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Transfer effects in spelling from transparent Greek to opaque English in seven-to-ten-year-old children*

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The study investigated single-word spelling performance of 33 English- and 38 Greek-speaking monolingual children, and 46 English- and Greek-speaking bilingual children (age range from 6;7 to 10;1 years). The bilingual children were divided into two groups on the basis of their single-word reading and spelling performance in Greek. In line with predictions, we found that scores on an assessment of phonological awareness were a significant predictor of spelling in English for the bilingual children with stronger Greek literacy skill. Phonological awareness scores were also a strong predictor of spelling in Greek in the monolingual Greek-speaking children. For the bilingual children with weaker Greek literacy ability, spelling in English was predicted by performance in a test of visual memory. This was more in line with results for the monolingual English-speaking children, for whom spelling performance was predicted by visual memory and phonological awareness scores. Qualitative analysis of misspellings revealed that phonologically appropriate errors were significantly greater in the strong Greek literacy ability bilingual group than the weaker Greek literacy ability bilingual group. Stimulus analyses using regression techniques are also reported. The results are interpreted to suggest that in biliterates literacy processes are transferred from one language to the other (Mumtaz & Humphreys, 2002).

Keywords: Greek spelling, English spelling, intra- and cross-linguistic factors

Introduction

Towards the end of the first decade of the 21st century in England, 14.4% of the primary and 10.8% of the state funded secondary population have a first language (L1) other than English (DfES, 2008). Notably, this diversity is not any more characteristic of the urban centers but it is characteristic of areas which never before had any English as an Additional Language (EAL) pupils (CiLT, 2005). Therefore knowledge of the factors that affect spelling of bilingual pupils is of great importance. Spelling is significant in its own right as it elucidates pupils' cognitive and linguistic strategies involved in literacy acquisition. Additionally, spelling skill seems to facilitate compositional writing (McCutchen, 1996; Graham, Berninger, Abbott, Abbott & Whitaker, 1997; Berninger, Abbott, Abbott, Graham & Richards, 2002) as pupils with spelling difficulties will be able to dedicate less processing resources to composition or expression of ideas.

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There is now good evidence that cognitive and linguistic abilities that are involved in literacy acquisition transfer from one language to another (e.g., Koda, 2005, 2008). In the present study the aim was to investigate the influence in biliterates of reading and spelling experience in a transparent orthography, Greek, on spelling in opaque English. First we investigated the processes involved in spelling in monolingual Greek and English children with the prediction that learning to read and spell in transparent Greek would lead to a reliance on phonological processes for spelling, and that learning to read and spell in opaque English would lead to a reliance on visually-based whole-word processes. Next, we tested the prediction that in a sample of Greek–English bilingual children, those with higher levels of Greek reading and spelling ability would show greater reliance on phonological processes for spelling in English, while those with lower levels of Greek reading and spelling ability would rely more on whole-word processes for spelling in English. In the introduction we first discuss differences between the Greek and English writing systems, and evidence for literacy transfer effects, before giving details of the present study and the rationale for the experimental hypotheses.

Alphabetic languages differ in level of orthographic depth (the variation between orthographies in the consistency of the relationship between letters and

sounds and vice versa) and syllabic complexity. For reading, Greek is rather transparent, with almost one-to-one grapheme–phoneme correspondences; however, for spelling it is rather deep. English is opaque for both reading and spelling, although, in English too, phoneme–grapheme correspondences are more equivocal than grapheme–phoneme correspondences, for example, the sound /i:/ can be written as e.g. <ee, i, ie, ei, ey, ea> (Perry, Ziegler & Coltheart, 2002). The inconsistency of English spelling makes the latter challenging even for highly literate adults. This derives from the fact that spelling is often divergent from the word's pronunciation. For both Greek and English, the orthography has remained the same despite changes in pronunciation over time. This makes spelling in both languages less predictable than reading.

Harris and Giannouli (1999) point out that Greek spelling is based on the etymology of the words rather than their current pronunciation. The Greek language has many words which contain different graphemes representing the phonemes /o/, /i/ and /e/, since certain phonemic distinctions (e.g., between the vowels represented by <η, ι, υ, οι, ει, υι> and those represented by <ο, ω> or by <ε, αι>) are no longer present in the language. Importantly though, Nunes, Aidinis and Bryant (2006) note that inconsistencies in Greek lie in the context of a system that is otherwise highly consistent. This is not the case for English. According to Vousden (2008), 38.9% of graphemes, 16% of onsets, and 17.8% of rime mappings are inconsistent. Stuart, Dixon, Masterson and Gray's (2003) analyses of children's early reading vocabulary in English revealed that 50% of the most frequent words are irregularly spelled. This high level of inconsistency might be expected to discourage use of phonological (or SUBLEXICAL) strategies and encourage more reliance on whole-word, visually-based (or LEXICAL) strategies for reading and spelling.

Cross-orthographic studies have indeed indicated that differences in phonological transparency result in different literacy acquisition processes. Ziegler and Goswami (2005, 2006) proposed the "grain size" theory, whereby differences in orthographic transparency result in developing reliance on different sublexical units. For example, English is highly inconsistent at the small grain level (single graphemes and clusters) and this can lead to dependence on larger units, such as onsets and rimes, which are less inconsistent (Treiman, Mullennix, Bijeljac-Babic & Richmond-Welty, 1995),though this will not be the case for consistent orthographies, such as Greek and German. Studies comparing German- and English-speaking pre-readers and novice readers (Goswami, Ziegler & Richardson, 2005) and Greek and English seven-, eight- and nine-year-old readers (Goswami, Porpodas & Wheelwright, 1997) indicated that larger grain sizes play a significant role for English readers. This was not the case for the German or Greek children who showed a clear preference for smaller grain sizes.

Additionally, cross-orthographic studies have shown that reading of words and pseudowords and phonological ability develops rapidly in transparent orthographies in comparison to opaque ones (Seymour, Aro & Erskine, 2003; Spencer & Hanley, 2003). Cross-orthographic research into spelling indicates that spelling in English is far more difficult than in more transparent orthographies such as French (Caravolas, Bruck & Genesse, 2003), with sublexical strategies being a stronger predictor of spelling performance in the former.

Turning to the investigation of language transfer effects, Figueredo (2006) provided a review of cross-linguistic research studies focusing on spelling acquisition, and how L1 affected English (L2). Figueredo concluded that a child who first learns an orthography more transparent than English may encounter difficulties in understanding the opaque nature of English orthography and make regularization errors when spelling in English, indicating reliance on sublexical strategies that have been developed as a result of the first-language transparency. Findings of Figueredo's review support Cummins' (2000) interdependence hypothesis, based on this positive transfer will occur when similarities exist between writing systems, and when differences exist negative transfer will temporarily affect the written language acquisition of L2. Occasions of negative transfer arise when students substitute an English letter by an L1 grapheme. Novice learners of L2 are found to produce more influence errors of L1 (Howard, Artteagoitia, Louguit, Malabonga & Kenyon, 2006). Therefore, it is important, in order to spell and read successfully, for the bilingual child to control interference from Greek to English, and vice versa.

Findings along similar lines have been reported for cross-linguistic transfer of reading skills. For example, Mumtaz and Humphreys (2002) carried out a study with seven-to-eight–year-old children who spoke Urdu (which has a transparent orthography) and English. They found that children with strong Urdu vocabulary had good phonological awareness skills and performed well in reading English regular words, but their visual memory and irregular word reading (in English) were weak. On the other hand, students with weak Urdu vocabulary had strong visual memory and performed well in reading irregular English words. The influence of the first language on reading in English was also examined by Holm and Dodd (1996) in a study of students learning English who were from Hong Kong, Vietnam, the People's Republic of China and Australia. The students with non-alphabetic first language literacy were comparable in reading English words to students with alphabetic first language literacy, but they had difficulties reading and

spelling nonwords, and had weak phonological awareness skills. The authors concluded that when phonological skills were not developed as a result of first language experience, then students were limited to a whole-word, visually-based strategy.

The present study was carried out with monolingual English- and Greek-speaking children aged between seven and ten years, and with age-matched bilingual Greek–English-speaking children who had differing levels of proficiency in reading and spelling in Greek, but who were at a comparable level in reading and spelling in English. On the basis of the findings reviewed above we might expect that, in the bilingual children, higher levels of Greek literacy skill would be associated with more reliance on sublexical processes for spelling in English, and lower levels of Greek literacy skill would be associated with greater reliance on lexical processes for spelling in English. In order to investigate reliance on one type of spelling process or the other we identified a range of child- and stimulus-related variables that have traditionally been considered to be associated with lexical and sublexical processing. Phonological ability was investigated as a child-related variable associated with sublexical processing for spelling, while phoneme–grapheme probability was investigated as a stimulus-related variable associated with sublexical processing for spelling. Visual memory was investigated as a child-related variable associated with lexical processing, and printed word frequency as a stimulus-related variable associated with lexical processing. These variables were analysed in relation to spelling performance using regression techniques. We also carried out qualitative analysis of spelling errors, with the prediction that phonologically appropriate errors, a marker of sublexical processing, should be higher in the strong Greek bilingual group and the monolingual Greek-speaking children. Previous findings associated with the child- and stimulus-related variables will be discussed next.

Child-related variables

The child-related variables investigated in the current study in relation to (single-word) spelling performance were visual short-term memory and phonological awareness (PA). Research on PA has shown that it appears to play an important role in reading and spelling development, not only for English (Caravolas, Kessler, Hulme & Snowling, 2005; Ehri, Nunes, Willows, Schuster, Yaghoub-Zadeh & Shanahan, 2001; Stuart, 2004; Stuart & Masterson, 1992), but also for other alphabetic languages (Caravolas, Volin & Hulme, 2005; Porpodas, 1991). Additionally, cross-linguistic transfer of PA has been reported in studies involving English and Spanish (Durgunoglu, Nagy & Hancin-Bhatt, 1993), Arabic and English (Abu-Rabia & Siegel, 2002), Portuguese and English (Da Fortuna & Siegel, 1995), and Greek and English (Loizou & Stuart, 2003). As noted earlier, several studies conducted in transparent orthographies indicate that a consequence of learning to read in these writing systems is rapid development of PA skills and grapheme–phoneme knowledge. Bergmann and Wimmer (2008) claim that in a transparent orthography, even for dyslexic children, the child's phonological impairment will be moderate and they will achieve ceiling on less demanding tasks. In contrast, Caravolas et al. (2005) found in a cross-orthographic study comparing transparent Czech to opaque English, and using normal and dyslexic readers, that PA was a strong predictor of reading and spelling in both orthographies. The results may be attributed to the demanding PA tasks that Caravolas et al. (2005) used. In accordance with this, Nikolopoulos, Goulandris, Hulme & Snowling (2006), in a longitudinal study with Greek children, found that PA was a predictor of reading at Time 1 (seven- and nine-year-olds) and for spelling at both Time 1 and Time 2 (eight- and ten-year-olds).

Nikolopoulos, Goulandris & Snowling (2003), based on their study involving Greek-speaking dyslexic children, also claim that the high transparency of the Greek language, in combination with a phonics approach in teaching reading, enables students to quickly develop PA skill. The Greek children's spelling errors, although they were phonologically plausible, contained incorrect graphemes (e.g., substituting the digraph <αι> /e/ with the equivalent <ε> in the word <μαχαίρι> "knife" and writing the incorrect <μαχέρι>), indicating that pupils' orthographic knowledge was incomplete. Reliance on sublexical processing for reading by Grade 1 Greek children (age 6 years) was demonstrated by Porpodas (1999). In a study with 50 six-year-old Greek participants, Masterson, Colombo, Spencer, Ftika and Syntili (2008) investigated the predictive power of child- and stimulus-related variables for single-word spelling. They observed a preponderance of phonologically appropriate spelling errors, and that performance in a PA task significantly predicted spelling performance. The researchers found a different pattern when they investigated six-year-old English children's spelling. These children's spelling performance was predicted by scores in a visual memory task, in addition to scores in a PA task.

Results related to visual short-term memory are less conclusive in comparison with PA. Stuart, Masterson and Dixon (2000) conducted two training studies with five-year-old novice readers. Children were screened and formed two groups of ten pupils. One group had good ability to segment the initial phoneme and the other poor. The aim of the first training study was focused on finding whether good graphophonic ability might enhance sight vocabulary acquisition or whether this might be attributed to rote learning of arbitrary associations, as proposed

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by Frith's (1985) logographic stage. The results were not supportive of a logographic stage, at least for the children with good graphophonic skills. Only those with poor graphophonic skills showed reliance on logographic reading, perhaps as a compensatory mechanism of their poor phonological skills. The latter group's reading also significantly correlated with visual memory which is a lexical processing measure. However, the same relationship was not found for the good graphophonic ability, albeit visual memory scores did not differ in the two groups. In relation to spelling performance, visual memory was not found to predict spelling by Caravolas, Hulme and Snowling (2001) in their longitudinal study with four-to-eight-year-old children or by Giles and Terrell (1997) in their study with poor spellers. By contrast, PA was found to be strong predictor of children's spelling performance in Caravolas et al.'s (2001) study. The outcome indicates that children's spelling attainment is found to be more closely related to PA than visual memorization skill.

Stimulus-related variables

Stimulus characteristics that have been found to increase the difficulty with which young children accurately spell words include printed word frequency and phoneme–grapheme transparency. For example, Spencer (2007) examined spelling performance in 207 Year 2–6 English pupils (ages between seven and eleven years) on the most frequent words in children's books selected from the Children's Printed Word Database (Masterson, Stuart, Dixon & Lovejoy, 2003). Regression analyses revealed that strong predictors of spelling accuracy were printed word frequency and phonographeme transparency. The latter refers to the frequency of a particular phoneme being represented by a specific grapheme, for example the phoneme /f/ corresponding to the grapheme <f> or digraph <ph>. An effect of phonographeme transparency has also been found for Greek: Masterson et al. (2008) reported a strong effect of phonographeme transparency in their study of Greek Grade 1 children's spelling. Printed word frequency has been considered in past literature to be a marker of lexical processing, and phonographeme frequency as a measure of sublexical processing. The results of Spencer's study therefore indicate that spelling (in English) is influenced by both lexical and sublexical processes in young children.

An effect of printed word frequency for English-speaking children's spelling was reported by Treiman (1993). Harris and Giannouli (1999) also found a strong word frequency effect for spelling in Greek Grade 2 and 3 children (age 7–8 years). A frequency effect was also reported in the spelling performance of six-to-eleven-year-old Greek-speaking children by Loizidou-Ieridou, Masterson and Hanley (2009). However, the younger participants in the Loizidou-Ieridou et al. study seemed to rely more on sublexical processes, manifested in a strong effect of phoneme–grapheme regularity.

The present study

The present study looked for evidence of the transfer of literacy processes used in transparent Greek to spelling in opaque English. We examined the predictors of spelling performance in a monolingual sample of English-speaking children and a monolingual sample of Greek-speaking children. Our third sample of children was Greek–English bilinguals. The sample of bilingual children was divided into two groups on the basis of their proficiency in reading and spelling Greek words. We reasoned, as outlined earlier, that for the Greek monolingual participants PA would be a strong predictor of spelling, whilst PA and visual memory might be predictors of spelling performance for monolingual English children. In relation to the bilingual participants we predicted that those with a high level of experience in reading and spelling in Greek would show more evidence of use of sublexical strategies for spelling in English. On the contrary, those with lower levels of experience of reading and spelling in Greek would show more evidence of use of whole-word lexical strategies for spelling in English. Therefore, in terms of the child-based variables PA should be more of a robust predictor of English spelling performance than visual memory in the strong Greek group, while for the weak Greek group visual memory should be the stronger predictor.

As well as examining spelling performance in relation to the child-based variables, we investigated stimulus-related variables. The aim was to see whether a different pattern of association of psycholinguistic characteristics of the words used in the spelling-to-dictation task might be observed across the two monolingual groups and strong and weak Greek literacy ability bilingual groups. The stimulus-related variables that we examined were printed word frequency, and phoneme–grapheme probability. It was predicted that the former would be more closely associated with the spelling performance of the monolingual English and weak Greek literacy ability bilingual groups, and the latter more closely associated with the spelling performance of the monolingual Greek and strong Greek literacy ability bilingual groups.

Finally, we carried out qualitative analyses of the children's spelling errors to investigate the rate of phonologically appropriate errors across the groups. We predicted that the rate of such errors would be higher in the monolingual Greek and the strong Greek literacy ability bilingual groups than in the monolingual English and the weak Greek literacy ability bilingual groups, since the former groups were expected to be relying on sublexical

Table 1. *Means of participant characteristics for the monolingual and bilingual groups (standard deviations in parentheses).*

	Monolingual		Bilingual	
Task	English	Greek	Weak Greek	Strong Greek
Age (years;months)	7;9 (0.59)	8;1 (0.73)	7;9 (0.67)	7;9 (0.62)
Non-verbal reasoning[a] (max = 34)	18.48 (6.27)	15.76 (6.33)	17.17 (6.05)	16.35 (6.37)
English reading accuracy[b] (max = 60)	52.06 (8.89)	–	49.22 (10.34)	51.17 (10.81)
English spelling accuracy[b] (max = 60)	35.21 (14.41)	–	32.52 (10.33)	36.22 (14.89)
Greek reading accuracy[c] (max = 60)	–	58.50 (1.44)	34 (13.4)	57 (2.81)
Greek spelling accuracy[c] (max = 60)	–	33.74 (9.57)	12.87 (4.66)	26.17 (6.87)

[a]Non-verbal reasoning = Matrix Analogies Test (Naglieri, 1985)
[b]60-word list from Masterson et al. (2008) translated in English
[c]60-word list from Masterson et al. (2008) translated in Greek

processing more than the latter, and this would result in a higher incidence of phonologically appropriate errors than the use of whole-word processes.

The children recruited to this study were aged between seven and ten years. Children of this age are still acquiring reading and spelling skills, and so it is an optimal age at which to examine reading/spelling errors and performance on literacy-related tasks for evidence of cross-orthographic influence (Seymour et al., 2003).

Method

Participants

Monolingual English-speaking group

The monolingual English-speaking participants were 33 children (15 girls) attending state primary schools in London, UK. Three of the schools were located in North London (students in the bilingual sample also attended these schools) and one school was in inner-London. Eighteen children were from the North London schools and 15 children were girls. The children's ages ranged from 6;7 to 9 years (mean: 7;9 years, SD: ±0.59). The chronological ages of the children in the four schools were compared using one-way ANOVA and there was no significant group effect ($F < 1$). In addition, one-way ANOVAs revealed no significant group effect across schools for non-verbal reasoning scores, or reading and spelling accuracy in the assessments described in the next paragraph (all Fs < 1). Literacy instruction in all of the schools, as reported by the teachers involved a phonics-based approach.

The children in this group, and in the monolingual Greek and bilingual Greek–English groups, were administered a single-word spelling-to-dictation task and a single-word reading task using a 60-word list taken from Masterson et al. (2008). The items cover a wide range of psycholinguistic variables in both Greek and English, and incorporate simple and complex spelling rules and consonant clusters and singletons in both Greek and English. In addition, the referents of the words are concepts known to most children from the age of six years. Data recorded were the number of items read and spelt correctly. A non-verbal reasoning test (the Matrix Analogies Test; Naglieri, 1985) was also administered to all children, in order to ensure that the experimental groups were matched in terms of general ability. Table 1 provides a summary of the participants' characteristics.

One-way ANOVAs revealed that results for chronological age, non-verbal reasoning, and reading and spelling accuracy did not differ significantly between the monolingual English and weak and strong Greek literacy ability bilingual groups (see next section for description of the weak and strong Greek literacy ability bilingual groups) (all Fs < 1).

Monolingual Greek-speaking group

The participants were 38 (19 girls) monolingual Greek-speaking children. Fifteen were from the island of Crete, and 23 were from Cyprus. Children in Crete and Cyprus receive the same literacy instruction (an analytic and synthetic phonics approach) and they have exactly the same primers. Many teachers in Cyprus gain their teaching degree in universities in Greece.

The children were recruited from private and state schools (19 participants attended private schools and 19 were girls). Their age ranged from 7;1 to 9;5 years (mean: 8;1, SD: ±0.73). Independent sample t-tests revealed no significant differences among the children attending the different schools for non-verbal reasoning scores, or for reading and spelling accuracy on the 60-word list ($p > .5$).

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A summary of the participants' characteristics is given in Table 1.

One-way ANOVAs were used to establish that results for chronological age and non-verbal reasoning did not differ among the monolingual Greek and weak and strong Greek literacy ability bilingual groups (both Fs < 1). Further one-way ANOVAs revealed that there were significant group effects for Greek reading and spelling accuracy, $F(2,81) = 90.64$, $p = .000$, $\omega = .50$ and $F(2,81) = 51.50$, $p = .000$, $\omega = .50$, respectively. Post-hoc analyses using the Games–Howell procedure revealed that the weak Greek literacy ability bilingual group had significantly poorer reading scores than both the strong Greek and the monolingual Greek groups, $t(81) = 10.78$, $p < .001$, $r = .60$ and $t(81) = 12.7$, $p < .001$, $r = .66$, respectively. The scores of the strong Greek literacy ability bilingual group and the Greek monolingual one did not differ significantly ($p > .05$). For the spelling scores, the weak Greek literacy ability bilingual group had significantly poorer scores than the strong Greek literacy ability bilingual group and the Greek monolingual one, $t(81) = 5.79$, $p < .001$, $r = .30$ and $t(81) = 10.14$, $p < .001$, $r = .60$, respectively. Finally, the spelling scores of the Greek monolingual group were significantly better than those of the strong Greek literacy ability bilingual group, $t(81) = 3.67$, $p < .0001$, $r = .15$.

Bilingual group

Participants in the bilingual group were 46 Greek- and English-speaking bilingual children recruited from one morning and two afternoon Greek schools in London. Their ages ranged from 7;1 to 10;1 years (mean: 7;9, SD: ±0.64).

The morning school followed the Greek national curriculum. Children ($N = 13$, four girls) received instruction in Greek language art (through the medium of Greek) for eight hours per week and English literacy (also through the medium of Greek) for ten hours per week. Most of the children spoke Greek at home. The afternoon school was for five hours per week, and approximately four hours were devoted to Greek literacy instruction. Children attending the afternoon schools ($N = 33$, 17 girls) attended mainstream English schools during the day, spoke English at home, and spoke Greek mainly with older members of the family. Pupils in both types of Greek school were instructed in Greek literacy by means of analytic and synthetic approaches, and in English literacy by a combination of whole-word and phonics methods. The pace of learning to read, write and speak Greek in the afternoon school is slower in comparison with that of the morning school, due to fewer hours of instruction in Greek. The sequence for instruction in Greek literacy is as follows. Pupils are taught the basic letters of the alphabet and how to read and write simple words using these letters. Then the children are taught digraphs, trigraphs, diphthongs, consonant and vowel clusters, and some basic grammatical rules which will guide their spelling. Teachers are allowed flexibility in choosing a primer from a wide range of materials written for pupils learning Greek as a second language.

The sample of bilingual children was divided into two groups on the basis of reading and spelling performance in Greek on the 60-word list. To identify the strong and weak Greek groups, the scores for reading and spelling accuracy were converted to z-scores, and the groups were formed on the basis of a median split of the composite z-scores. There were 23 students in each group. The weak Greek literacy ability bilingual group consisted of 14 girls and 9 boys, and the strong Greek group had 7 girls and 16 boys. As anticipated, the majority of the children from the morning school (12 out of 13 children), where children received more hours of Greek language arts instruction than in the afternoon schools, were in the strong Greek literacy ability bilingual group. A language experience questionnaire was completed by the participants. In the weak Greek literacy ability bilingual group, 70% of the participants reported that at home they mainly spoke English and 30% used both languages; in the strong Greek literacy ability bilingual group, 26% of the participants reported that at home they mainly spoke Greek, 22% mainly spoke English and 52% used both languages.

Independent t-tests were used to examine differences between the two groups on the background variables. These revealed that the strong and weak Greek literacy ability bilingual groups did not differ in terms of chronological age or scores on the non-verbal reasoning test. Nor did they differ on English reading and spelling accuracy. There were significant group differences for Greek reading accuracy ($t(81) = 10.78$, $p < .0001$, $r = .76$) and Greek spelling ($t(81) = 5.79$, $p < .0001$, $r = .54$). These latter two differences were to be expected, given the procedure used for grouping the bilingual participants.

Materials

The bilingual and monolingual participants were assessed in the same experimental tasks, as outlined below. All were administered by the first author who is bilingual in Greek and English.

Child-related variables

Scores on two assessments were used to examine possible differences between the groups in child-related variables associated with spelling performance on the 60-word list.

Phonological awareness (PA)

The blending subtest from the Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen & Rashotte, 1999) was used to assess PA in English. The blending subtest from the Athena Test (Paraskevopoulos,

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Kalatzi-Azizi & Giannitsas, 1999) was used to assess PA in Greek.

Visual short-term memory

The Memory for Designs and Pictures subtests from the Athena Test (Paraskevopoulos et al., 1999) were used to assess visual memory. The tests require reproduction of a series of abstract designs (Memory for Designs) or familiar pictures (Memory for Pictures) following a five-second retention interval.

Stimulus-related variables

Values for the words in the 60-word list on two variables were used in order to examine possible differences across the groups in stimulus-related factors associated with spelling performance.

Printed word frequency

Values for printed word frequency in children's books for the stimuli were obtained from two language-specific sources. Word frequencies for Greek children's primers were obtained from unpublished work by Ken Spencer, Jackie Masterson and Athanasia Syntili, and for British English children's books for the age range 5–9 years from Masterson et al. (2003).

Least Transparent Phonographeme probability

The second set of values obtained for the stimuli concerned transparency of sublexical units: Least Transparent Phonographeme (LTPG). This refers to the probability of a phoneme corresponding to a particular grapheme in the language. Phoneme–grapheme correspondences vary in probability, for instance the phoneme /o/ is found in 87 English words, though with the spelling <au> only once. Thus, the /o/ → <au> correspondence has a very low probability of 1 out of 87.[1] LTPG values for English for the words in the 60-word list were obtained using Masterson et al.'s (2003) Children's Printed Word Database (Ken Spencer, personal communication). LTPG values for the Greek words were obtained from Spencer, Loizidou-Ieridou and Masterson (2010).

It was noted that there were 11 cognates (e.g. elephant → ελέφαντας) in the Masterson et al. 60-word list.[2] Since cognates have been shown to affect word processing in bilinguals in previous research, we carried out the statistical analyses with and without these items. The results of the analyses were not found to be different with cognates in or out. Results reported hereafter will be based on the 60 items in the Masterson et al. list.

Procedure

The study began once Ethical Committee approval had been given to the Institute of Education, University of London, and letters of parental consent for children's participation were received. The testing of the bilingual participants took place in two different periods. Of the Greek–English bilingual group, 28 participants were tested in February–May 2009 and 18 participants were tested in February–May 2011. Monolingual children were tested in February–May 2011. Children were seen in a quiet room at their schools. Children were asked to read the 60 words as accurately as possible. Children's responses were recorded for later verification. In a separate testing session (one month later) children were presented with the words for spelling to dictation. The stimuli for spelling to dictation, in the case of the bilinguals, were split into three sets of 40 items (both English and Greek words – total 120 items), with a block of 20 Greek and 20 English words in each set, and two sets of 30 items for the monolingual controls. The sets were presented in three for the bilingual and two for the monolingual groups in separate sessions lasting from 15 to 20 minutes each. Finally, the blending test and visual memory and non-verbal reasoning tests were administered in further sessions lasting 15–25 minutes, in order to avoid participant fatigue.

Results

Analyses conducted

Intra-language correlational analyses, using the Predictive Analytics SoftWare (PASW, version 18), were conducted. Regression analyses were also conducted, first with the child-related and then the stimulus-related variables, looking at predictors of spelling performance. The final section of the "Results" section provides the outcome of a qualitative analysis of the children's spelling errors.

Child-related variables

Descriptive statistics are reported in Table 2 for the scores for the two monolingual groups and the strong and weak Greek literacy ability bilingual groups on the visual memory and phonological awareness (PA) assessments. Reliability for all tasks was above .80.

One-way ANOVAs were conducted on the results to investigate whether there were significant differences among the two bilingual groups and the English monolingual group in PA and visual memory. In no case was there a significant effect (all Fs < 1). The same

[1] Least Transparent Phonographeme values (LTPG) were obtained for the stimuli, rather than overall or average phonographeme values for each word, or an alternative, because LTPG was found to be the strongest predictor of spelling performance in Spencer's (2007) study of children's spelling performance.

[2] We are grateful to an anonymous reviewer for pointing this out.

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Table 2. *Mean scores for the four groups of children on the phonological awareness and visual memory assessments (standard deviations are in parentheses).*

	Monolingual		Bilingual	
Task	English	Greek	Weak Greek	Strong Greek
Phonological awareness English[a] (max = 20)	14.12 (2.47)	–	14.35 (1.90)	14.91 (3.50)
Phonological awareness Greek[b] (max = 32)	–	24.16 (5.77)	18.22 (7.85)	21.39 (7.90)
Visual memory pictures[c] (max = 32)	18.55 (5.85)	15.74 (5.26)	19.09 (5.46)	16.65 (5.63)
Visual memory designs[d] (max = 32)	13.82 (5.31)	13.61 (5.58)	14.74 (5.88)	14.26 (5.11)

[a]Phonological awareness English = Blending subtest, Comprehensive Test of Phonological Processing (Wagner, Torgesen & Rashotte, 1999)
[b]Phonological awareness Greek = Blending subtest, Athena Test (Paraskevopoulos et al., 1999)
[c]Visual memory pictures = Memory for Pictures subtest, Athena Test (Paraskevopoulos et al., 1999)
[d]Visual memory designs = Memory for Designs subtest, Athena Test (Paraskevopoulos et al., 1999)

analyses were carried out for the bilingual groups and the Greek monolingual group. There was a significant group effect for PA, $F(2,81) = 5.21$, $p < .01$, $r = .60$. Post-hoc analysis using the Games–Howell procedure showed that scores for the weak Greek literacy ability bilingual group and the Greek monolingual one differed significantly, $t(81) = 3.21$, $p < .01$, $r = .11$, and there were no other significant differences.

Interrelationships among variables

Prior to analyses, data were checked for positive or negative skew. Positive skew in the scores for English spelling was corrected by applying first logarithmic and then square route transformation. Inspection of the correlation coefficients showed no differences whether data were transformed or not. Consequently transformation was not applied to the spelling scores. Correlations between the measures were calculated for each group and the outcomes are presented in the Appendix. Monolingual English children's spelling scores were significantly associated with reading accuracy, non-verbal ability, PA and visual memory for pictures. For the monolingual Greek group spelling scores were significantly associated with reading accuracy and PA. English spelling for the weak Greek literacy ability bilingual group correlated significantly with reading accuracy, non-verbal ability and visual memory for designs, but not with PA. For the strong Greek literacy ability bilingual group, significant correlations were observed between spelling and reading accuracy, non-verbal ability, PA and visual memory for pictures.

Regression analyses

Separate simultaneous multiple regression analyses were conducted for each group. The dependent variable consisted of spelling scores in the Masterson et al. (2003) list. Predictor variables in each analysis were scores for PA plus scores for visual memory for pictures for the monolingual groups (since scores on this variable correlated most highly with spelling performance for at least one monolingual group), and scores for visual memory for designs for the bilingual groups (since scores for this variable correlated most highly with spelling performance for at least one of the bilingual groups). The overall regression model was significant for the monolingual English group, $F(2,30) = 8.29$, $p < .001$, and the monolingual Greek group, $F(2,35) = 7.05$, $p < .01$, and for the strong Greek literacy ability bilingual group, $F(2,20) = 26.73$, $p < .0001$, and the weak Greek literacy ability bilingual group, $F(2,20) = 9.43$, $p < .001$. A summary of the analyses is provided in Table 3.

The results revealed that both PA and visual memory for pictures were significant predictors of spelling in the monolingual English group: PA explained 15% of variance and visual memory 21% of variance. PA was also a strong predictor of Greek spelling for the monolingual Greek participants, explaining 23% of variance. For the strong Greek literacy ability bilingual participants, PA was a significant predictor and accounted for 70% of variance. For the weak Greek literacy ability bilingual group visual memory for designs was a significant predictor, and accounted for 36% of variance.

It can be seen then that the spelling performance of the bilingual children with high levels of proficiency in Greek appears to be strongly affected by PA, as in the case of monolingual Greek children, and in line with the notion that learning to read and spell in Greek leads to a reliance on phonologically-based sublexical processing for spelling. The results for the bilingual children with lower levels of proficiency in Greek instead indicate that spelling performance is influenced by visual memory. This suggests use of visually-based lexical processing, and is in line with the results for the monolingual English children, for whom visual memory was also a significant predictor of spelling performance. Unlike the weak Greek literacy ability bilingual group, the spelling of the monolingual English group was also significantly predicted by PA. This difference in pattern of results across the two groups

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Table 3. *Simultaneous multiple regression analyses with spelling scores (English for the English monolingual and two bilingual groups, and Greek for the Greek monolingual group) as the dependent variable. Bold indicates significant predictions.*

	Monolingual						Bilingual					
	English			Greek			Weak Greek			Strong Greek		
	B[a]	SE[b]	β[c]	B	SE	β	B	SE	β	B	SE	β
Phonological awareness	2.1	0.9	**.35***	0.8	0.2	**.46****	1.7	0.8	.31	3.6	0.5	**.87*****
Visual memory	1.0	0.4	**.42****	0.3	0.2	.22	1.2	0.3	**.66*****	−0.3	0.3	−0.1

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$
[a]B = Unstandardized beta values
[b]SE = Standard error of the unstandardized coefficients
[c]β = Standardized beta values

Table 4. *Results of simultaneous multiple regression analyses with item spelling data (for English in the case of the English monolingual and two bilingual groups, and Greek for the Greek monolingual group) as the dependent variable. Bold indicates significant predictions.*

	Monolingual						Bilingual					
	English			Greek			Weak Greek			Strong Greek		
	B[a]	SE[b]	β[c]	B	SE	β	B	SE	β	B	SE	β
Frequency	13.4	2.9	**.47*****	9.4	3.3	**.31****	6.5	1.6	**.42*****	5.3	1.3	**.44*****
LTPG	860	252	**.35*****	685	184	**.41*****	485	139	**.37*****	308	111	**.31****

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$
[a]B = Unstandardized beta values
[b]SE = Standard error of the unstandardized coefficients
[c]β = Standardized beta values

may be due to the lack of statistical power as a result of the smaller number of participants in the bilingual group compared to the monolingual English group (23 in the former vs. 33 in the latter).

Stimulus-related variables

Separate simultaneous multiple regression analyses were conducted for each group with the item data (number of correct spelling responses per item in the 60-word list calculated across participants) as the dependent variable. The stimulus-based variables were predictors. Prior to the analyses the data were checked for normality. A logarithmic transformation improved the fit of frequency; consequently, analyses reported will be based on the log frequency values.

Regression analyses

Item totals for spelling in English were used as the dependent variable in the regression analyses for the monolingual English and bilingual groups. Item data for spelling in Greek was the dependent variable in the analyses for the Greek monolingual group. Printed word frequency and Least Transparent Phonographeme values (LTPG) were the predictor variables. A summary of the results is provided in Table 4. The overall regression model was significant for the monolingual English group, $F(2,57) = 17.63, p < .0001$, the monolingual Greek group, $F(2,57) = 11.76$, $p < .0001$, the strong Greek literacy ability bilingual group, $F(2,57) = 13.28$, $p < .0001$, and the weak Greek literacy ability bilingual group, $F(2,57) = 15.20$, $p < .0001$

Both printed word frequency and LTPG were significant predictors of spelling accuracy for all the groups. Specifically, the results revealed that for the monolingual English group, printed word frequency explained 26% of variance and LTPG 16% of variance. For the monolingual Greek participants, LTPG explained 19% of variance and printed word frequency 10% of variance. For the strong Greek literacy ability bilingual participants, printed word frequency accounted for 22% of variance and LTPG for 12% of variance. For the weak Greek literacy ability bilingual group, printed word frequency accounted for 21% of variance and LTPG for 17% of variance. The finding that both frequency and LTPG predicted the spelling performance of the monolingual English group

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is in line with the results obtained by Spencer (2007) with English-speaking children, indicating the use of both lexical and sublexical processing. We might have expected to observe that the monolingual Greek group and weak Greek literacy ability bilingual group would show less evidence of use of lexical processing; however, previous studies in transparent orthographies have also indicated that both lexical and sublexical procedures are used for reading and spelling, at least after the earliest stages of literacy acquisition have been surpassed (see e.g., Zoccolotti, De Luca, Di Filippo & Martelli, 2009).

Qualitative analysis

A qualitative analysis of the children's misspellings was conducted. Errors were divided into two categories:

1. Phonologically appropriate errors, which involved retaining the correct phonology, but where the spelling was incorrect (for example, *elephant* > ELEFANT).
2. Non-phonologically appropriate errors, where the misspelled word did not appear to retain the phonology of the target (for example, *monastery* > MONASTREET).

Percentages of each category of error were calculated for the groups separately. The monolingual English-speaking children made an average of 67% phonologically appropriate errors, while monolingual Greek participants made an average of 91% phonologically appropriate errors. The strong Greek literacy ability bilingual group made more phonologically appropriate errors (mean: 55%) than the weak Greek literacy ability bilingual group (mean: 42%). The difference between the two groups was significant, $t(44) = 2.1$, $p < .05$, $r = .09$.

Additionally, in the spelling-to-dictation task, 16 words were irregular ones. Analyses of the type of errors made revealed that the strong Greek literacy ability bilingual group made more regularization errors (57%) on irregularly spelled items that the weak Greek literacy ability bilingual group (40%). Paired samples *t*-test conducted revealed a significant difference between the two groups ($t(15) = 2.19$, $p < .05$, $r = .24$).

Discussion

The focus of the present study was to look for evidence of possible differences in the processes used for spelling in English in children with different levels of proficiency in reading and spelling in the transparent Greek spelling system. Specifically, the aim was to investigate whether a sublexical strategy might be more apparent in Greek–English bilingual children with strong Greek literacy skills, due to the transparent nature of the Greek orthography, while visually-based whole-word processes might be more apparent in the spelling of Greek–English bilingual children with weak Greek literacy skills.

The results indicated that the weak and strong Greek literacy ability bilingual groups did differ in their reliance on different processes for spelling in English. In analyses of child-related variables, spelling accuracy in the strong Greek literacy ability bilingual group was significantly predicted by a measure of phonological awareness (blending), while for the weak Greek literacy ability bilingual group, scores on a visual memory assessment significantly predicted spelling accuracy. The analyses indicated that the strong Greek literacy ability bilingual group was relying more on phonological processes for spelling in English, while the weak Greek literacy ability bilingual group was relying more on visually-based processes. The results were consistent with the results obtained from the monolingual groups. Monolingual English children's spelling accuracy was predicted by visual memory scores as well as PA scores, while monolingual Greek children's spelling performance was predicted by PA scores only.

The findings are in agreement with studies which indicated that cognitive processes are transferred from one language to another (Holm & Dodd, 1996; Liow & Lau, 2006; Mumtaz and Humphreys,2001, 2002; Sun-Alperin & Wang, 2011; Wang, Koda & Perfeti, 2003; Xuereb, 2009). As noted in the introduction, Mumtaz and Humphreys (2002) reported that English–Urdu bilingual children with weak Urdu vocabulary awareness made fewer regularization errors when reading in English and had stronger visual memory skills than those with strong Urdu vocabulary knowledge. Although that study investigated reading, and the present study investigated spelling, both sets of findings (as well as those of a number of other studies) indicate that levels of exposure to a transparent orthography can influence the use of lexical and sublexical processes in opaque English spelling (Holm &Dodd, 1996; Mumtaz & Humphreys, 2002).

For monolingual English participants, visual memory scores as well as PA were strong predictors of spelling performance. The former result is not consistent with the findings of Caravolas et al. (2001), who did not find a significant association between visual memory and spelling performance. However, this discrepancy could be attributed to the different ages of the participants in the two studies, or to differences in the tasks used. In the Caravolas et al. (2001) study, children were aged between four and eight years, while in the present study they were aged between seven and ten years. Consequently, phonological ability may be a strong

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predictor of monolingual English children's spelling in the early years of instruction, but with further experience of the opaque English orthography, visual memory may come to play a more significant role.

Giles and Terrell (1997) in their study of poor spellers with mean age 14;3 concluded that visual sequential memory (employing nameable and non-nameable pictures) did not have a significant role in spelling for these children. The study involved two experiments with students divided into "Phoenician" and "Chinese" groups based on qualitative analyses of spelling errors. They found a difference between visual memory scores for the two groups for nameable pictures in the first experiment, but they could not replicate the results with a new group of participants matched in intelligence in a second experiment. Again, differences between the Giles and Terrell study and the present one including age of participants and tasks used could have caused the discrepancy in findings.

The analyses of stimulus-related variables in the present study indicated that significant predictors of spelling performance were printed word frequency and Least Transparent Phonographeme probability, in both bilingual and monolingual groups. These results are in line with the findings of Spencer (2007) for monolingual English-speaking children aged between six and ten years. The results indicate that children of this age use both lexical and sublexical processes for spelling in the alphabetic orthographies of English and Greek.

A qualitative analysis of the spelling errors in the different groups revealed that the vast majority (91%) of the errors of the monolingual Greek group were phonologically appropriate. While this was also the predominant type of error made by the monolingual English group, the percentage of such errors was lower there. In line with these findings, the strong Greek literacy ability bilingual group made more phonologically appropriate spelling errors than the weak Greek literacy ability bilingual group, indicating greater involvement of phonological or sublexical processes in spelling in the case of the former group. Interestingly, the weak Greek literacy ability bilingual group made more non-phonologically appropriate errors than the monolingual English group.

The overall findings indicate that bilingual children with low Greek literacy ability rely more on lexical procedures for spelling in English and bilingual children with strong Greek literacy ability rely more on sublexical processes for spelling in English. The results are in agreement with studies which maintain that cognitive skills are transferred from one language to another (Holm & Dodd, 1996; Liow & Lau, 2006; Pae,Sevcik & Morris, 2010; Wang et al., 2003; Xuereb, 2009). Perfetti, Liu, Fiez, Nelson, Bolger and Tan (2007) reviewed event-related potential and fMRI studies in an attempt to explain the cross-linguistic transfer effect among Chinese–English and English–Chinese bilinguals. The researchers suggest that Chinese second language learners accommodate neural networks not essential for reading an alphabetic language such as English in order to read Chinese, while English second language learners assimilate neural networks crucial for Chinese reading into English decoding, especially those related with procedures of lexical/whole-word processing. This study provides evidence of the flexibility and plasticity of the neural networks in order to successfully accommodate the new linguistic system. Similar event-related potential and fMRI studies among Greek–English and English–Greek bilinguals could be also informative. A significant limitation of the present study was the modest sample size.

Thus, a replication of the study with a larger sample would strengthen the conclusions. Specifically, a replication with different opaque and transparent orthographies, also investigating the neural network of the participants, would be informative.

In summary, the results were in accordance with our prediction that we would observe evidence of differential reliance on lexical and sublexical processes for spelling in English in bilingual children according to their level of proficiency in transparent Greek. The field of language transfer effects is a relatively new one, and the accumulating results indicate the flexible nature of developing processing systems in adapting to the language characteristics of the input (Koda, 2008). This line of enquiry would seem to be potentially productive for increasing our knowledge of the acquisition of literacy in biliterate and bilingual children and also, more generally, for increasing our knowledge of the organization of linguistic and cognitive processing systems (Ellis, 2005).

Appendix. Correlations between spelling accuracy and scores on other assessments

Table A1. *Correlations between spelling accuracy and scores on other assessments, the upper orthogonal represents correlations for the Greek monolinguals and the lower orthogonal represents correlations for the English monolinguals.*

	Spell[α]	Age[b]	NVR[c]	Read Ac[d]	PA[e]	VMP[f]	VMD[g]
Spell	–	.03	.08	.46**	.51***	.29	.11
Age	.34	–	.35*	−.21	−.13	.09	.02
NVR	.56***	.24	–	−.08	.29	.30	.18
Read Acc.	.83***	.27	.38*	–	.13	−.02	−.12
PA	.42*	.06	.26	.46**	–	.24	.08
VMP	.48**	.34	.41*	−.29	.16	–	.49**
VMD	.22	.37*	.53**	.25	.23	.28	–

[a]Spelling accuracy for 60-word list from Masterson et al. (2008)
[b]Chronological age in months
[c]Non-verbal reasoning ability
[d]Reading accuracy for 60-word list
[e]Phonological awareness
[f]Visual memory for pictures
[g]Visual memory for designs

Table A2. *Correlations between spelling in English and other measures, the upper orthogonal presents correlations for the strong Greek group and the lower for the weak Greek group.*

	Spell[α]	Age[b]	NVR[c]	Read Ac[d]	PA[e]	VMP[f]	VMD[g]
Spell	–	.32	.45*	.82***	.85***	.55*	.06
Age	.30	–	.46*	.33	.42*	.39	.23
NVR	.76***	.41	–	.36	.51*	.11	.12
Read Ac.	.79***	.23	.73***	–	.83***	.41	.13
PA.	.21	.12	.34	.45*	–	.38	.20
VMP	.15	.14	.01	.04	.08	–	.46
VMD	.62***	.27	.51*	.39	−.13	.36	–

[a]Spelling accuracy for 60-word list from Masterson et al. (2008)
[b]Chronological age in months
[c]Non-verbal reasoning ability
[d]Reading accuracy for 60-word list
[e]Phonological awareness
[f]Visual memory for pictures
[g]Visual memory for designs

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