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Pathways from morphological awareness to reading fluency: the mediating role of phonological awareness and vocabulary

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Abstract

The goal of this study was to examine the relation of morphological skills with reading fluency in 2nd grade Greek-speaking children and if phonological awareness and vocabulary mediate their relation. The sample consisted of 105 2nd grade Greek-speaking students (46 males; Mage = 7.83 years, SD = 3.31). Morphological awareness was assessed with four tasks, examining inflectional and derivational morphology both at an epilinguistic and metalinguistic level. Reading fluency was assessed with oral and silent measures. Results of path analyses indicated that inflectional and derivational morphology contributed to reading fluency through multiple pathways, controlling for the effect of Rapid Automatized Naming. Phonological awareness fully mediated the relation of inflectional and derivational morphology with text reading fluency. Vocabulary partially mediated the relation of inflectional and derivational morphology with silent reading fluency. Furthermore, derivational morphology directly affected silent reading fluency. Overall, the relation of morphological awareness with reading fluency appeared to be dynamic and varied depending on the morphological awareness skill and measure of reading fluency. Regarding the mediating role of phonological awareness and vocabulary, the results showed that children in lower elementary grades in a transparent orthography with a rich morphological system used morphological skills as activators to existing phonological and semantic skills in supporting reading fluency processes.

Keywords Reading fluency · Morphological awareness · Phonological awareness · Vocabulary · Transparent orthography

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Introduction

Reading fluency is typically defined as the ability to read text with accuracy, speed, and prosody (NICHD, 2000). Previous studies have shown that reading fluency is a multidimensional and dynamic reading skill, which relies upon multiple linguistic and cognitive skills, contributing at different levels in the processing hierarchy, such as phonological awareness (PA) (de Jong & van der Leij, 1999), rapid automatized naming (RAN) (Georgiou et al., 2012), morphological awareness (MA) (Carlisle, 2000), information processing speed (van den Bos et al., 2003), vocabulary (Tibi & Kirby, 2017, 2018), and orthographic processing (Berninger et al., 2010). The magnitude of contribution of these skills seems to vary across orthographies (Desrochers et al., 2018), grade levels (Landerl & Wimmer, 2008), and reading modes (oral versus silent) (Görgen et al., 2021; van den Boer et al., 2014).

Linguistic skills appear to contribute to a larger extent to reading fluency in lower elementary grades (Cohen-Mimran et al., 2022; Manolitsis et al., 2019; Shechter et al., 2018). In particular, MA plays a significant role in mastering decoding, reading comprehension, and spelling both in opaque (Carlisle, 2000; Desrochers et al., 2018; Nunes et al., 2003) and transparent orthographies (Diamanti et al., 2017; Haase & Steinbrink, 2022; Manolitsis et al., 2017). However, the findings regarding the role of MA in reading fluency in lower elementary grades are mixed. Some studies indicated that MA is not a significant contributor to reading fluency (Desrochers et al., 2018; Diamanti et al., 2017; Kirby et al., 2012; Manolitsis et al., 2017; Müller & Brady, 2001), while others showed significant effects (Burani et al., 2008; Cohen-Mimran et al., 2022; Freitas et al., 2018; Giazitzidou & Padeliadu, 2022; Görgen et al., 2021). Thus, the precise role and way in which MA is linked to reading fluency remains unclear. MA refers to the explicit understanding of morphological relations between word forms and meanings, such as grammatical inflection and productive derivation and the ability to manipulate the morphological structure of words (Bowers et al., 2010; Carlisle, 1995; Nunes & Bryant, 2009). In line with the above evidence and taking into account the high correlation among linguistic skills (Mahony et al., 2000) the present study aimed to examine the relation between MA and reading fluency and the possible mediating role of PA and vocabulary in the context of the Greek language that provides an interesting medium for exploring its exact role, because of its transparency and rich morphological system (Protopapas, 2017).

Morphological awareness and reading fluency

According to *Morphological Pathways Framework* (Levesque et al., 2021), MA is a component of the linguistic system, multidimensional in nature, that shares common parts with phonological and syntactic awareness. This model suggests that MA skills impact literacy skills through multiple pathways operating at different levels. For instance, MA is related to word identification processes through morphological analysis skills that enable parallel activation of semantic, phonological, and syntactic representations. Accordingly, morphological analysis skills are expected to impact reading fluency either directly or indirectly.

Direct contribution of MA to reading fluency is supported both theoretically and empirically. In terms of theory, MA seems to be a binding agent between the different lexical representations, since morphemes carry multidimensional information (phonological, orthographic, syntactic, and semantic) (Kirby & Bowers, 2017). According to the prominent theory of lexical quality (Perfetti, 2007), MA increases the lexical quality by adding semantic information that enhances the links among different lexical representations, resulting in more efficient recognition and retrieval of word lexical representation. In addition, semantic activation of morphemes compared to meaningless bigrams and trigrams may booster top-down processes, leading to faster and more accurate word recognition (Nation, 2009).

A number of studies have provided evidence regarding the significant effect of inflectional and derivational morphology on reading fluency in transparent orthographies i.e., Dutch (Rispens et al., 2008), Portuguese (Freitas et al., 2018), German (Görgen et al., 2021; Haase & Steinbrink, 2022), Greek (Diamanti et al., 2017; Giazitzidou & Padeliadu, 2022), Italian (Burani et al., 2008), and in early grades Hebrew (Cohen-Mimran et al., 2022; Shechter et al., 2018; Vaknin-Nusbaum et al., 2016). For instance, Görgen et al. (2021) found that inflectional and derivational morphology had a small, but unique, contribution to silent reading fluency of 3rd and 4th grade German-speaking children. They argued that the use of text units, such as morphemes, facilitate word recognition even in a transparent orthography where readers do not rely on larger units in order to read a word. In addition, Rispens et al. (2008) reported that awareness of noun inflectional morphemes, assessed with the WUG test (Berko, 1958), accounted for approximately 4% of the variance in word reading fluency of 1st grade Dutch-speaking children. On the contrary, in 6th grade, only derivational morphology contributed 3% of the variance in word reading fluency, beyond the effect of PA, age, and vocabulary. In a study conducted with Greek-speaking children, Pittas and Nunes (2014) showed that inflectional and derivational morphology had a unique contribution to text reading fluency and comprehension (combined score) of 1st and 3rd grade children 8 months later, after controlling for grade, verbal ability, PA, and initial reading level.

Despite the recent surge of interest in the relation between MA and reading skills, and the strong evidence for its involvement in literacy development, the relevant literature has not conclusively established the precise role of inflectional and derivational morphology in attaining reading fluency. Existing studies have focused on the contribution of inflectional and derivational morphology to word reading fluency using mostly composite scores or examining only a few aspects of reading fluency. The current study sheds new light on the role of inflectional and derivational morphology in oral and silent reading fluency in a language with rich morphology that poses minimal decoding challenges because of its transparent orthography.

The relation between morphological awareness, phonological awareness, and vocabulary

Based on Levesque et al.'s (2021) Morphological Pathways Framework, MA may contribute to word identification processes not only directly, but also indirectly. Morphological processing of words involves interactive processes of words linguistic dimensions (Carlisle, 2003), including PA, semantic, and syntactic processing (Carlisle, 2003; Kuo & Anderson, 2006). These, in turn, activate phonological, semantic, and syntactic lexical representations, respectively. Phonology, in particular, is considered to be the basis for initial morphemes recognition (Anglin, 1993a; Deacon & Kirby, 2004). A substantial number of studies have confirmed the strong association between MA and PA (Deacon & Kirby, 2004; Sparks & Deacon, 2013). Especially, in lower elementary grades MA and PA share a high level of covariance (Kuo & Anderson, 2006), as the development of the former is largely based upon early phonological skills (Ehri, 2005).

Longitudinal studies conducted in lower elementary grades have revealed the crucial role of PA in MA development (Kirby et al., 2012; Sparks & Deacon, 2013). Cunningham and Carroll (2015) for example showed that early phonological processing skills of 4 to 6-year-old English-speaking children predicted MA three years later. However, the available findings come from studies conducted in opaque orthographies, raising the need to carry similar investigations in transparent orthographies that ease higher degrees of decoding accuracy and fluency rates (Seymour et al., 2003).

Furthermore, research has demonstrated that MA and vocabulary are related constructs, with MA explaining unique variance in vocabulary (Anglin, 1993b; Kirby et al., 2012; McBride-Chang et al., 2008). Morphemes carry semantic information, which facilitates decomposition of words into meaningful units, constituent known morphemes, in order to infer words' meaning (Tibi & Kirby, 2017). In addition, morphological knowledge may support access, retrieval, and storage of the semantic representation of morphologically complex words (Nagy et al., 2014). Therefore, morphological "problem solving" appears to play an important role in constructing the meaning of words (Deacon & Kirby, 2004).

Several studies have shown that MA predicts vocabulary knowledge, both concurrently and longitudinally, even after controlling for linguistic and cognitive skills (Carlisle, 2000; Cheng et al., 2015; Fejzo, 2021; McBride-Chang et al., 2008). For instance, Sparks and Deacon (2013) showed that MA in 2nd grade uniquely explained 14.9% of the variance in 3rd grade vocabulary, even after partialling out the effects of PA, nonverbal reasoning, age, and 2nd grade reading skills. Generally, it appears that middle grade elementary children use a morphological analysis strategy to understand morphologically complex words (Carlisle, 2000). Based on this hypothesis, MA may be regarded as an analytic skill that enables inferences about word structure and meaning (Anglin, 1993). Despite the previous research confirming the strong connection between MA with PA and vocabulary, respectively, the contribution of skills to MA in relation to reading fluency development remains understudied.

Linguistic and orthographic characteristics of Greek language

Greek orthography is an interesting language to examine the role of morphology in reading fluency, since it is a highly transparent language with rich morphology. In transparent orthographies, morphological processing skills may have a more important role in reading processes, where the demands of phonological processing are lower compared to opaque orthographies. This claim is substantiated by studies showing that acquisition of morphology in transparent orthographies occurs earlier than in deep orthographies, after the development and acquisition of grapheme–phoneme correspondences and the syllabic system of the language (Seymour et al., 2003). Protopapas and Vlachou (2009) conducted a quantitative analysis, estimating that the Greek orthographic consistency is around 95% for reading and 85% for spelling. The Greek phonemic inventory includes five vowels. There is no consensus as far as consonants are concerned. The number of consonants ranges from 15 to 31, depending on the theoretical and empirical criteria applied by different researchers. Modern Greek uses 24 letters. Greek language has many multisyllabic words, using relatively few monosyllables, most of which are closed-class (grammatical) words or otherwise atypical (Protopapas, 2017). Greek morphology is rich with a complex inflectional and derivational morphology. Inflectional morphemes identify the grammatical markers of words for denoting word's gender, person, number, case, tense, voice, and aspect. Nouns and adjectives are obligatorily inflected for gender, number, and case via fusional suffixation while verbs are obligatorily inflected for voice, tense, person, number, and aspect. Verb forms include a stem and inflectional ending, which may be simple or complex. Derivation is generally considered as the core of word formation. Derived words are the product of a word-formation rule, which combines a stem and a derivational affix. Greek derivational morphology is less productive than the inflectional one. There are various derivational morphemes (prefixes and suffixes), which interact with inflectional morphemes in order to form new words added in stems (Ralli, 2003).

The present study

The goal of this study was to examine the relation of morphological skills with reading fluency in 2nd grade Greek-speaking children and if phonological awareness and vocabulary mediate their relation. The role of MA may be increased in scripts that represent morphemes of the spoken language in a clear and consistent manner, like Greek. Thus, investigating the relationship between MA and reading fluency in Greek generates knowledge on how this relationship unfolds in a morphologically rich language with a transparent orthography. Specifically, we wanted to examine the mediating role of PA and vocabulary in the relation of inflectional and derivational morphology skills with oral (pseudoword and text), and silent (word) reading fluency, after partialling out the effect of RAN. We used RAN as a control variable, since it is a key predictor of reading fluency in Greek (Georgiou et al., 2012; Papadopoulos et al., 2016). We aimed at determining (a)

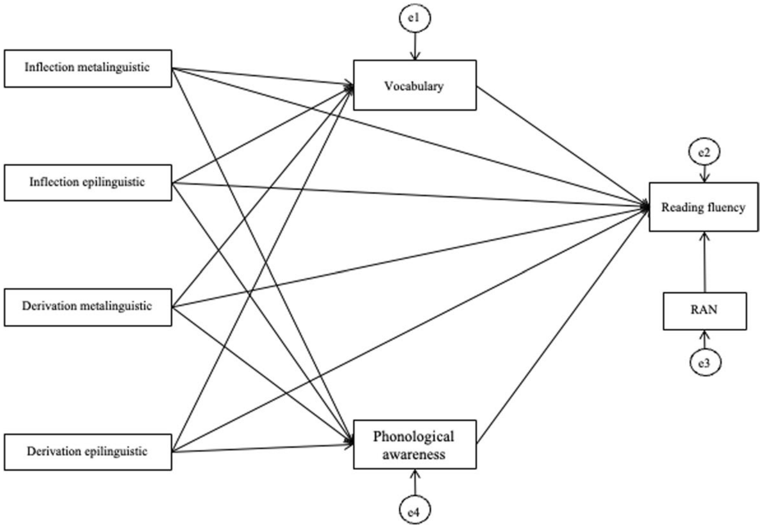

Fig. 1 Hypothesized relational models of reading fluency, morphological awareness, phonological awareness, and vocabulary

whether inflectional and derivational morphology directly affect oral (pseudoword and text), and silent (word) reading fluency and (b) whether PA and vocabulary mediate the relation of inflectional and derivational morphology with oral (pseudoword and text) and silent (word) reading fluency. We focused on 2nd grade children based on developmental criteria of reading fluency. In 2nd grade, Greek children master grapheme-phoneme correspondences and mechanisms of phonemic analysis and synthesis (Seymour et al., 2003), with morphological awareness sharing to a large extent covariance with PA and vocabulary during the early elementary grades (Manolitsis et al., 2017).

Based on previous research, we hypothesized that MA would directly contribute to oral pseudoword reading fluency (Burani et al., 2008), oral text reading fluency (Pittas & Nunes, 2014; Rothou, 2012), and silent word reading fluency (Giazitzidou & Padeliadu, 2022; Görgen et al., 2021). In addition, given both the high correlation between MA and PA (Görgen et al., 2021; Manolitsis et al., 2019) and the interactive processes involved in word recognition (Carlisle, 2003; Levesque et al., 2021), we hypothesized that MA would impact oral pseudoword, oral text, and silent word reading fluency through PA. Finally, based on the strong association between MA and vocabulary (Anglin, 1993b; Kirby et al., 2012; McBride-Chang et al., 2008), the semantic information of morphemes and the morphological analysis skills that children use to process word meaning (Carlisle, 2007; Sparks & Deacon, 2013), we hypothesized that MA would impact oral pseudoword, oral text, and silent word reading fluency through vocabulary (see Fig. 1).

Method

Participants

The study sample consisted of 105 (46 males) monolingual Greek-speaking children (Mage = 7.83 years, *SD* = 3.31) attending 28 2nd grade classrooms. All participants had non-verbal ability above the 85th percentile according to the Greek standardization of the *Coloured Progressive Matrices* (Raven, 2004). Participants were recruited through a stratified randomized approach, using school, class and gender as stratum, from 19 state primary schools of five urban (85.7%) and semi-urban (14.3%) cities in Greece, including Athens and Thessaloniki, representing a variety of socioeconomic backgrounds. Permission to conduct the research was granted by the Research Office of the National Educational Policy Institute, supervised by the National Ministry of Education. Parental and school approvals, as well as the child's assent, were provided prior to test administration.

Materials

PA, MA, and vocabulary tasks were adapted from existing research instruments. Tasks were tested in a pilot study. The adaptation process was undertaken at two levels. At the first level of tasks design, we tried to follow the paradigm of the original tasks, keeping the same rationale in terms of administration and demands. At the second level, the items were selected in relation to phonological and morphological complexity, syllabic structure, word length, and frequency, considering the special characteristics of Greek language and orthography.

Nonverbal intelligence

Nonverbal intelligence was assessed with the Raven's Coloured Progressive Metrices Test (2004). The test required participants to select one of six options that best completed a matrix with a part missing. The total number of correct answers was recorded. Cronbach's alpha in the Greek standardization is .90 (Sideridis et al., 2013).

Reading fluency

Reading fluency was measured with three tests. Pseudoword reading fluency was assessed via the TOWRE task (Torgesen et al., 2012) adapted in Greek (Mouzaki & Sideridis, 2007; Simos et al., 2013), requiring participants to orally read a list of 70 pseudowords as fast and accurately as possible within a 45-s time limit. Items were arranged in three columns in order of ascending difficulty. Reported test–retest reliability for primary students is .79. Text reading fluency was measured with a "ΔΑΔΑ" subtest (Padeliadu et al., 2019), requiring participants to orally read as fast and accurately as possible a 274-word informative text in 1 min. According to the test manual, test–retest reliability is .97. For both pseudoword and text reading fluency measures, a participant's score was the correct number of words read orally within the specified time limit. Silent reading fluency was assessed with the Word Chain task, adapted in Greek by Georgiou et al. (2012). In this task, participants were asked to scan 50 words presented as a continuous line of print without interword spaces (e.g., βιβλιοκαλοφως; 'bookgoodlight') within a 1 min time limit. Participants were asked to identify the words in each row by drawing a line to indicate where the spaces should be (e.g., 'book/good/light'). The first two rows comprised two words whereas the last three rows consisted of seven words. Omega in our sample was .95. The Word Chain task was preferred over other measures of silent reading fluency because of its valued use in previous studies with young Greek readers (Papadopoulos et al., 2016) and because it is less dependent on semantic processing than the lexical decision, maze, and sentence verification tasks. The total number of correctly identified or read aloud words on each test provided three complementary measures of reading fluency.

Phonological awareness

We assessed phonological awareness with two tasks, blending and segmentation. In the blending task (16 items), the sounds of a word were presented separately and participants were asked to orally blend them and say the resulting word. The first eight items were taken from the standardized language skills test Logometro® (Mouzaki et al., 2017). The additional eight items consisted of words with consonant clusters and complex phonological and syllabic structure [e.g., δέντρο; /déntro/ tree]. In the phonemic segmentation task (16 items), children were asked to segment a word into phonemes. The first six items were taken from Logometro® (Mouzaki et al., 2017). The additional ten items consisted of words with consonant clusters and complex phonological and syllabic structure [e.g., *κέντρο*; */kédro/* center], were frequent words and are used in the 2nd grade textbooks. Omega reliability for the phonemic blending and segmentation were .90 and .86, respectively. The mean number of phonemes per word was 5 and 5.31 for blending and segmentation task, respectively. A PA composite score was calculated by summing up the total number of correct answers across the two tasks. Omega reliability for both PA tasks was .87.

Rapid Automatized Naming

Rapid Automatized Naming (RAN) was assessed with a digit naming task (1, 2, 5, 7, 8). Participants were presented with a page of fifty printed digits arranged in five rows of 10. Participants were asked to name these digits in sequence from left to right as quickly as possible. Time to name all digits served as the children's score.

Vocabulary

We examined only receptive vocabulary with a subtest of the CREVT-2 test (Wallace & Hammil, 2002). The subtest was adopted in Greek, using 29 new items. The target words were related to five different themes (animals, jobs, tools, clothes, means of transportation, and office staff). Vocabulary measured concrete ($n=14$) and abstract ($n=15$) concepts, such as pilot and fluid, respectively. For each theme evaluation, the same pictures ($n=6$) were used. Participants were asked to look the pictures and point out the one that represented the word provided by the examiner. The total number of correct responses was recorded. Omega reliability in our sample was .79.

Morphological awareness

Inflectional and derivational morphology was assessed at the epilinguistic and metalinguistic level. According to Diamanti et al. (2017), epilinguistic level refers to an intermediate level of elementary awareness that has been posited to intervene developmentally between the acquisition of the linguistic skill and the acquisition of metalinguistic awareness. On the contrary, metalinguistic awareness refers to the individual's ability to reflect upon and consciously manipulate morphemes, as well as the ability to apply word formation rules. Four MA tasks were administered orally. Participants' total score per task was the total number of correct items. No discontinuation rule was applied. Inflectional level at epilinguistic level was measured with a modified version of the *Wug test*, using a sentence completion procedure (Berko, 1958). The *Wug test* is a pseudoword task developed to examine the ability to apply a morphological change to mark inflections. Participants were instructed to complete a statement that required the addition of a suffix to the target pseudowords. The task contained eight items assessing noun and verb transformations. Four regular verbs had to be converted from present to past in the third person. One verb in present had to be changed in person, from singular to plural form and three nouns had to be changed in cases, from singular to plural forms. Six pseudowords were taken from the adjusted task of the *Wug test* adapted in Greek by Aidinis (1998). The additional two pseudowords were developed following Greek morphological and orthographic rules. Examiners presented orally a short sentence that contained the target pseudoword (e.g., The boy /valǒni/). Then they asked a short question in order to confirm that participants correctly heard the pseudoword (e.g., What is he doing?) and finally they provided an incomplete sentence. Participants were asked to complete the sentence by adding a suffix to the target pseudoword (e.g., Now, the boys… /valǒn- un/). Omega reliability in the present study was .70. Derivational morphology at epilinguistic level was evaluated with a sentence completion task, which developed based on the rationale of Carlisle's (2000) task (16 items). The task measured the ability to complete a sentence with either a derived word ($n=8$) given the base or with a base word ($n=8$) given the derived word. In nine items the initial base did not change phonologically in the derived form [e.g., συμπληρώνω /siblirôno/ complete → συμπληρωμένος /sibliroménos/ completed]. In seven items, the base changed phonologically in the derived form through a transformation process [e.g., εννιά /eniá/ nine → ένατη /énati/ ninth]. Sentences were short with simple syntactic structure and meaning. Initially, a target word was provided orally. Then participants were asked to complete a sentence with the target word, making the necessary transformations on it based on derivational rules [e.g., complain. George is always (complaining)]. Omega reliability of this task was .81. Inflectional and derivational morphology at the metalinguistic level were examined with the word analogy task, following the rationale of the Nunes et al.'s (1997) task, using new items. In this task, participants were asked to provide a missing word by identifying a morphological relationship between a pair of words and applying the same relationship-analogy to complete a second pair of words. Words, consisting of two or three syllables, were taken from the Greek Elementary language textbooks. For assessing inflectional morphology, 12 items were used with several transformations of nouns, adjectives, and verbs. In six items, the stem of the inflected word remained unchanged [e.g., λάθος /láθos/: λάθη /láθi/:: δάσος / ðásos/: (δάση / ðási/), eye: eyes:: table: (tables)]. In the other six items, the stem of the inflected word was changed phonologically [e.g., μπλέκω /bléko/: έμπλεξα /ébleksa/:: βάφω /váfo/: (έβαψα /évapsa/), wear: wore:: give: (gave)]. The transformation was based on morphological rules and not on phonological similarities. Omega reliability was .84. For derivational morphology, 10 items were used with several transformations: from verbs to nouns, from verbs to adjectives, from nouns to adjectives and from adjectives to verbs. In five items, the stem of the derived word remained unchanged [e.g., όμορφη /ómorfi/: ομορφιά /omorfiá/:: νόστιμη /nóstimi/: (νοστιμιά /nostimiá/), beautiful: beauty:: tasty: (taste)]. The stem of the derived word in the other five items changed phonologically [e.g., σκάβω /skávo/: σκάψιμο /skápsimo/:: τρέχω /tréço/: /τρέξιμο /tréksimo/), run: running:: rub:(rubbing)]. Omega reliability on this task was calculated to .88.

Procedure

Tasks were administered in a fixed order, individually to each participant in a quiet room in the schools by specially trained research assistants; each testing session lasted approximately 45 min.

Statistical analysis

The study hypotheses involving complex associations between MA, PA, vocabulary, and reading fluency (Fig. 1) were examined using path analyses (Pedhazur, 1997) in AMOS version 6. Full information maximum likelihood estimation was applied and percentile and bias-corrected bootstrap procedures to calculate 95% confidence intervals of the direct and indirect effects (Preacher & Hayes, 2008, based on 2,000 bootstrap samples). As presented in Fig. 2, we constructed separate models for oral (pseudoword and text), and silent (word) reading fluency. Inflectional and derivational morphology measures were included as independent variables, PA and vocabulary were included as mediating variables and RAN as a control variable.

In view of the cross-sectional nature of the study it was essential to rule out bidirectional effects among the variables. Thus, a separate alternative model was built for each of the reading fluency outcomes (pseudoword, text, and silent reading). Phonological awareness and vocabulary were included in the models as independent variables, inflectional and derivational morphology measures as mediating variables, and RAN as a control variable.

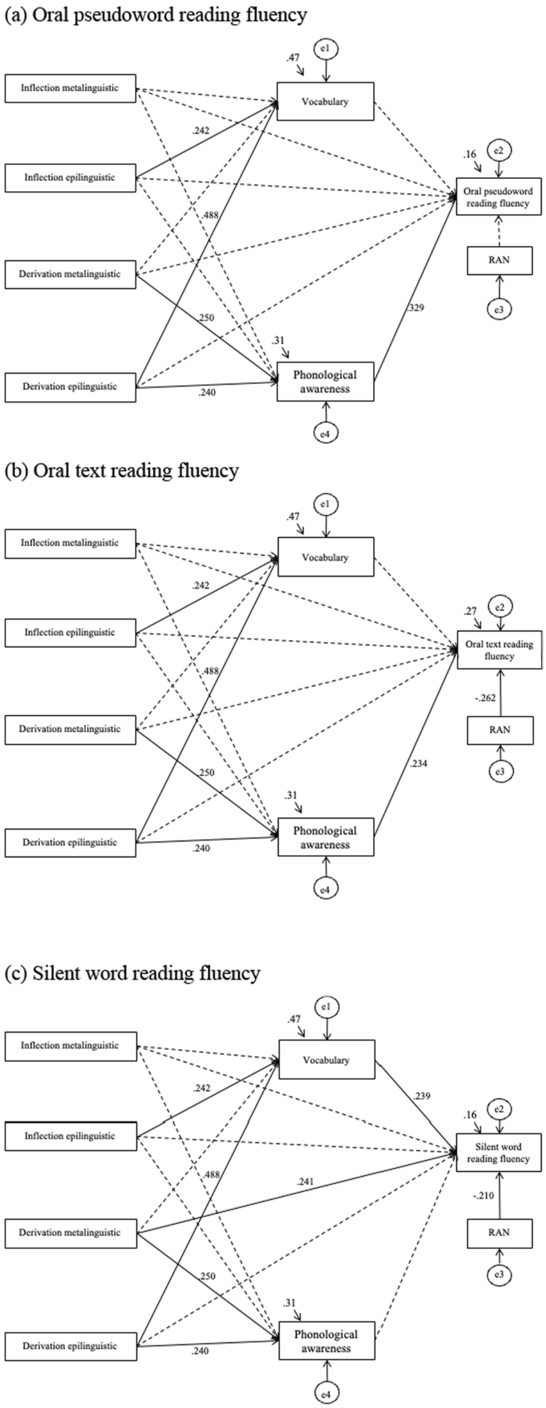

Fig. 2 Path analysis results of the association between morphological awareness and reading fluency as mediated by phonological awareness and vocabulary, controlling for RAN. Significant paths (according to bootstrapped 95% confidence intervals) are shown by solid lines. R^2 values are linked through arrows to each mediator and dependent variable. Dashed lines represent non-significant relations

Table 1 Descriptive statistics for the dependent and independent variables

Variables (Maximum number of items)	Mean (SD)	%[a]	Reliability	Skewness	Kurtosis
Pseudoword reading fluency (70)	19.14 (5.10)	27.34	0.79	0.102	0.974
Text reading fluency (274)	71.78 (19.69)	26.20	0.97	0.351	– 0.307
Silent reading fluency (50)	21.16 (7.09)	42.32	0.95	0.079	– 0.847
Phonological awareness (32)	28.07 (3.21)	87.71	0.83	– 0.803	– 0.317
Vocabulary (29)	18.62 (3.89)	64.20	0.87	– 0.133	– 0.249
Inflection metalinguistic level (12)	9.18 (2.17)	76.50	0.84	0.236	– 0.11
Inflection epilinguistic level (8)	4.96 (1.52)	62.00	0.70	– 0.203	– 0.586
Derivation metalinguistic level (10)	8.06 (2.13)	80.60	0.88	– 1.35	1.25
Derivation epilinguistic level (16)	11.14 (2.47)	69.63	0.87	– 0.353	– 0.255
RAN digits	28.19 (4.08)			0.278	– 0.317

[a]Success percentage was calculated based on the maximum number of items per task

The model fit was assessed using the following indices: Chi square, the ratio between Chi square and degrees of freedom, the Comparative Fit Index (CFI), the Tucker Lewis Index (TLI), the Root Mean Square Error of Approximation (RMSEA), Akaike Information Criterion (AIC), and Browne and Cudeck Criterion (BCC). CFI and TLI indices > .95 (Hu & Bentler, 1999) and RMSEA values < .08 are considered acceptable (Brown & Cudeck, 1993).

Results

Descriptive statistics

Descriptive statistics for the measures used in this study are shown in Table 1. Missing values ($n = 3$) were replaced by the mean of the entire series for each variable. An examination of the distributional properties of the measures showed that they were within acceptable levels (Kim, 2013). Results showed that students scored higher in PA compared to MA after two years of reading instruction. Based on the success percentage of MA tasks, we found that metalinguistic derivation had the higher mean score, while the lower mean score was found in epilinguistic inflection. Preliminary bivariate correlational analyses (see Table 2) revealed that reading fluency measures correlated significantly with vocabulary, PA, MA, and RAN. In particular, derivational tasks were correlated higher with oral text reading fluency and silent word reading fluency than inflectional tasks (Cohen, 1988). Oral pseudoword reading fluency correlated significantly only with the metalinguistic MA measures. Correlations of phonological awareness and vocabulary with each of the MA measures ranged from .356 to .634 ($p < .001$). The MA tasks were correlated highly with each other (Cohen, 1988). The smaller correlation was found between epilinguistic inflection and epilinguistic ($r = .546$, $p < .01$) and metalinguistic ($r = .441$, $p < .01$) derivation.

Table 2 Pearson correlations between study variables

Variables		1	2	3	4	5	6	7	8	9
1	psRF									
2	tRF	0.547**								
3	SRF	0.482**	0.598**							
4	PA	0.371**	0.418**	0.255**						
5	Voc	0.045	0.346**	0.256**	0.363**					
6	Inf. met	0.202*	0.343**	0.213*	0.440**	0.486**				
7	Inf. ep	0.139	0.186	0.065	0.356**	0.473**	0.546**			
8	Dr. met	0.213*	0.373**	0.314**	0.491**	0.437**	0.665**	0.441**		
9	Dr. ep	0.177	0.352**	0.200*	0.472**	0.634**	0.570**	0.385**	0.558**	
10	RAN	− 0.236*	− 0.350**	− 0.287**	− 0.221*	− 0.062	− 0.129	0.017	− 0.223*	− 0.126

psRF, pseudoword reading fluency; tRF, text reading fluency; SRF, silent reading fluency; PA, phonological awareness; Voc., vocabulary; Inf., inflection; Dr., derivation; met., metalinguistic; ep., epilinguistic. $*p < .05$; $**p < .01$

Table 3 Direct, indirect, and total effects of morphological skills on reading fluency

Effects	β	psRF 95% CI	β	95% CI	β	SRF 95% CI
Total effect						
Inf. meta	0.081	(− 0.127, 0.310)	0.119	(− 0.104, 0.339)	0.020	(− 0.184, 109)
Inf. epi	0.055	(− 0.129, 0.242)	0.010	(− 0.157, 0.186)	− 0.074	(− 0.256, 0.109)
Der. meta	0.073	(− 0.150, 0.274)	0.142	(− 0.075, 0.339)	0.266	(0.045, 0.455)
Der. epi	0.051	(− 0.155, 0.259)	0.177	(− 0.021, 0.363)	0.046	(− 0.142, 0.686)
Direct effect						
Inf. meta	0.072	(− 0.129, 0.308)	0.079	(− 0.121, 0.280)	− 0.015	(− 0.201, 0.210)
Inf. epi	0.060	(− 0.118, 0.257)	− 0.063	(− 0.244, 0.131)	− 0.145	(− 0.339, 0.059)
Der. meta	− 0.012	(− 0.211, 0.169)	0.086	(− 0.114, 0.294)	0.241	(0.025, 0.422)
Der. epi	0.060	(− 0.158, 0.269)	0.028	(− 0.181, 0.243)	− 0.098	(− 0.316, 0.121)
PA	0.329	(0.170, 0.479)	0.234	(0.060, 0.398)	0.112	(− 0.088, 0.303)
Vocabulary	− 0.181	(− 0.392, 0.027)	0.191	(− 0.009, 0.382)	0.239	(0.046, 0.428)
Indirect effect						
Inf. meta	0.009	(− 0.084, 0.095)	0.040	(− 0.019, 0.112)	0.035	(− 0.017, 0.100)
Inf. epi	− 0.006	(− 095, 0.070)	0.073	(0.005, 0.154)	0.071	(0.002, 0.153)
Der. meta	0.085	(− 0.001, 0.189)	0.056	(− 0.019, 0.139)	0.025	(− 0.040, 0.112)
Der. epi	− 0.009	(− 0.133, 0.127)	0.149	(0.025, 0.272)	0.143	(0.001, 0.303)

Direct effect	β	Phonological awareness	β	Vocabulary
Inf. meta	0.085	(− 0.114, 0.312)	0.106	(− 0.045, 0.243)
Inf. epi	0.115	(− 0.055, 0.269)	0.242	(0.107, 0.367)
Der. meta	0.250	(0.015, 0.454)	− 0.013	(− .198, 0.879)
Der. epi	0.240	(0.039, 0.449)	0.488	(0.333, 0.624)

psRF, oral pseudoword reading fluency; tRF, oral text reading fluency; SRF, silent word reading fluency; PA, phonological awareness; Inf., inflection; Dr., derivation; met., metalinguistic; ep., epilinguistic. Significant paths (according to the 95% CI's are shown in bold)

Path analysis

The model indices suggest that the three models (Fig. 2) fitted the data well for all reading fluency measures. For oral text, pseudoword, and silent word reading fluency fit indices are acceptable, $\chi^2 = 9.848$, $\chi^2/df = 1.41$, $p = .197$, CFI = .989, TLI (oral text = .957, oral pseudoword = .954, silent words = .954). The squared multiple correlations (R^2) for oral pseudoword and text reading fluency and silent word reading fluency were significant ($p < .001$), with the three proposed models explaining moderate[1] to large proportions of variance, as shown in Fig. 2. The direct, indirect, and total effects for each model are shown in Table 3.

[1] According to Cohen's (1988) classification, the effect size is considered small (.02), moderate (.13), and large (> .26).

The main hypothesis was supported in part. Specifically, as shown in Fig. 2, in the silent reading fluency model, vocabulary partially mediated the relation of MA with silent word reading fluency, with inflectional and derivational morphological skills having direct and indirect effects on silent word reading fluency. Derivational morphology at metalinguistic level had a significant and moderate direct effect on silent word reading fluency, $\beta = .241$, [.025, .455]. Also, inflectional and derivational morphology at epilinguistic level had a significant indirect effect on silent word reading fluency through vocabulary. The magnitude of mediation from derivational morphology on silent word reading fluency through vocabulary was $\beta = .143$, [.002, .153] and from inflectional morphology $\beta = .071$, [.010, .136]. The total effect size was .266 [.001, .303]. In addition, path coefficients displayed that inflectional morphology at epilinguistic level had a significant and unique contribution to vocabulary, $\beta = .242$, [.107, .367], derivational morphology at metalinguistic level to PA, $\beta = .250$, [.015, .454], and derivational morphology at epilinguistic both to PA, $\beta = .240$, [.039, .449] and vocabulary, $\beta = .488$, [.333, .624]. In the model of oral pseudoword reading fluency, only PA had a significant effect on oral pseudoword reading fluency, $\beta = .329$, [.170, .479]. In this model, PA and vocabulary did not have mediating effects on the relation of MA with oral pseudoword reading fluency. In the model of oral text reading fluency, PA fully mediated the relation of MA with oral text reading fluency. Specifically, inflectional and derivational morphology at epilinguistic level displayed a small but significant indirect effect on oral text reading fluency through PA (from inflectional morphology: $\beta = .073$, [.005, .154], from derivational morphology: $\beta = .149$, [.025, .272]). No direct effects of MA measures on oral text reading fluency were observed.

Importantly, none of the alternative models, using phonological awareness and vocabulary as independent variables and morphological skills as mediating variables, fit the data well (Fig. S1): $\chi^2 = 61.401$, $\chi^2/df = 5.3$, $p < .001$, CFI (pseudoword = .790, text = .803, silent = .791), TLI (pseudoword = .509, text = .540, silent = .511), RMSEA = .205, AIC = 128.401, and BCC = 134.464. The initial recommended model had better values of the fit indices of CFI, TLI, and RMSEA. In addition, the initial model was preferable according to AIC and BCC values, which were lower.

Discussion

In this study we explored the relation between MA and reading fluency in 2nd grade Greek-speaking children and the potential mediating role of PA and vocabulary. The results indicated that epilinguistic inflectional and derivational morphology indirectly contributed to oral text reading fluency through PA and to silent word reading fluency through vocabulary. In addition, metalinguistic derivational morphology affected directly silent word reading fluency. These results underline the important role of MA not only in reading comprehension and spelling, but also in reading fluency. Our findings shed new light on the multiple pathways contributing to reading fluency, providing additional support to the Morphological Pathways Framework (Levesque et al., 2021).

Our results corroborate previous findings in transparent orthographies regarding the significant effect of MA on reading fluency (Cohen-Mimran et al., 2022; Giazitzidou & Padeliadu, 2022; Görgen et al., 2021; Shechter et al., 2018). Specifically, our results extended Pittas and Nunes' (2014) findings, which indicated that inflectional and derivational morphology of 1st and 3rd grade Greek-speaking children had a unique contribution to text reading fluency and comprehension (combined score) 8 months later, after controlling for grade, verbal ability, PA, and initial reading level. Our results are also compatible with those of Rothou (2012), who showed in a cross-sectional study that morphology contributed to oral text reading fluency of 2nd grade Greek-speaking children, after controlling for PA, vocabulary, and syntax. This contribution of morphological skills to oral text reading fluency may be fostered by the syntactic and semantic cues that are involved in text processing. Syntactic and semantic information may guide children to predict the inflected and derived morphemes of the upcoming words, resulting in faster reading (Giazitzidou & Padeliadu, 2022).

In addition, the results confirmed our hypothesis regarding the full mediation of the association between inflectional and derivational morphology and oral text reading fluency by PA. This revealed both the multiple pathways through which morphological skills impact reading fluency and the significant role of PA in this relationship. MA is possible to function as an activator to existing phonological skills in attaining reading fluency. This hypothesis is supported in both theoretical and empirical grounds. In terms of theory, phonology is being considered a component of morphology (Deacon et al., 2008; Mahony et al., 2000), while morphology, reflects the associations among orthography, phonology, and semantics as they emerge in a graded, interlevel activation pattern (Verhoeven & Perfetti, 2011). On the other hand, previous evidence confirmed that phonological and morphological awareness share much of their variance during the early elementary grades (Kuo & Anderson, 2006; Sparks & Deacon, 2013). In this framework, the mediating role of PA may arise as a reflection of the strong interaction and connection among these metalinguistic skills involved in word recognition during initial stages of reading development (Carlisle, 2003; Levesque et al., 2021). An alternative explanation for the mediating role of PA concerns the common demands and characteristics of tasks used to assess MA, PA, and oral text reading fluency. These three skills were examined with tasks which required oral responses, increasing the need for phonological processing, compared to silent reading fluency. Thus, high phonological demands may attribute a greater role to PA in the relation of MA with oral text reading fluency. On the other hand, in transparent orthographies with rich morphology, analysis of lexical phonological representations into smaller units, such as morphemes, may be an "accelerating reading tool" to support reading fluency processes (Giazitzidou & Padeliadu, 2022).

Another remarkable finding that emerged from our study is the direct and indirect contribution of MA to silent word reading fluency, supporting previous findings in deep (Elbro & Arnbak, 1996) and transparent orthographies (Görgen et al., 2021). The significant predictive relationship between inflectional and derivational morphology and silent reading fluency in a transparent orthography has also been shown with older children by Görgen et al. (2021). Specifically, they indicated that inflectional and derivational morphology (composite score) of 3rd and 4th grade German-speaking children had a distinct effect on silent reading fluency, after controlling for non-verbal ability, orthographic sensitivity, and PA. This finding raised the interesting possibility that the role of MA is getting greater in silent reading condition, where the demands of phonological processing are fewer (Share, 2008). In addition, in silent reading mode orthographic representations are directly linked to semantic representations, without loading heavily onto phonological processing factors, fostering the role of semantic cues (van den Boer et al., 2014). Thus, the lower phonological demands may enhance the role of semantic qualities of morphemes in word recognition.

In this framework, word meaning may function as another binding agent between MA and silent reading fluency. This is a possible explanation for the mediating role of vocabulary in the relation of MA with silent word reading fluency, confirming our hypothesis. The semantic qualities of morphemes may increase the speed of access to lexical representations, making morphemes more accessible reading units (Elbro & Arnbak, 1996). This assumption agrees with the view of MA as a more analytic skill, which involves inferences about word structure and meaning (Carlisle, 2007). Thus, young readers may rely upon implicit knowledge of word forms to recognize written words through semantic information. In other words, we could argue that during the silent word reading task in the present study children accessed and retrieved faster lexical representations for words by relying on the identification of semantic information of familiar word morphemes. Therefore, retrieval of lexical representations could be facilitated by the semantic qualities of the constituent morphemes in words.

In contrast, our findings do not appear to corroborate previous studies conducted in opaque (Desrochers et al., 2018; Kirby et al., 2012) and transparent orthographies (Müller & Brady, 2001), which show that MA do not predict significantly reading fluency in grades 1 and 2, after controlling for the effects of general cognitive ability. For instance, Desrochers et al. (2018) examined the contribution of MA to reading fluency in 2nd grade Greek-speaking children, after controlling for PA and RAN. They found that MA was a significant predictor only of reading comprehension and spelling, but not of reading fluency. This difference to our results may be attributed to the fact that we did not use PA as a control variable in our model. Similarly, other studies conducted in Greek (Diamanti et al., 2017; Manolitsis et al., 2017) showed that MA (assessed in kindergarten and 1st grade) did not affect text and word reading fluency 1 and 2 years later, after controlling for the effects of vocabulary, PA, and RAN. Furthermore, in our study MA was assessed at the end of the 2nd grade, whereas in previous studies (Diamanti et al., 2017; Manolitsis et al., 2017) in kindergarten and at the 1st grade. In 2nd grade, MA has been developed to a large extent at metalinguistic level, representing a more stable skill (Anglin, 1993a; Kuo & Anderson, 2006), increasing in turn its predictive role. In addition, Diamanti et al. (2017) evaluated MA only at epilinguistic level. In contrast, in our study both inflectional and derivational morphology were assessed also at metalinguistic level, with the analogy, increasing the processing demands. Given that MA may have not been adequately developed so early in schooling it is not surprising that it did not significantly impact reading fluency one and two years later.

Furthermore, our findings provide considerable insight into the significant role of derivational morphology in reading fluency regardless of the reading mode (silent/oral). Derivational morphology tasks contributed both directly and indirectly to oral and silent reading fluency, supporting previous findings (Rispens et al., 2008). Rispens et al. (2008) indicated that only derivational morphology among the MA tasks significantly affected reading fluency of 6th grade Dutch children, after controlling for the effects of age, PA, vocabulary, and mathematics. It is possible when inflectional morphology development reaches a plateau, the role of derivational morphology becomes more prominent in reading processes. In a longitudinal study conducted by Diamanti et al. (2018), inflectional and derivational morphology showed different developmental trajectories over three years. Inflectional morphology had significantly higher developmental rate compared to derivational morphology, at least for tasks with higher metalinguistic demands. This study demonstrated that Greek-speaking children have developed explicit morphological awareness of noun and verb inflection before entering primary education, supporting our hypothesis.

Overall, the current findings add to a growing body of research on MA by showing that morphological skills are linked through multiple pathways to text and silent reading fluency, and by revealing the mediating role of PA and vocabulary in this relationship. There are indications for a more significant role of MA in both transparent orthographies and in languages with rich morphology that support employment of morphological strategies. Taken together, we could suggest that the relation of MA with reading fluency is dynamic, depending on the morphological awareness skill and measure of reading fluency. In addition, our findings suggest that in beginner readers the nature of MA may be not only multidimensional (Deacon et al., 2008; Levesque et al., 2021), but also "multi-contributor". Phonological and semantic information are core components of MA (Mahony et al., 2000), with the latter activating these linguistic dimensions of words, resulting in faster reading. Furthermore, the present study may improve the knowledge of MA in suggesting that is a significant factor not only for reading comprehension and spelling, but also for reading fluency.

Some limitations of this study need to be considered in order to inform further investigations. First, due to differences in language characteristics, evidence for relations between MA and literacy from studies carried out in a particular language cannot be directly transferred to other languages. Thus, any generalization and comparison of our findings with those of deep orthographies should be treated with caution. Second, the Wug test was found less sensitive, having negative skewness. Finally, the main limitation of the present study lies in the fact that the data are cross-sectional, although some support to the proposed directionality of the effects was provided by examining, alternative models involving the reverse paths. Longitudinal studies are needed to support our results and shed additional light on the mediating role of PA and vocabulary. Moreover, given the small sample size, caution must be exercised and further studies will need to be undertaken to confirm our findings. Nevertheless, unveiling the significance of MA may assist to the proper support of children who learn reading in a transparent orthography with rich morphological system, focusing on teaching of the morphological structure of words (Burani, 2010). The present findings reveal that a thorough exploration of different pathways between MA and reading fluency may be both theoretically and practically useful for understanding reading fluency acquisition. Future research should focus on the effects of training in MA in conjunction with PA and vocabulary in order to examine to what extent teaching different and highly associated linguistic skills is related to better performance in reading fluency.

Finally, our findings have educational implications for those who support children in learning to read. MA is multidimensional in nature (Levesque et al., 2021), the intermediate size of morphemes and their phonological and semantic qualities make them more accessible to readers, supporting in turn the involved reading fluency processes (Giazitzidou & Padeliadu, 2022). Thus, providing systematic instruction to the knowledge of morphological analysis skills, vocabulary, and PA may be instrumental in reading fluency acquisition in children learning to read Greek.

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