each target word was divided into graphemes (letters or sequences of letters) according to their corresponding phonemes (e.g., 'tight' divided into t| aɪ |t, see also Martin et al., 2020). We then coded for each grapheme whether the spelled word maintained its intended phonological form. To illustrate, if the word 'tight' was spelled as 'taith', the first grapheme (|t|) maintained its phonological form, but the second grapheme corresponding to the vowel (|eɪ| instead of |aɪ|) and the third grapheme (|θ| instead of |t|) did not. Such a spelling error thus preserved its phonological form in 1 out of 3 graphemes and would receive a score of 0.33. Therefore, the measure ranged from no phonological preservation (0, for instance 'tough' for 'though') to complete phonological preservation (1, for instance 'neet' for 'neat'). Partial phonological preservation could yield 0.5 (for a 2 or 4 phoneme word, e.g., 'sheek' for 'sneak', 'hate' for 'eight'); 0.33 or 0.66 (for 3 phonemes, e.g., 'chick' for 'cheek') and 0.25, 0.5, 0.75 (for 4 phonemes, e.g., 'blod' for 'blood').

Table 3 provides mean Spelling Accuracy and mean Phonological Preservation of the errors produced by Time (Pre-exposure vs. Post-exposure) and Condition (Reading Aloud; Reading while Listening; Nonlinguistic Control). Raw data is available upon request.

[3] The words 'toll' and 'cop' were excluded from analyses when the 8 less-familiar items were removed (see Footnote 2).

Analysis

Spelling accuracy and phonological preservation in errors were analyzed using linear mixed-effects models in R (version 4.0.3, R Core Team, 2020). The accuracy data was analyzed following the binomial distribution in logistic mixed effects as each trial was coded as 0 or 1.

The models included dummy-coded fixed effects of Time as a within-participant variable (Pre-Exposure vs. Post-Exposure, with Pre-Exposure set as the reference) and Condition as a between-participant variable (Reading Aloud; Reading while Listening; Nonlinguistic Control, with the nonlinguistic condition set as the reference), as well as the interaction between them.

A maximal model including by-participant and by-item intercepts and a by-participant slope for Time and a by-item slope for Condition (Bell et al., 2019; Brauer & Curtin, 2018) was submitted to a *buildmer* function in the *buildmer* package (v. 1.3, Voeten, 2019) which uses the *(g)lmer* function from the *lme4* package (v 1.1.-21, Baayen et al., 2008; Bates et al., 2015). Starting from the maximal model, and using a backward-fitting model selection procedure, the *buildmer* function systematically simplifies the random slopes until convergence, in addition to using likelihood ratio tests (LRTs) to examine the contribution of random slopes to the fit of the model. Following these procedures, no random slopes were maintained in the selected models. All relevant fixed effects (Time, Condition, Time by Condition) were kept in the model using the *include* subcommand. P-values for all fixed effects were determined based on Satterthwaite degrees of freedom using the *lmerTest* package (v. 3.1–0, Kuznetsova et al., 2017), or the Wald degrees of freedom for binomial distribution. For pairwise comparisons, estimated means, and *SEs* we used the *contrast* function from the *emmeans* package (Version 1. 5. 2-1; Lenth, 2020). In the tables below, estimations of β, *SE*, *t/z* and *p* values are based on the *summary* function and the *tab_model* function from the *sjPlot* package (Version 2.8.7; Lüdecke, 2021). The main effects of each fixed variable were obtained from the *anova* function and are presented in the text.

Spelling accuracy

Figure 1 presents Spelling Accuracy as a function of Time and Condition. The Spelling Accuracy analyses (see Table 4) revealed a significant effect of Time ($F = 4.74$, $p = 0.03$) with higher accuracy post-exposure ($M = 0.83$, $SE = 0.03$) as compared to pre-exposure ($M = 0.81$, $SE = 0.03$).[4] The effect of Condition and the interaction

[4] Analysis using 72 words (excluding the less familiar 8 items) resulted in a non-significant Time effect for the Accuracy data ($F = 1.60$, $p = 0.21$) and the Percentage of Phonological Preservation in Errors ($F = 2.66$, $p = 0.10$). However, whereas the effect of Time did not reach significance in any of the conditions for the accuracy data when analyzed separately [Reading Aloud condition ($F = 2.64$, $p = 0.10$); Reading while Listening condition ($F < 1$); Control condition ($F < 1$)], or for the Reading Aloud ($F < 1$) and Control conditions ($F < 1$) in the preservation of phonology analysis, there was a significant Time effect in the Reading while Listening condition ($\beta = 0.04$, $SE = 0.02$, 95% CI [0.00, 0.07], $t = 2.15$, $p = 0.03$), with more preservation of phonology post-exposure ($M = 0.77$, $SE = 0.02$) than pre-exposure ($M = 0.74$, $SE = 0.02$).

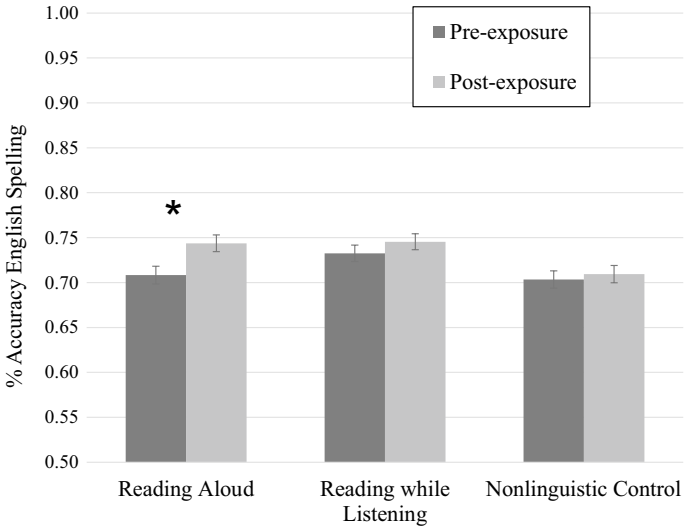

Fig. 1 Spelling accuracy as a function of condition and time. Error bars represent SE

Table 4 Model summary predicting spelling accuracy as a function of time and condition

	β	*SE*	95% CI	*z*	*p*
Fixed effects					
Intercept	3.79	0.99	[2.27, 6.34]	5.07	**<.001**
Condition [Reading while Listening]	1.31	0.36	[0.77, 2.23]	1.00	0.32
Condition [Reading Aloud]	1.05	0.29	[0.62, 1.79]	0.18	0.85
Time [post-exposure]	1.08	0.12	[0.87, 1.34]	0.66	0.51
Condition [Listening] * Time [post-exposure]	1.02	0.16	[0.75, 1.40]	0.14	0.89
Condition [Aloud] * Time [post-exposure]	1.21	0.19	[0.88, 1.65]	1.18	0.24
Random effects					
σ2	3.29				
τ00 Participant	0.91				
τ00 Item	2.55				
ICC	0.51				
N Item	80				
N Participant	89				
Observations	7120				
$R^2_{marginal}/R^2_{conditionnal}$	0.003/0.514				

Fixed effects reflect simple effects relative to the reference level when other variables are at their reference level without correction for multiple comparisons. For instance, the effect of Time here, refers to the baseline Non-linguistic condition level, whereas the effect of Condition refers to the baseline Pre-Exposure time level. For main effects, see *F* values in the text

Values in bold highlight a significant effect at the $p < .05$

between Time and Condition were not significant ($Fs < 1$, but see Fig. 1). However, planned comparisons were nonetheless conducted to examine whether the effect of exposure was reliable in each condition separately.

Results revealed that in the Reading while Listening condition, there was no effect of Time, ($\beta = 0.09$, $SE = 0.11$, 95% CI [-0.13, 0.32], $Z = 0.83$, $p = 0.41$), with accuracy post-exposure ($M = 0.85$, $SE = 0.04$) not differing from accuracy pre-exposure ($M = 0.83$, $SE = 0.04$). Interestingly, in the Reading Aloud condition the effect of Time was significant ($\beta = 0.27$, $SE = 0.11$, 95% CI [0.04, 0.49), $Z = 2.36$, $p = 0.02$), such that accuracy post-exposure ($M = 0.84$, $SE = 0.04$) was higher than pre-exposure ($M = 0.80$, $SE = 0.04$). Finally, in the Nonlinguistic Control exposure condition, there was no effect of Time, ($\beta = 0.08$, $SE = 0.11$, 95% CI [-0.14, 0.29], $Z = 0.68$, $p = 0.50$), with accuracy post-exposure ($M = 0.80$, $SE = 0.04$) not significantly differing from accuracy pre-exposure ($M = 0.79$, $SE = 0.04$).

Preservation of phonology in errors

Figure 2 presents the Preservation of Phonology in Errors as a function of Time and Condition. We analyzed whether Time (Pre-Exposure vs. Post-Exposure, with Pre-Exposure set as the reference) affected the degree to which participants preserved the phonology of the word in their spelling errors (see Table 5). Thus, only incorrectly spelled trials were included in this analysis ($N = 1968$). The model revealed greater phonological preservation post-exposure ($M = 0.73$, $SE = 0.01$) compared to pre-exposure ($M = 0.72$, $SE = 0.01$), but this effect did not reach significance ($F = 3.09$, $p = 0.08$). Further, there was a significant effect of Condition ($F = 5.27$, $p = 0.007$). Pairwise comparisons with Bonferroni adjustments revealed that phonological preservation was significantly higher in

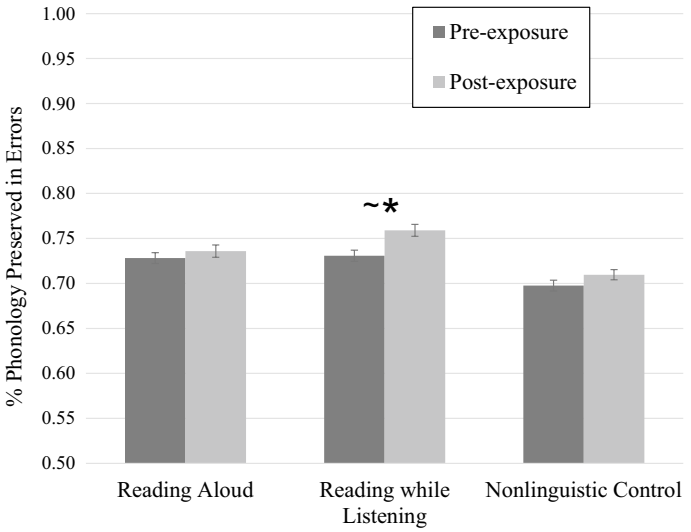

Fig. 2 Percentage of phonological information preserved in spelling errors as a function of condition and time. Error bars represent SE. ~ * represents a difference at $p = 0.055$

Table 5 Model summary predicting average phonological preservation in errors as a function of time and condition

	β	*SE*	95% CI	*df*	*t*	*p*
Fixed effects						
Intercept	−0.14	0.08	[−0.29, 0.02]	1833	43.14	**< .001**
Condition [Reading while Listening]	0.15	0.08	[−0.01, 0.32]	2007	1.86	0.06
Condition [Reading Aloud]	0.15	0.08	[−0.00, 0.06]	1910	1.80	0.07
Time [post-exposure]	0.04	0.07	[−0.10, 0.17]	1871	0.55	0.59
Condition [Listening] * Time [post-exposure]	0.11	0.10	[−0.08, 0.31]	1879	1.17	0.24
Condition [Aloud] * Time [post-exposure]	−0.01	0.10	[−0.20, 0.18]	1879	−0.11	0.91
Random effects						
σ2	0.03					
τ00 Participant	0.00					
τ00 Item	0.01					
ICC	0.23					
N Item	78					
N Participant	89					
Observations	1968					
$R^2_{marginal}/R^2_{conditionnal}$	0.010/0.239					

Fixed effects reflect simple effects relative to the reference level when other variables are at their reference level without correction for multiple comparisons. For main effects, see *F* values in the text

Values in bold highlight a significant effect at the $p < .05$

the Reading while Listening condition ($M = 0.75$, $SE = 0.02$) compared to the Nonlinguistic Control condition ($M = 0.70$, $SE = 0.01$; $t(79) = 3.12$, $p = 0.008$). Performance in the Reading Aloud condition ($M = 0.73$, $SE = 0.02$) did not significantly differ from the Reading while Listening ($t(81.1) = 11.01$, $p = 0.94$) or the Control condition ($t(77.4) = 2.1$, $p = 0.12$). The interaction between Time and Condition did not reach significance ($F < 1$, but see Fig. 2). However, planned comparisons were nonetheless conducted to examine whether the effect of Time was reliable in each condition separately.

Results revealed that in the Reading while Listening condition, errors produced post-exposure ($M = 0.76$, $SE = 0.02$) preserved phonology more than pre-exposure ($M = 0.73$, $SE = 0.02$), but this Time effect failed to reach conventional significance level, ($\beta = 0.14$, $SE = 0.07$, 95% CI [-0.00, 0.29], t (586.43) = 1.93, $p = 0.055$). In the Reading Aloud condition the effect of Time ($M_{pre} = 0.73$, $SE_{pre} = 0.02$; $M_{post} = 0.73$, $SE_{pre} = 0.02$) was not significant ($\beta = 0.05$, $SE = 0.07$, 95% CI [-0.09, 0.19), $t(588.77) = 0.73$, $p = 0.47$,), as was the case in the Nonlinguistic Control condition ($\beta = 0.03$, $SE = 0.07$, 95% CI [-0.10, 0.17], $t(648.9) = 0.50$, $p = 0.61$; $M_{pre} = 0.70$, $SE_{pre} = 0.02$; $M_{post} = 0.71$, $SE_{pre} = 0.02$).

Modulations of short-exposure by long-term English experience

Finally, we examined whether short-term English exposure (i.e., the effect of Time) interacted with long-term English experience. To this end, and following examination of the correlation among the language background measures in our sample (see "Appendix 3"), we created a composite score using a principal component analysis, capturing 54% of the variance in the original predictors including (1) overall self-rated English proficiency; (2) overall self-rated current English use; (3) percent of current exposure to English (relative to other known languages, such that the sum of all languages is 100); (4) percent of preference to read in English relative to other known languages, such that the sum of all languages is 100. To examine modulations of short-term exposure by long-term English experience, we included this new English factor as a fixed effect in the model and allowed it to interact with the effects of Time and Condition (for the full model see "Appendix 4").

In the accuracy analysis, the results revealed that although participants' long-term English experience, as measured by the English factor, modulated spelling accuracy, as greater English experience was associated with higher spelling accuracy ($\beta = 1.44$, $SE = 0.25$, 95% CI [1.03, 2.02], $Z = 2.12$, $p = 0.034$), this long-term effect did not interact with the short exposure manipulation (i.e., did not interact with Time, Condition, or both, Fs < 1).

In the analysis of preservation of phonology in errors, long-term English experience as measured by the English factor did not modulate performance ($\beta = -0.003$, $SE = 0.01$, 95% CI [-0.03, 0.02], $t = -0.28$, $p = 0.78$), and did not interact with the effect of Condition ($F = 2.16$, $p = 0.12$), Time ($F < 1$) or Time and Condition ($F < 1$).

Discussion

The current study aimed to examine whether spelling performance in an L2 can differ as a function of short exposure to a reading task in the L2. Results showed that spelling performance in English post-exposure to an English text improved, especially for participants who read the text out loud. Further, although participants who listened to a recorded narration of the text while silently reading it did not show significant improvements in spelling accuracy, they did show a trending change in terms of the pattern of their spelling errors. Specifically, participants in the Reading while Listening condition preserved the phonological form of the target words in their spelling errors, more so post-exposure than at baseline, although this difference failed to reach conventional significance level ($p = 0.055$, but see Footnote 4). These improvements in spelling performance following a brief L2 task were not present for a control group who performed a nonlinguistic task.

Short-term reading exposure

These results suggest that brief targeted reading exposure can serve to improve spelling performance for items not presented during the reading exposure. These findings extend the results of studies on word retrieval (Degani et al., 2020; Stasenko & Gollan, 2019; Kreiner & Degani, 2015) to show that such brief exposure may similarly operate on orthographic information. These dynamic changes in spelling performance can be explained by two complementary mechanisms: *learning* of general orthographic conventions and changes in language *activation*, as explained below.

First, brief exposure to an English text may have served as a *learning* opportunity of relevant orthographic spelling patterns. Indeed, incidental extraction of functional patterns linking graphemes and phonemes has been shown to occur as children learn to read (for review see Treiman & Kessler, 2022). Further, effects of reading on spelling have been documented in the context of the *Self-Teaching Hypothesis* framework (for review see Share, 2008) showing that reading can provide a learning opportunity for item-specific spelling information. Of note, whereas those previous studies focused on novel words, here we examined spelling with familiar words and tested individuals who are moderately proficient in the target language. As such, the reading exposure was not the first learning opportunity of orthographic knowledge, but nonetheless could have strengthened earlier learning.[5] Further, previous studies tested learning of item-specific orthographic information, in that the same items were presented during a reading task and the spelling task (e.g., Shahar-Yames & Share, 2008). Here, in contrast, we verified that the target items in the spelling dictation task were not presented during the reading exposure task. As such, it is unlikely that the reading exposure served as a learning opportunity for specific items, but rather may have supported learning of more general GPC rules. Specifically, exposure to the written text strengthened the availability of common spelling patterns that are of relevance for the spelling task. These include, but are not limited to, the challenging orthographic conventions identified in previous research with L1 Hebrew speakers, including vowel digraphs (Martin, 2017), silent < e > and the consonant digraph < th > , (Schwartz et al., 2016), as well as consonant doubling (Kahn-Horwitz, 2020).

Second, the brief reading exposure may have operated to change the activation balance of the different languages known to the participants (Degani et al., 2020; Kreiner & Degani, 2015; Wodniecka et al., 2020). In previous research the effects of brief language exposure on word retrieval have been explained in terms of the activation, or availability, of representations in the given languages. Although both languages of bilingual speakers are always active to some extent (Kroll et al., 2006), the use of one language may come at the expense of the availability of the other language (e.g., Green, 1998). Thus, Kreiner and Degani (2015) proposed that brief language exposure may change the activation balance of the two languages, making the

[5] The term *learning* here is used in the broader sense, and is not limited to only the initial stages of learning.

representations in the recently used language more active and available (and those of the other language less available) (see also Degani et al., 2020; Wodniecka et al., 2020). In the current context, this mechanism would imply that a brief reading task in English served to increase its activation level, making lexical and sub-lexical representations in English more available post-exposure than pre-exposure. As a result, spelling of familiar words post-exposure was more accurate, especially if the reading exposure task involved oral reading.

The critical difference between the learning opportunity and the language activation accounts lies in the stability and durability of the effects. In particular, under a learning perspective, the reading exposure served to strengthen language specific (but not item specific) orthographic knowledge such that it should presumably be available to the user from now on. In contrast, the language activation-balance mechanism emphasizes the transient nature of the effect, such that presumably exposure to the other language of the speakers (i.e., Hebrew) could offset these benefits (as exposure to the other language has been shown to hinder word retrieval e.g., Degani et al., 2020; Kreiner & Degani, 2015). The current findings do not allow one to discern whether spelling gains were the result of transient changes in activation balance or a more long-lasting learning of the relevant orthographic information. Future studies in which delayed gains are examined may be revealing in this respect. To the extent that general orthographic learning took place, it may be expected to be as durable as the item-specific learning demonstrated by the self-teaching mechanism (Share, 2004).

Relatedly, according to the learning mechanism described above, the source of the spelling gains is in the exposure to written text, in which participants encountered common spelling patterns. Accordingly, brief exposure to English in a different modality (i.e., without print) would not be expected to facilitate spelling. In contrast, under the language activation account, the exposure served to increase the availability of all English representations, including lexical and sub-lexical units, and this increased activation then supported spelling of familiar words in the post-exposure phase. Under this account, mere exposure to English, irrespective of its modality, would result in improved spelling. Future studies may thus dissociate these accounts in two ways. First, including a listening only (no text) exposure condition would reveal whether any type of increase in language activation would result in spelling gains. Second, spelling of nonwords would presumably be less affected by the increase in activation of familiar lexical items and would therefore elucidate the involvement of lexical activation vs. learning of general spelling patterns.

Type of reading exposure

Although the interactions between time (pre- vs. post-exposure) and the type of exposure did not reach significance in the current study, potentially due to limitations in power, the pattern of results hints at a possible differential effect of the reading conditions. In particular, Reading Aloud led to higher overall spelling accuracy, whereas the gains from the Reading while Listening condition were evident in the preservation of phonology exhibited in spelling errors. Thus, reading aloud, being a more active and demanding task, may have acted

to draw readers' attention to the relevant common spelling patterns, supporting subsequent spelling performance. Thus, in terms of overall accuracy, the Reading Aloud condition appears to have been a more efficient exposure. At the same time, exposure that included listening to a narration of the story while reading perhaps acted to encourage participants to focus on the mapping between phonemes and graphemes. As a result, during the post-exposure phase participants in the Reading while Listening condition were more likely to preserve the phonology of the dictated words, even when they were unable to retrieve the correct spelling. Spelling errors, by definition, indicate that item-specific orthographic information was not available, but when these errors maintain the phonological form of the word, they provide evidence for at least partial orthographic knowledge in that participants were able to convert the heard phonemes into plausible (albeit inaccurate) graphemic forms.

The difference between the two exposure types examined here was apparent only when the pattern of performance was examined separately in each condition, but not as a significant interaction. This may be partially alleviated in future studies with more statistical power. Moreover, the two conditions we tested here differ in several ways. In the Reading Aloud condition participants were presented with the written text, but indirectly also with a phonological form which was produced by the participants themselves. In contrast, in the Reading while Listening condition participants were presented with both the written form and the phonological form, but the alignment of the two was dependent on participants' engagement with the task and the degree to which they actively followed along. Indeed, future studies in which eye tracking is utilized to measure participants' eye movements during reading may shed light on this issue. Moreover, to better understand the contribution of each of these task-related processes, future studies may opt to include additional exposure types. As alluded to earlier, a listening only condition would reveal whether presentation of a printed text is necessary. Further, the Reading Aloud and Reading while Listening conditions were targeted in the current study as these were expected to require readers to pay attention to the relevant linkage of orthography and phonology promoting phonological recoding of the graphemes during reading. Nonetheless, previous work shows that phonological recoding may operate in silent reading as well (De Jong & Share, 2007; Share, 2008), and thus future studies should examine how silent reading (without a recorded narration) affects subsequent spelling of unpresented items. Silent reading may help reveal whether the presence of the phonological form during exposure is required. Furthermore, because participants in the Reading Aloud condition were free to read at their own pace, the timing of exposure in the two conditions differed. Thus, whereas the amount of English exposure was equated across the Reading Aloud condition and the Reading while Listening condition, as both included the same two stories, timing differences may have confounded the difference between conditions. Future studies in which the duration of exposure is kept constant are needed.

Long-term language exposure

In the current study, L1 Hebrew speakers who have accumulated more English experience throughout their lives, and reached higher proficiency in the language, performed better in the spelling dictation task, consistent with previous research (e.g., Burt, 2006). Notably, however, we did not find evidence for modulations of the brief exposure effect by long-term language experience. Thus, in both the accuracy analysis and the phonological preservation in errors analysis, the English factor did not interact with the effects of Time or Condition. The lack of modulation may partially stem from limitations of the long-term exposure measures employed here, in that only self-report measures were collected. Indeed, Tomoschuk et al. (2019) discuss the limitations of self-report especially for comparisons across groups, but other research does suggest that such measures can provide at least a proxy, within a single group, of individual differences on relevant accumulated experience (Marian et al., 2007, and more recently Gullifer et al., 2021). At the same time, it is also possible that long-term and short-term effects are independent, as such a pattern has also been observed in word retrieval studies (Degani et al., 2020; Kreiner & Degani, 2015). Specifically, Kreiner and Degani (2015) observed that although early Russian-Hebrew bilinguals experienced fewer tip-of-the-tongue instances in Hebrew compared to late Russian-Hebrew bilinguals, both groups were similarly affected by a brief language exposure manipulation (a Russian movie), suggesting independence of the long-term and short-term language experience.

At face value, this may suggest that participants' long-term language experience is not important in determining the brief language exposure effect. However, note that all participants in the current study (as was the case in the word retrieval studies described above) were at least moderately proficient in the target language. In the current study, participants have been learning and exposed to English to some extent for about 11 years. This baseline proficiency level may be necessary for the effects of brief language exposure to affect subsequent spelling. Indeed, brief exposure including text reading may be suitable for readers with at least moderate proficiency in the target language who have some relevant orthographic knowledge, because in the Reading Aloud condition, readers with lower proficiency may not be able to convert the presented graphemes into phonemes as required for oral reading. Thus, although the findings demonstrate that a brief reading aloud exposure can support spelling, future studies with larger samples and greater variability in terms of long-term language experience may shed more light on the degree to which such reading exposure may serve as an effective literacy pedagogical strategy for beginning learners.

A related interaction between long-term and short-term exposure may be revealed by manipulating item frequency (for related work with word retrieval see Kleinman & Gollan, 2018). Specifically, it is possible that representations that are more available at baseline (e.g., frequent words or frequent GPCs) would be less affected by brief language exposure than those representations that are less available to begin with. However, in a study testing word retrieval, Degani et al. (2020) observed that although objects that were often used in the L1 were named more accurately in the L1 than objects that were typically named via borrowed L2 words, both types of words were similarly affected by a brief language exposure manipulation. Future

studies may reveal if interactions between long-term and short-term exposure nonetheless affect spelling performance.

Limitations and future directions

The current study demonstrates that a brief reading exposure, on the order of a few minutes, was sufficient to lead to spelling gains on non-presented items. These effects were evident for participants who engaged in oral reading during the exposure task, but the error analysis suggests that reading while listening to a narration may also affect participants' spelling performance, in that they tended to exhibit at least partial phonological preservation of the dictated word especially post-exposure. However, there are several limitations that need to be addressed in further research. First, the current study was not designed to examine the degree to which spelling performance was affected by participants' L1, but previous research convincingly shows that such cross-language influences are important for spelling performance (e.g., Figueredo, 2006; Martin, 2017; Russak & Kahn-Horwitz, 2015; Schwartz et al., 2016, among others). Thus, participants' ability to correctly spell the dictated words in the current study may have been affected by their sensitivity to phonemic contrasts that do not exist in their L1 (e.g., long vs. short vowels). It is possible, for instance, that the brief exposure manipulation would differentially affect such items, as increased activation due to the brief exposure may be accompanied by decreased activation of the L1 (Green, 1998). If this is the case, then reduced cross-language influences may be present post-exposure because of reduced availability of the L1 after exposure to the L2. Relatedly, the stimuli in the current study were designed to reveal overall spelling performance but were not specifically designed to elucidate participants' sensitivity to particular challenging orthographic conventions (e.g., consonant doubling). Thus, it remains to be examined if brief reading exposure differentially affects participants' spelling performance on different types of orthographic conventions, and whether these effects depend on the frequency of occurrence of each orthographic convention in the language and in the exposure text.

Finally, three methodological aspects of the current study should be improved on in future work. First, as the stimuli were recorded by a Hebrew-English bilingual, pronunciation may have diverged somewhat from native exemplars due to phonological transfer from the L1. Second, because the different exposure conditions were matched in terms of their linguistic content (two stories), and due to the self-paced nature of the reading aloud task, the two conditions diverged in terms of the duration of language exposure. Future work in which the duration of language exposure is purposefully manipulated may be revealing with respect to the durability of the brief language exposure effect. Moreover, as noted above, the durability of the effect may be important in distinguishing the mechanism at play. Specifically, if the brief language exposure operates via increased language activation, then the effect should be short-lived, in that with time activation decays and the observed spelling facilitation decays with it. In contrast, if the brief language exposure effect served as a learning opportunity of the relevant GPCs, then presumably such learning may continue to be available in future encounters with relevant targets. Finally, limitations of power may have obscured relevant condition by time interactions as well as modulations

by long-term language experience, and thus additional work is needed before strong conclusions can be made.

Nonetheless, the current study suggests that brief reading exposure to an L2 text can improve subsequent spelling performance on L2 items that are not presented during the reading phase. These findings may prove valuable in educational settings whereby a brief text-reading experience can support learners' L2 spelling. Further, on the theoretical front, the findings extend the literature to show that in addition to the operation of long-term factors, such as accumulated language exposure and use, short-term factors are also involved in explaining spelling performance. Thus, performance in a comparable task that is measured at two points in time, only a few minutes apart, can reveal differential abilities depending on the language context in which the task was performed. Therefore, L2 performance should be conceived of as dynamic in nature, modulated by both short-term and long-term experiences.

Appendix 1: Target words in the dictation task

	List A	Martin, 2017 item replaced	Consonant/ vowel	List B	Martin, 2017 item replaced	Consonant/ vowel
1	Bite		C	Blade		V
2	Blow		C	Born		V
3	Church		C	Cheek		V
4	Deem		V	Cake		V
5	Mate		V	Threat		V
6	Neat	Great	V	Wall		C
7	Through		C	Roof		C
8	Toll		C	Free		V
9	Blood	Floor	V	Spoon	Soon	V
10	Loop		V	Third		V
11	Sweep		V	Noise		C
12	Thumb		C	Clue		C
13	True	Once	C	Cope		V
14	Gaze		V	Aid	Claim	C
15	Raise		C	Should		C
16	Wound		V	Word		V
17	Works		V	Dog		C
18	Nod		C	Cop		C
19	Stop		C	Grow		C
20	Slow	Snow	C	Lame	Late	V
21	Page	More	C	Horse		C
22	Bone	Home	V	Joke		V
23	Small		C	Clay		C
24	Tear		V	Wheat		C

	List A	Martin, 2017 item replaced	Consonant/ vowel	List B	Martin, 2017 item replaced	Consonant/ vowel
25	Sneak		V	Cold	Clock	C
26	Goal		V	Load		V
27	Worse	Whole	C	Smoke		V
28	Fight		C	Eight		C
29	Pie		V	Tight		C
30	Cloud		C	Tough	Sigh	C
31	Dirt		V	Field		V
32	Crew		C	Sink	First	C
33	Cut		C	Screw		C
34	Girl		V	Doll		C
35	Rape		V	Fade		C
36	Shirt		V	Scare		C
37	Suit		V	Sick		C
38	Quote		C	Gold		V
39	Shy	fly	C	Jail		V
40	Main		V	Snow		C

Appendix 2: English stories presented in the *Reading Aloud* and *Reading while Listening* conditions

The Cookie Thief (by Valeri Cox).

A woman was waiting at an airport one night, with several long hours before her flight. She hunted for a book in the airport shops, bought a bag of cookies and found a place to drop. She was engrossed in her book but happened to see, that the man sitting beside her, as bold as could be...grabbed a cookie or two from the bag in between, which she tried to ignore to avoid a scene. So she munched the cookies and watched the clock, as the gutsy cookie thief diminished her stock. She was getting more irritated as the minutes ticked by, thinking, "If I wasn't so nice, I would blacken his eye." With each cookie she took, he took one too, when only one was left, she wondered what he would do. With a smile on his face, and a nervous laugh, he took the last cookie and broke it in half. He offered her half, as he ate the other, she snatched it from him and thought… oooh, brother. This guy has some nerve and he's also rude, why he didn't even show any gratitude! She had never known when she had been so galled, and sighed with relief when her flight was called. She gathered her belongings and headed to the gate, refusing to look back at the thieving ingrate. She boarded the plane, and sank in her seat, then she sought her book, which was almost complete. As she reached in her baggage, she gasped with surprise, there

was her bag of cookies, in front of her eyes. If mine are here, she moaned in despair, the others were his, and he tried to share. Too late to apologize, she realized with grief, that she was the rude one, the ingrate, the thief.

The Stone Soup (modified from the story retrieved from https://simplifypersonalproductivity.wordpress.com/2012/10/10/inspire-cooperation-with-stone-soup/).

One day, two soldiers were returning from war talking with each other: "How I would like a good dinner tonight," said the first soldier. "And a soft bed to sleep in," added the second soldier. The two men continued walking in silence when they noticed some lights ahead of them. They were hoping to find something to eat and a bed to sleep in for the night. When they arrived in the little village, they began to ask about food and a place where they could stay. "We have no food for ourselves! In fact, there's nothing to eat in the whole village", lied the villagers. "You'd better keep on moving."

The first soldier said out aloud, "Good people! We are hungry soldiers; we've asked you for food and you have none. I suppose we will have to make stone soup". The villagers were shocked. The soldier added mysteriously, "Our king gave me a very special gift when I saved his life in the war". He then asked for a big pot and water to fill it. When the villagers brought the cauldron, the two soldiers placed it in the middle of the square and built a huge fire underneath. Then the first soldier took out a bag from a secret pocket of his jacket, removed three very ordinary-looking stones from the bag and dropped them into the water.

A crowd started gathering in the square to see what all the commotion was about. "A good soup needs salt and pepper. If only I had some salt and pepper!" the first soldier said, so one of the villagers sent his children to fetch some salt and pepper.

As the soldiers sniffed the soup and licked their lips in anticipation, hunger began to overcome the villagers. "Oh!" the soldier said to himself rather loudly, ''I do love stone soup. Of course, stone soup with carrots…that's hard to beat. If only I had some carrots!".

Hearing this, one of villagers sent his son home to fetch some carrots hidden in the house. Soon the son returned and they added the carrots to the pot. "Magnificent!" exclaimed the soldier. "You know, I once had stone soup with carrots and some beef as well, and it was fit for the king!" The village butcher managed to find some beef. And so it went, until soon there were onions, potatoes, barley, cabbage, and milk added to the boiling pot.

"It's soup," yelled the soldiers, "but first we must prepare the place for a party!" Tables, chairs, torches, and banners were arranged and the soldiers and villagers sat down together to eat. One of the villagers said, "A great soup would be better with bread and some apple juice," so he brought out these last two items. The villagers had never before tasted anything so good that were made of stones, and soon they began singing, dancing, and making merry well into the night.

The soldiers were weary from their travels, so they inquired again to see if there was a hayloft or spare floor corner somewhere where they could rest for the night. "Oh, no, a hayloft or a corner won't do for men such as you!" cried the mayor. "You two must have the best beds in the village!" One soldier spent the night in the mayor's house, while the other was offered lodging in the baker's house. The next morning the villagers gathered to say goodbye to the soldiers and offered them a great sum of money for the "magic" stones. The soldiers said the stones were not for sale, politely refused the offer, and then traveled on.

Appendix 3: Details of principal component analysis for proficiency

See Tables 6, 7.

Table 6 Pearson correlations among the proficiency measures

Measure	1	2	3
1 Self-rated English proficiency	–		
2 Self-rated current English use	.35**	–	
3 Percent of current English exposure	.38**	.20*	–
4 Percent of preference to read in English	.53**	.46**	. 32*

*$p < .05$; **$p < .001$. $KMO = .71$, Bartlett's Test of Sphericity $p < .001$

Table 7 Loadings of each original factor on the extracted component

Measure	1
1 Self-rated English proficiency	.80
2 Self-rated current English use	.68
3 Percent of current English exposure	.61
4 Percent of preference to read in English	.82

Appendix 4: Modulations of short-exposure by long-term English experience

See Tables 8, 9.

Table 8 Model summary predicting spelling accuracy as a function of time, condition and the English factor

	β	*SE*	95% CI	*z*	*p*
Fixed effects					
Intercept	3.46	0.87	[2.12, 5.65]	4.96	**< .001**
Condition [Reading while Listening]	1.51	0.37	[0.93, 2.45]	1.68	0.09
Condition [Reading Aloud]	1.22	0.30	[0.75, 1.98]	0.81	0.42
Time [post-exposure]	1.06	0.12	[0.85, 1.33]	0.55	0.58
English Factor	1.45	0.25	[1.03, 2.04]	2.12	**0.034**
Condition [Listening] * Time [post-exposure]	1.06	0.17	[0.77, 1.46]	0.34	0.73
Condition [Aloud] * Time [post-exposure]	1.23	0.20	[0.89, 1.69]	1.27	0.20
Condition [Listening] * English Factor	1.11	0.26	[0.70, 1.76]	0.44	0.66
Condition [Aloud] * English Factor	1.16	0.32	[0.68, 1.98]	0.55	0.58
Time [post-exposure] * English Factor	1.07	0.13	[0.85, 1.35]	0.57	0.57
Condition [Listening] * Time [post-exposure] * English Factor	1.02	0.16	[0.74, 1.40]	0.10	0.92
Condition [Aloud] * Time [post-exposure] * English Factor	0.97	0.17	[0.68, 1.38]	−0.16	0.88
Random effects					
σ2	3.29				
τ00 Participant	0.68				
τ00 Item	2.55				
ICC	0.50				
N Item	80				
N Participant	89				
Observations	7120				
$R^2_{marginal}/R^2_{conditionnal}$	0.036/0.514				

Fixed effects reflect simple effects relative to the reference level when other variables are at their reference level without correction for multiple comparisons

Values in bold highlight a significant effect at the $p < .05$

Table 9 Model summary predicting percentage of phonological preservations in erros as a function of time and condition and English factor

	β	*SE*	95% CI	*t*	*p*
Fixed effects					
Intercept	−0.13	0.08	[−0.29, 0.03]	43.05	**< .001**
Condition [Reading while Listening]	0.15	0.09	[−0.02, 0.32]	1.65	0.10
Condition [Reading Aloud]	0.15	0.08	[−0.02, 0.31]	2.02	**0.045**
Time [post-exposure]	0.03	0.07	[−0.11, 0.17]	0.52	0.60
English Factor	−0.02	0.06	[−0.13, 0.10]	−0.28	0.78
Condition [Listening] * Time [post-exposure]	0.11	0.10	[−0.09, 0.31]	0.92	0.36
Condition [Aloud] * Time [post-exposure]	0.00	0.10	[−0.20, 0.19]	−0.22	0.83
Condition [Listening] * English Factor	−0.04	0.08	[−0.19, 0.12]	−0.48	0.63
Condition [Aloud] * English Factor	0.11	0.09	[−0.06, 0.28]	1.25	0.21
Time [post-exposure] * English Factor	0.04	0.07	[−0.10, 0.17]	0.52	0.60
Condition [Listening] * Time [post-exposure] * English Factor	−0.08	0.10	[−0.27, 0.11]	−0.79	0.43
Condition [Aloud] * Time [post-exposure] * English Factor	−0.08	0.11	[−0.28, 0.13]	−0.74	0.46
Random effects					
σ2	0.03				
τ00 Participant	0.00				
τ00 Item	0.01				
ICC	0.23				
N Item	78				
N Participant	89				
Observations	1968				
$R^2_{marginal}/R^2_{conditionnal}$	0.014/0.240				

Fixed effects reflect simple effects relative to the reference level when other variables are at their reference level without correction for multiple comparisons. Pairwise comparisons with Bonferroni adjustments revealed that phonological preservation was significantly higher in the Reading while Listening condition ($M = 0.74$, $SE = 0.02$) compared to the Nonlinguistic Control condition ($M = 0.70$, $SE = 0.02$; $t(72.3) = 2.93$, $p = .014$). Performance in the Reading Aloud condition ($M = 0.73$, $SE = 0.01$) did not significantly differ from the Reading while Listening ($t(79.9) = 0.90$, $p = 1.00$) or the Control condition ($t(69.5) = 2.1$, $p = 0.13$)

Values in bold highlight a significant effect at the $p < .05$

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Code availability Analyses code are available upon request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval The study was conducted following the approval of the ethics committee of the University of Haifa #1293 to TD.

Consent to participate All participants signed an informed consent form approved by the ethics committee.

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