Visual processing and dyslexia: evidence from stress marker assignment in Greek

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Visual Processing and Dyslexia: Evidence from Stress Marker Assignment in Greek

Abstract

The present exploratory study investigated whether targeted visual intervention can improve stress assignment during oral reading in children with developmental dyslexia. The Greek orthography uniquely marks lexical stress with a diacritic visual mark, allowing testing in-text sensitivity to fine visual-linguistic information. A total of one hundred participants took part in the study. Seventy children with developmental dyslexia (Mean age = 9.3, *SD* = 1.07) were assigned to attend either a visual or an auditory single-session intervention. The visual stimuli consisted of visual discrimination and crowding tasks aiming to enhance visual processing abilities, whereas the auditory stimuli comprised matched discrimination and crowding tasks. Data were collected from pre- and post-test oral reading tests, and error types were analysed and compared to a control group (*N* = 30, Mean age = 9.7, *SD* = 0.8). Results revealed a significant improvement in lexical stress assignment after the visual single-session exposure, with no significant changes in segmental errors or fluency. These findings suggest that visual intervention may improve the decoding of fine orthographic features, especially in transparent orthographies where visual markers carry critical linguistic weight. The study highlights the role of visual-based interventions as a complementary approach to support the reading development of children with dyslexia.

Keywords: Developmental Dyslexia; Visual Processing; Lexical stress; Oral Reading; Single-session exposure

Highlights:

- The study offers a new perspective on how the processing of fine linguistic features can be improved following the use of a visual-based intervention.
- Significant improvement in the assignment of stress markers was observed after participants were exposed to visual tasks.
- Diacritic-marked stress provides a unique context for understanding students with dyslexia's reading processes.
- Findings support the integration of visual strategies into reading interventions for transparent orthographies.

Introduction

Developmental dyslexia is characterised by difficulties in reading and writing and is not related to a lack of adequate intelligence or sociocultural opportunities (Brimo et al., 2021; Centanni, 2020; Horowitz-Kraus et al., 2014). It impacts language-related skills and is one of the most common learning disabilities affecting 3–20% of school-aged children (see, e.g. Snowling et al., 2020; Yang et al., 2022, Vlachos et al., 2013 for Greece). Children with dyslexia face difficulties in word decoding and spelling abilities, particularly in recognising unfamiliar words, and they often read at a slower pace (Hulme & Snowling, 2016). According to the American Psychiatric Association (DSM-5, 2018), dyslexia is defined as a specific learning disorder (SpLD) with impairment in reading.

A prominent theoretical explanation of dyslexia is the phonological deficit hypothesis, according to which individuals with dyslexia have difficulties with phonological awareness, processing speed, and memory (Goswami, 2002; Snowling, 2000; Stanovich & Siegel, 1994; Ziegler & Goswami, 2005). Deficits in phonological awareness are manifested in phoneme segmentation, manipulation and blending (Snowling, 2000) while decoding, another integral process of reading, is also impaired (Ziegler & Goswami, 2005) and is often manifested by reading errors such as omission, deletion and addition (Snowling, 2000; Torgesen et al., 2001). However, a number of studies have provided evidence of visual deficits that may help explain the causes and variability of this disorder as we present next (Archer, Pammer & Vidyasagar, 2020; Everratt et al., 1999; Gori & Facoetti, 2015; Schulte-Körne, 2010; Stein, 2024).

Visual Factors of Dyslexia

Although it is now well established that most individuals with dyslexia present difficulties in phonological processing skills, reading difficulties were initially considered to be rooted in the visual perceptual processing. The relationship between dyslexia and a visual deficit has been present since the discovery of dyslexia as early as 1878, when dyslexia was discovered by Kussmaul (1878), as a hereditary deficit particularly affecting the visual processing of letters and words. In the current dyslexia context, various forms of visual processing impairments have been identified, such as the visual attention deficit, the magnocellular pathway deficit, and the double deficit (Facoetti et al., 2008; Lobier et al., 2012; Niolaki, Terzopoulos & Masterson, 2020; Ramus & Szenkovits, 2007). In particular, one of the most prominent theories is that dyslexia might be associated with a deficit in the magnocellular visual pathway (Flint & Pammer, 2019; Lawton & Shelley-Tremblay, 2017; Livingstone et al., 1991; Stein, 2024; Stuart et al., 2006). Individuals with dyslexia often exhibit impaired cognitive and neurophysiological functions transmitted through the magnocellular-dorsal pathway. Magnocellular deficits are present in low spatial and high temporal frequency (Gori et al., 2014; Leung et al., 2022), motion discrimination (Benassi et al., 2010) and attention load (Stein, 2024) compared to students without dyslexia. Students with dyslexia are also reported to be less sensitive than control groups in fast, accurate visual identification of words, a function in which the dorsal stream of the magnocellular pathway is involved (Galaburda & Livingstone, 1993; Stein, 2001, 2024).

In the study by Ebrahimi et al. (2022), 30 students with dyslexia were compared with a control group in a magnocellular-based visual training, and they found improvements in post-test magnocellular measures, reading abilities, and visual spatial attention in the group with dyslexia. Bosse et al. (2007) and Valdois et al. (2003) have extended these findings, showing impairments in the visual attention span (Bosse & Valdois, 2009). Lobier et al. (2012) investigated visual attention span as a possible cause of dyslexia and whether it is related to a visual or a verbal deficit. By incorporating into their methodology both visual and verbal tasks, a visual attention assessment, and a reading assessment, a significant relationship was found between visual tasks and visual attention, confirming their relationship.

Regarding the Greek language, Georgiou et al. (2012) examined whether visual and auditory processing deficits are related to dyslexia and found that half of the participants experienced visual processing deficits, whereas evidence for auditory processing deficits was inconclusive. This evidence indicates that although phonological processing skills impact students' reading skills, only this aetiology and its interventions are not sufficient for long-term improvements in all dyslexia symptoms. The above evidence suggests that dyslexia is increasingly conceptualised as a multifactorial condition involving the interaction of not only phonological but also visual and other processing mechanisms, rather than a single-deficit difficulty (Carroll et al., 2025).

Stress Errors and the Greek Orthographic system

Lexical stress is a suprasegmental feature and refers to a syllable-level characteristic in every word of two or more syllables, with stress falling on a single syllable that protrudes phonologically and phonetically (Holliman, 2016). In languages with lexical stress, such as Italian, Greek, and Spanish, stress placement varies, and stress sensitivity is essential for correct pronunciation. Greek is especially well-suited for investigating stress assignment in reading and spelling because it is explicitly marked with a unique diacritic (΄) placed on one of the last three syllables of a word. Thus, stress assignment in Greek is such a salient property that applying stress on the wrong syllable is one of the least tolerated mispronunciation errors a non-native speaker can make (Arvaniti, 2007). The position of the stress in every word is morphologically determined and is not related to sound-related rules (Arvaniti, 2007), thus it is taught at great length in primary school. The diacritic is present in every Greek word consisting of two syllables or more, carrying linguistic weight (e.g., πίσω /ˈpiso/"back" vs. πισω /piso/, which is non-existent) (Protopapas, Gerakaki & Alexandri, 2007). If stress is not included, the word is considered a misspelling.

Thus, lexical stress carries a significant functional load in Greek, to a greater extent than stress in English, as there are many pairs and even triplets of words that are only distinguished by stress location (Arvaniti, 2007), e.g. ['poli] "city" and [po'li] "much". Since only a few single-syllable content words (6.7% of tokens; Protopapas & Vlachou, 2009) exist in Greek, it means that stress pattern affects the majority of the written and spoken words and that correct identification and decoding of lexical stress are essential for word decoding and meaning.

In the context of dyslexia, Anastasiou and Protopapas (2015) found that Greek children made more errors in lexical stress assignment than the control group. In the study, they investigated impaired segmental phonology versus lexical stress and observed that stress errors persist even when grapheme-phoneme correspondence (phonological ability) is accurate. This suggests that stress sensitivity requires not only phonological competence but also a good ability to visually process orthographic information and details.

Cross-linguistically, similar findings have been observed. Transparency of language can affect the extent to which phonological processing affects reading fluency (Georgiou, Parrila, &

Papadopoulos, 2008). Difficulties of students with dyslexia in segmental phonology have been observed across both transparent and non-transparent languages (Caravolas, Volin, & Hulme, 2005; Landerl et al., 2013; Paulesu et al., 2001; Ziegler et al., 2010). Thus, errors at the word level have been attributed to a phonological deficit and documented as omissions, repetitions, substitutions, and mispronunciations (Pedersen et al., 2016; Yang, 2021).

In addition to phonological awareness at the segmental level, awareness of suprasegmental (prosodic) units, such as stress, rhythm, and pitch, is also a key skill in language acquisition (Ziegler & Goswami, 2005). Barry et al. (2012) and others (Goswami, Gerson, & Astruc, 2009; Leong et al., 2011; Mundy & Carroll, 2012) have established that both children and adults with dyslexia show reduced awareness of syllabic stress patterns. Similarly, Dulay and Hanley (2015) reported reduced stress perception among Filipino readers, Paizi et al. (2011) among Italian readers, and Athanasiou and Protopapas (2015) among Greek readers. In a study of 5- to 7-year-old children, Wood (2006) found that metrical stress sensitivity, assessed using a mispronounced-word recognition test, explained variation in word recognition and spelling skills. Using the same task as well as a compound-noun recognition task, Goodman et al. (2010) discovered that lexical stress, but not metrical stress sensitivity, was related to phonological awareness and early reading ability in kindergarten; however, after controlling for phonological awareness, lexical stress sensitivity did not contribute to reading ability. Thus, given that stress in Greek is orthographically visible and morphologically functional, stress assignment errors may not solely reflect impaired phonological awareness but may also result from visual processing factors.

Visual and Auditory Intervention in Dyslexia

In dyslexia research, intervention strategies were traditionally centred around phonological awareness and verbal training. A particular focus has been made on the design of tasks based on auditory-centred processes such as phonological decoding, auditory discrimination and phoneme segmentation. However, studies have sought to diversify beyond verbal interventions by introducing non-verbal tasks using visual interventions to examine whether there is an improvement in students' reading fluency. For example, Lawton (2016) focused on magnocellular function and trained 58 children with dyslexia by instructing them to do a visual direction discrimination task to activate the magnocellular neurons. It was found that magnocellular sensitivity increased progressively, and, as a consequence, children's reading improved. Similarly, Chouake et al. (2012) conducted a training study to determine whether there is a relationship between magnocellular activity and reading abilities in 35 Hebrew-speaking adults. They conducted a visual intervention that included a motion-detection task and a control task of pattern detection. They tested reading ability using a lexical decision task before and after training. The results suggest improvement following low-grade visual training and highlight the role of the visual system in reading.

Moreover, Valdois et al. (2014) conducted a case study of a Spanish-French bilingual girl by administering a visual attention span training. The post-test revealed an improvement in visual attention span, which was also related to reading ability. Stronger effects were observed in French compared to Spanish, and positive effects of the visual attention span training suggest that multiple visual elements are causal to successful reading acquisition. Similar positive findings were reported by Author 2 & XXX (2013) using a visual attention span intervention with a Greek-monolingual adolescent with dyslexia and a single visual attention span deficit. At the end of the intervention, the individual's reading accuracy and fluency scores significantly improved. In another study, Meng et al. (2014) conducted visual texture discrimination training using a texture display and examined whether reading fluency in Chinese could be improved after completing the training. A significant effect of the visual intervention was observed on the reading measures.

On the other hand, auditory-based intervention has been widely utilised in dyslexia, based on the principle of improving phonological awareness and temporal auditory resolution in readers with dyslexia (e.g., Boets et al., 2011; De Martino et al., 2001; Goswami et al., 2011; White et al., 2006). A growing body of research has demonstrated that training in auditory modalities may have positive effects not only on auditory temporal processing but also on phonological awareness and reading (Goswami et al., 2013; Guerra et al., 2024). Goswami et al. (2002) reported a deficit in the perceptual experience of auditory timing, which is linked to dyslexia. In their research, 101 participants were tested on a battery of tasks assessing auditory and phonological processing. They found a significant difference between typically reading children and students with dyslexia in amplitude-envelope onsets, which affect the suprasegmental attributes of speech vowels. In a later study, Goswami et al. (2012) found that musical beat perception and amplitude rise-time discrimination were significantly poorer in students with dyslexia than in younger, reading-level-matched controls.

McArthur et al. (2008) conducted auditory training with 28 children exhibiting reading or language challenges, employing several modalities of auditory training. The children, aged 6 to 16 years, received tailored interventions focusing on frequency discrimination, quick auditory processing, vowel discrimination, or consonant-vowel discrimination, based on their performance levels from early assessments. In the study by Schäffler et al. (2004), the effect of daily practice in low-level auditory discrimination tasks on phonological skills and spelling in individuals with dyslexia was examined. After targeted intervention, participants showed significant improvements in auditory discrimination, which enhanced phonological processing and reduced spelling errors.

While much of the existing literature on dyslexia has explored phonological deficits in non-transparent orthographies such as English, less is known about how non-phonological interventions can support reading development in transparent orthographies, where consistent letter-sound mapping reduces decoding complexity but reveals other cognitive demands. Specifically, languages like Greek, Spanish, and Italian provide explicit orthographic markers (e.g., stress diacritics in Greek) that require fine-grained visual discrimination. As such, they present a compelling opportunity to examine the role of visual processing in reading. The effectiveness of visual training in decoding fine orthographic cues in transparent languages, such as Greek, may thus offer valuable cross-linguistic insights into the broader applicability of visual-based interventions for reading disorders. Investigating these mechanisms in transparent systems can help refine theoretical models of dyslexia that integrate both phonological and visual pathways.

Current study

Much of the existing literature on dyslexia is centred on segmental phonology and non-transparent languages such as English, with limited emphasis on languages with unique features, such as Greek orthography. Although stress assignment is historically considered a suprasegmental phonological feature, in Greek it is indicated with a diacritic mark. For this reason, during oral reading in Greek, correct stress assignment requires efficient visual detection of the diacritic mark and successful integration of orthographic and phonological information. As the Greek stress diacritic mark is embedded within crowded orthographic environments and is small, its accurate processing may depend more on visual processing than on purely auditory processing. On this basis, we explore whether a visual intervention may improve the detection of the diacritic mark and the accuracy of stress assignment.

We examined the role of visual versus auditory processing training in Greek students with dyslexia and whether these can directly strengthen stress assignment scores. Given that reading performance can be enhanced by visual training (King, Wood & Faulkner, 2007; Meng et al., 2014; Taskov & Dushanova, 2020), the application of an 'outlier' orthographic structure (Greek) will be examined.

Thus, the primary issue to be investigated is stress errors in Greek. Three research questions were investigated in the study: 1) Do students with dyslexia produce a higher number of lexical stress errors compared to typically developed students?, 2) Does visual intervention improve lexical stress assignment compared to the auditory intervention?, 3) Are improvements in lexical stress decoding associated with improvements in oral reading fluency?

Method

Participants

One hundred students, aged 8 to 11 years (Grade 4-6, $M = 9.3$, SD = 1.07), participated in the study. Participants were Greek speakers, recruited from 50 public primary schools in Athens, Greece. Of the total participants, 70 students had a formal diagnosis of developmental dyslexia (DD), and 30 age-matched typically developing students comprised the control group (CTG; see Table 1). The two groups were matched in age, $t\,(98) = 1.28$, $p = .10$, sex $\chi^2\,(1, N = 100) = 0.43$, $p = .51$ and Greek language status. Inclusion criteria for the DD group required reading performance below the 11-point cut-off for the error gain scores and above 14 on oral reading fluency (ORF). These cut-offs were established for similar populations relative to normal readers by Bakhshalizadeh (2012).

Students with dyslexia were recruited only if they had received a formal diagnosis of developmental dyslexia issued by Greece's official Interdisciplinary Assessment, Counselling and Support Centers (KEDASY), qualifying them for SEN support during the study. The certification of dyslexia is provided to individuals in the presence of differences between cognitive ability and standard level of educational performance in accordance with the DSM-5 criteria. The diagnostic label is issued following an analytical psychoeducational evaluation, reviewing the individual's history, a medical examination, IQ assessment and personality tests. The IQ ability is assessed with the Wechsler Intelligence Scale for Children–V (Stogiannidou et al., 2017). The verbal and non-verbal IQ should be within the normal range (> 85). Reading performance was measured with the standardised test provided by the Ministry of Education, the TestA (Padeliadu & Antoniou, 2008). For a diagnosis, reading performance needs to be scored significantly below age expectations (at least 1.5 SD below the mean). This symptomatic approach examines various learning parameters- excluding the influence of other factors- including emotional disturbances, family issues, poor reading skills, and intellectual disabilities (Rothou & Georgiou, 2024). Similar procedures for recruiting participants with dyslexia have been used in previous studies (Boets et al., 2013; Snowling et al., 2019; Pedersen et al., 2016). To further ensure diagnostic validity, the two groups (DD and CTG) differed in their pretest reading accuracy, $t(98) = 7.32$, $p = .001$, confirming the diagnostic classification between students with and without dyslexia.

All participants had typical verbal, visual, and auditory abilities, attended school regularly, and were enrolled in age-appropriate grades. They had no diagnosed neurodevelopmental, psychiatric, or other neurological disorders, which were confirmed by their diagnoses and teachers' reports. Informed consent was obtained from the parents, and the study received ethical approval from the Greek Ministry of Education and the University of Essex.

Participants with dyslexia (DD) were assigned to two equal training groups; the Visual Intervention group (VIG, $N = 35$) and the Auditory Intervention group (AIG, $N = 35$). Stratification was used to assign groups, balancing for age, gender, and baseline reading accuracy.

(Insert Table 1 about here)

Group	N	Mean Age (SD)	Female	Male
Total DD	70	9.3 (1.07)	33	37
VIG	35	9.31 (1.1)	16	19
AIG	35	9.20 (0.9)	17	18
CTG	30	9.7 (0.8)	12	18

Table 1. *Descriptive Statistics of the participants*
DD = Developmental Dyslexia; VIG = Visual Intervention Group; AIG = Auditory Intervention Group; CTG = Control Group; SD = Standard Deviation.

Design

A pretest–post-test control group design was used to explore the effect of visual and/or auditory single-session intervention, on stress assignment and reading fluency. All groups completed a reading assessment before and after the session. VIG and AIG groups received training in the (a) visual tasks and (b) auditory tasks, respectively. Intervention conditions (visual, auditory, or control) served as the independent variable. The dependent measures were lexical stress errors, segmental decoding errors, and oral reading fluency (ORF).

Oral Reading Texts

Two narratives were selected, and participants were asked to read aloud (Appendix A). The narratives were retrieved from the Portal for the Greek language (Centre for the Greek Language, 2008), an educational and research database developed by the Centre for the Greek Language (CGL), an organisation run under the Greek Ministry of Education.

Text selection was guided by criteria: (1) To increase internal validity (Dooley, 2001), the texts were new to the participants. To achieve this, we administered a short questionnaire to all participants prior to data collection to ensure they had not read or been exposed to the selected materials. (2) We ensured that the selected texts were age-appropriate. All the passages were aimed to be at the same level in terms of vocabulary, length, type of grapheme-phoneme correspondence, and familiarity with the words. In the database, the selected narratives are categorised as part of the same difficulty level and schooling category. The set of narratives comprised an equal number of high-frequency and low-frequency words to permit checking for a variety of errors. In both narratives, the selected words contained 2-10 letters and ranged from one syllable to five-syllable words. (3) A suitable text for reading error analysis must exhibit a clear theme along with identifiable elements (Goodman & Burke, 1972). The two narrative texts we chose both contain a defined theme reinforced by several details. (4) To reduce variability, randomisation and counterbalancing were applied; the post-test was thus different from the pretest task.

Visual and Auditory Intervention Tasks

The two sessions were matched in duration, cognitive effort and visual/auditory complexity. To exclude an underlying phonological factor, such as the use of verbal tasks which might activate phonological performance, stimuli were nonlinguistic and did not include any direct phonological input for participants (Boets et al., 2011; Meng et al., 2014; Stein, 2014; Taskov & Dushanova, 2020)

Visual Intervention

The visual intervention protocol involved a series of "spot-the-difference" tasks designed to target visual discrimination and visual crowding resolution. Participants were required to find subtle differences in two almost identical pictures presented side by side and identify and name each depicted item. Participants viewed image pairs with increasing complexity and were asked to identify the subtle visual differences. The session consisted of three levels: 7, 15, and 19 visual discrepancies. The task was adapted from Beck et al. (2008) and used nonlinguistic stimuli to avoid activating phonological processes. This task was selected for two reasons. Firstly, it is suggested that by having a 'spot the difference' type format, the task may be more child-friendly. Secondly, this method more closely matches reading, in which children naturally move their eyes back and forth across a single image or text (Shore & Klein, 2000). Performance was continuously monitored, and assistance was provided when needed, with care to avoid affecting standardisation. Participants had to meet 100% accuracy to progress to the next set of the intervention.

(Insert Figure 1 about here)

Figure 1. *Sample of the visual task*

Auditory Intervention

The task design mirrored the visual intervention. The task was designed to target temporal auditory discrimination and auditory crowding resolution. Participants listened to paired rhythmic melodies and were asked to identify and explain sound differences in the sequences. Stimuli included 30 melodies with three levels of difficulty (1 to 3 altered notes per sequence), based on paradigms used by Aidinis and Nunes (2001) and Goswami et al. (2012). Melodies were composed of beats with short or long-time intervals between them: ¼ s or 1s, and were produced and recorded in a microphone (M-audio, Microtrack II). Both verbal responses and points with a pencil were accepted as responses. Participants' performance was continuously monitored, and assistance was provided when needed, with care to avoid affecting standardisation. Participants had to meet 100% accuracy to progress to the next set of the intervention.

Both session types were nonverbal and matched in duration (approximately 30 minutes).

Procedure

Participants were tested individually in a quiet, separate room at their school. Each session included (1) a pretest oral reading task, (2) a visual or auditory session and (3) a post-test oral reading task (different from the pretest). Before the training, participants completed two practice trials, for which they received instructions and feedback. Feedback was accompanied by further verbal explanation and reinforcement by the researcher. After completing the training, a 15-minute break was included, and additional breaks were provided if the children became tired.

Stimuli were presented as printed A4 photocopies in Calibri font, size 16, and participants were asked to read the texts as they would normally do. Photocopies were selected as the preferred mode based on research by Protopapas and Skaloumbakas (2007, p. 18). Responses were recorded and timed using the M-audio, Microtrack II and all auditory stimuli were presented at a comfortable volume. The experiment was conducted during regular school hours, and participants were seated in comfortable seats.

Scoring and Measures

Reading Errors

Participants' oral readings were evaluated for (1) stress errors and (2) segmental errors. Stress errors referred to the stress being omitted or errors made in the incorrect syllable by either assigning dominant stress to a non-dominant syllable, or no stress assignment to dominant stressed syllables. Segmental errors were defined as errors in word decoding that alter phonological congruence. Types of segmental errors included omissions, substitutions, repetitions, and insertions. This classification was based on the categorisation of Anastasiou and Protopapas (2015), Pedersen et al. (2016), and Yang (2021), aiming to provide insight into the different constituents of reading accuracy.

For the scoring of stress and oral reading errors, three native speakers of Greek assessed the oral reading data. The assessors were teachers who had experience working with children with dyslexia. The recruitment of raters was designed to increase the validity and reliability of the results; raters were asked to identify and record all types of reading errors in each's recordings. The aim was to provide a more comprehensive evaluation of how a visual single-session intervention impacts reading and stress performance, and to allow raters to assess all reading errors and avoid bias toward stress errors only. An incorrect segment/word was classified as an error only if it was marked by two or more assessors. The interrater agreement reached 95%. The discrepancies that emerged in scoring were discussed and resolved. The final scores were the number of reading errors after applying the consensus threshold. This approach strengthens the validity of the study, considering that in the past, researchers themselves had been assigning error measures.

(insert Table 2 about here)

	Correct Reading	Incorrect Reading
Stress	Μετακινήσεις /me.ta.kiˈni.sis/ *movements*	*μετακίνησεις /me.ta.ˈkini.sis/
Omission	Στον κήπο του φύτρωναν κι άνθιζαν /ston ˈcipo tu ˈfitronan‿ci ˈanθizan/ *In his garden they grew and bloomed*	*Στον κήπο του φύτρωναν (OM) άνθιζαν /ston ˈcipo tu ˈfitronan (OM) ˈanθizan/
Substitution	Έφερνε μυρωδιές ωραίες /ˈefɛrne miroˈðjes oˈrees/ *It brought beautiful smells.*	*έφερνα μυρωδίες ωραίες /ˈefɛrna miroˈðjes oˈrees/
Repetition	Και στις εικόνες της γειτονίας μου /ce stis iˈkonez tis ʝitoˈnias mu/ *And in the images of my neighborhood*	Και στις και στις εικόνες της γειτονίας μου /ce stis ce stis iˈkonez tis ʝi.toˈni.as mu/
Insertion	ο κυρ Νικόλας /o cir niˈkolas/ *Mr. Nicholas*	*ο κύριος Νικόλας /o cir niˈkolas/

Table 2. *Types of oral reading miscues*

Oral reading fluency (ORF) was calculated as Words Correct Per Minute (WCPM) for the first minute of reading. It was calculated by subtracting the number of reading errors from the total number of words attempted during a 60-second reading task. Stress errors were not counted in this score.

Data Analysis

A priori power analysis was conducted using G*Power (Faul et al., 2007) to estimate the required sample size for detecting a medium effect size ($f = 0.25$) with a power of 0.80 and alpha = .05, using a one-way ANOVA with 3 groups (VIG, AIG, CTG). The analysis showed a minimum of 66 participants (22 per group) would be required. Our sample ($N = 100$; VTG = 35, ATG = 35, CTG = 30) exceeded this requirement, ensuring adequate power to identify medium-sized group differences. Descriptive statistics (mean and standard deviation) were computed per group for pretest, post-test, and gain scores of all dependent variables. Error gain scores were calculated for each participant by subtracting post-test scores from pretest scores for each variable. Firstly, a t-test was used to determine whether there was a significant difference in stress error scores between the DD and CTG groups. Pretest equivalence across groups for all dependent variables was confirmed with one-way ANOVA. To explore the effect of the training on gain scores, a one-way MANOVA was conducted. Following this, one-way ANOVAs and post hoc comparisons were computed for each dependent variable to examine whether there was an improvement in stress errors, segmental errors, and ORF. Effect sizes were reported through partial eta squared (η^2). Correlation analysis was used to examine the relationship between stress errors and ORF, and a simple linear regression was used to determine whether ORF predicts stress error performance. Stress errors were scored separately from ORF and were not included in the calculation of oral reading fluency scores. Therefore, ORF and stress errors were treated as independent measures in correlational analyses.

Results

The following analysis is based on 3,645 individual reading errors. To measure reading improvement after the visual/auditory training, gain scores were measured from pre-test to post-test. Descriptive statistics are presented in Table 3.

(Insert Table 3 about here)

	Measures	Pretest M(SD)	Posttest M(SD)	Gain Score M (SD)	*p* (Pretest)
VIG	Stress Errors	6.69 (3.31)	5.17 (3.18)	-1.82 (2.93)	.206[1]
	Segmental Errors	16.4 (10.5)	14.3 (12.6)	-2.05 (8.32)	> .05[1]
	ORF	60.5 (19.83)	54.4 (22.82)	-6.14 (14.62)	1.000[1]
AIG	Stress Errors	5.46 (3.08)	6.06 (3.48)	0.42 (3.68)	< .001*[2]
	Segmental Scores	15.23 (9.27)	15.34 (9.6)	0.11 (6.97)	< .001*[2]
	ORF	56.28 (22.04)	54.89 (24.99)	-1.4 (8.43)	< .001*[2]
CTG	Stress Errors	1.8 (2.19)	2 (1.68)	0.45 (1.82)	< . 001*[3]
	Segmental Scores	1 (0.97)	0.7 (0.86)	-0.3 (0.57)	< .001*[3]
	ORF	107.25 (17.78)	104.75 (22.3)	-2.5 (12.78)	< .001*[3]

Table 3. *Descriptive statistics for stress errors, segmental errors and ORF for all groups.*
[1]post hoc pretest comparison between VIG and AIG
[2] post hoc pretest comparison between AIG and CIG
[3] post hoc pretest comparison between VIG and CIG

DD and CG in the pre-test

To address the first research question, we investigated whether there was a significant difference in pre-test stress error scores between the DD and CTG groups. An independent-samples t-test was performed, and as predicted, DD students performed significantly worse than CTG students ($t(98) = 7.32, p = .001$). Following this, One-way ANOVAs were conducted on the pretest measures of stress errors, segmental errors, and ORF to assess equivalence of the baseline between the VIG, AIG, and CTG groups before training. Analysis showed significant differences at baseline for Stress Errors ($F(2, 97) = 34.086$, $p < .001$, $\eta^2 = .413$), Segmental Errors ($F(2, 97) = 22.957$, $p < .001$, $\eta^2 = .321$) and ORF ($F(2, 97) = 53.223$, $p < .001$, $\eta^2 = .523$). Post hoc comparisons revealed no significant differences in pretest scores between experimental groups for all measures, but significant differences between the experimental groups (VIG and AIG) and CG for all measures (see Table 3 for *p* values).

The effect of the training on reading measures

Gain scores of the measures were computed and analysed to capture any acceleration of the intervention (Stuart, 2007). Scores were normally distributed, and a one-way MANOVA was performed to evaluate the effect of training type on stress error gains, segmental error gains and ORF gains. The multivariate effect of training type approached significance *Wilk's Λ* = .878, $F(6, 190) = 2.13$, $p = .052$, $\eta^2 = .063$. Exploratory univariate ANOVAs were then conducted to examine the measure effects on each dependent variable. These revealed a significant effect of the single session intervention on stress errors $F(2, 97) = 5.59$, $p < .005$, $\eta^2 = .103$, indicating a moderate to strong effect on stress performance but not on segmental errors, $F(2, 97) = 0.71$, $p = .493$, $\eta^2 = .014$ and ORF, $F(2, 97) = 0.86$, $p > .427$, $\eta^2 = .017$. Post-hoc analysis showed that VIG had significantly greater improvement in stress error than both the AIG ($p = .026$) and CTG ($p = .009$) groups. For AIG and CTG, there were no statistically significant changes in any of the measured items across the test points.

(Insert Figure 2 about here)

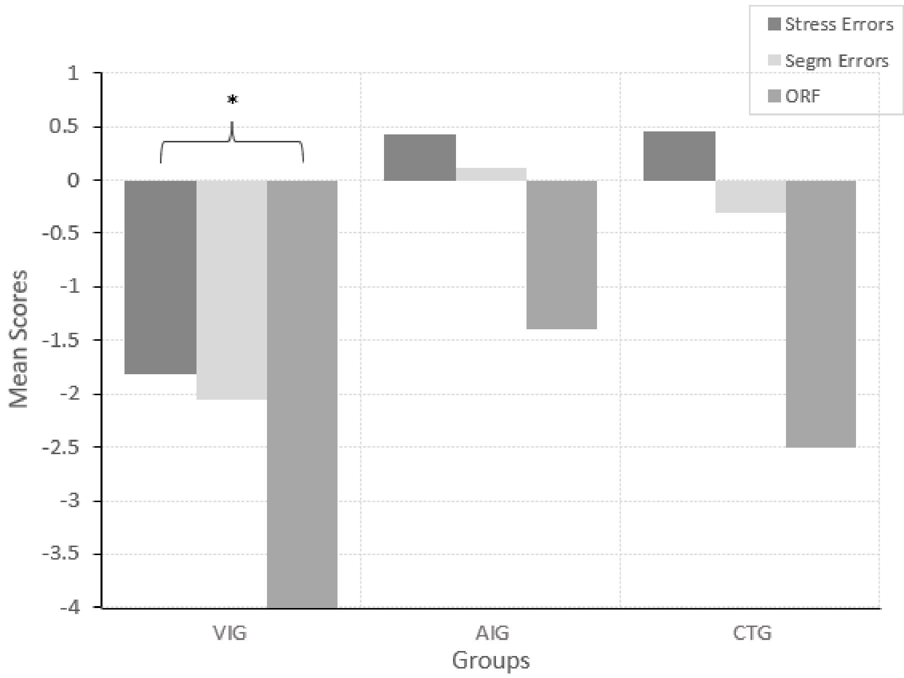

Figure 2*. Mean gain scores of stress errors, segmental errors, and ORF by group.*

Relationship between stress errors and ORF

The next step was to investigate whether there is correlation between stress errors and ORF. The results suggest a statistically significant moderate negative correlation between lexical stress errors and oral reading fluency, *r*(33) = –.341, *p* = .045. It suggests that students who produce fewer stress errors tend to present accurate ORF. Followingly, a simple linear regression was conducted to examine whether ORF predicts lexical stress errors. The model was statistically significant, *F*(1,33) = 4.34, *p* = .045 and showed that ORF is a significant negative predictor of stress errors, $\beta = -0.34$, *p* = .045, suggesting that students with higher oral reading fluency tend to produce fewer lexical stress errors.

Discussion

The present exploratory study constitutes a first attempt to explore whether visual single-session intervention, using discrimination and crowding tasks, could improve lexical stress assignment in students with DD. The results confirmed that students with dyslexia make significantly more stress errors compared to typically developed students, and the present experimental visual intervention provided short-term improvement. Specifically, it improved Greek stress assignment among students with dyslexia. Our findings align with models of dyslexia emphasising visual processing bottlenecks (Facoetti et al., 2008; Lobier et al., 2012; Niolaki, Terzopoulos & Masterson, 2020; Niolaki & Masterson, 2013; Ramus & Szenkovits, 2007), especially in decoding orthographically transparent languages such as Greek. The effect size for the improvement in stress assignment was moderate to strong ($\eta^2 = .103$) by traditional practice (Cohen, 1988), and these findings suggest preliminary evidence for the role of visual processing in supporting orthographic decoding in transparent languages such as Greek. A moderate negative correlation between stress errors and oral reading fluency (ORF) was observed, suggesting that training visual processes may positively affect reading fluency. As Goswami et al. (2013) and Stein (2014) have suggested, there are cross-linguistic orthographic differences that should be taken into consideration in the design of language-specific interventions.

Initially, we found that students with dyslexia made significantly more errors in lexical stress assignment than typically developing students (research question 1). This indicates that students with dyslexia exhibit difficulties in decoding, processing, and assigning lexical stress in Greek and supports previous evidence (Anastasiou & Protopapas, 2015). Despite the fact that in both tests, only a few of the words did not follow the correct stress pattern, participants with dyslexia showed significant difficulty in stress assignment. As such, the research found that after a single-session exposure, stress error scores decreased, indicating improved stress assignment in children with dyslexia. This evidence supports studies on stress sensitivity and dyslexia, which have identified impaired stress sensitivity among students with dyslexia across languages (for Greek, Athanasiou & Protopapas, 2015; for other languages, Barry et al., 2012; Goswami et al., 2013; Jiménez-Fernández et al., 2015; Paizi et al., 2011).

Considering the difficulty in lexical stress, we designed an intervention (single-session exposure) consisting of either visual or auditory modalities. The aim of this was to explore whether individuals with dyslexia can improve their sensitivity to textual features, especially the lexical stress marker in Greek, through training and, potentially, by improving their identification and crowding skills through exposure to visual and auditory nonlinguistic stimuli. To test the single-session efficacy on stress sensitivity and participants' overall reading performance, an oral reading test was administered before and after the training. The oral reading test comprised narratives, which were analysed subsequently for reading accuracy, including lexical stress errors and oral reading fluency (ORF).

In response to research question 2, a significant reduction in lexical stress errors in the post-test was found, indicating that visual single-session exposure training improved the identification and assignment of the Greek lexical stress marker, whereas auditory training did not lead to significant improvements in the stress pattern. Greek is an orthographically transparent language in which the lexical stress is explicitly represented by a diacritic mark in the majority of the words, and its position is considered essential, as a false assignment can change a word's meaning (Protopapas & Gerakaki, 2009) or can create an ungrammatical word, highlighting its key role in the orthography of Greek. Given that stress errors can disrupt word recognition and meaning in the context of Greek orthography, even modest reductions in stress assignment can yield disproportionate benefits for fluency and comprehension among students with dyslexia. This evidence suggests that successful stress assignment requires and employs not only phonological skills but also rapid, correct visual discrimination of the stress marker within an utterance. It is indicated that apart from the grapheme-phoneme correspondence skills, a reader must utilise the visual and attentional skills for the identification and processing of the stress marker in Greek. Our study provides preliminary evidence for a visual deficit in Greek children with dyslexia, building on a limited number of previous studies (Georgiou et al., 2010) on impaired visual processing. Taking into consideration the short nature of the intervention, the effects found are likely to reflect short-term performance modulation. Without questioning the traditional view of phonological factors in dyslexia (Goswami et al., 2003), the study supports the use of visual training to enhance language skills in students with dyslexia and underscores its multifactorial nature (Carroll et al., 2025). Univariate ANOVAs were conducted despite the non-significant MANOVA, given the exploratory nature of the study and the theoretical distinction of the types of errors, which reflect different aspects of reading performance.

It is also consistent with what has been reported in previous studies, which have found links between reading performance and visual interventions (Calet et al., 2019), confirming that tasks which focus on visual processing impairments are linked to improvements in reading performance and which are unambiguously not contaminated by visual-phonological processing (Provazza et al., 2022). Similar findings were reported by Aylward et al. (2003), who tested 10 children with dyslexia and 11 average readers before and after intervention. They compared the two groups of students on reading tests as well as the level of activation during tasks of identifying letter sounds. They found that while the control children showed no differences between the two images, the students who received the treatment showed a significant increase in activation in areas important for reading and language during the phonological task. Before the intervention, the children with reading disabilities showed significant underactivation in these areas compared to the control children, and after the treatment, their profiles were very similar. In relation to the applicability of the training to literacy, Vidyasagar and Pammer (2010) argued that if a deficit in visual attention exists, it may mean that it affects the processing of sequences such as those of letters.

In contrast, stress assignment errors were not reduced after the auditory stimuli. The present short-term single-session exposure, reflecting on the auditory phonological deficits in dyslexia (Ziegler & Goswami; 2005) and the phonological processing theory (Stanovich & Siegel, 1994) focused on auditory discrimination in this study, did not offer adequate exposure to the features of stress assigning to engender significant improvement. It is theoretically possible that differences in auditory sensitivity cannot be related to difficulties in acquiring lexical stress patterns (Goswami & Leong, 2013). Moreover, as argued by Ramus & Ahissar (2012) and McArthur et al. (2008) auditory processing skills may not be consistently associated with reading performance. These findings confirm Anastasiou and Protopapas' (2015) finding that students with dyslexia produce stress errors despite intact phonological awareness representations and further support the view that the phonological awareness deficit does not explain the mixture of difficulties in dyslexia (Ramus & Szenkovits, 2008; Stein, 2024).

In the study by Heiervang, Stevenson and Hugdahl (2002), 39% of the total number of participants with dyslexia had a significant auditory deficit. However, the potency of auditory training can depend on the transparency and the orthographic characteristics of a language. The lack of significant improvements after the auditory single session intervention may reflect the specific characteristics of the Greek alphabet and stress assignment. Assigning stress in Greek requires successful correspondence between orthographic (stress mark) and prosodic features, and auditory training fails to capture the full extent of dyslexia's characteristics due to stress-specific orthographic processing. On the other hand, English stress assignment is implicit, not marked and phonologically dependent, aligning well with the decoding properties of an auditory training.

Regarding segmental errors, research has shown that individuals with dyslexia commonly make reading errors, including substitutions, omissions, and misreadings of visually similar words (Snowling, 2000). These errors often stem from phonological processing deficits, making it difficult to accurately decode unfamiliar or irregular words (Torgesen et al., 2001). The identified error types were similar to findings from previous research in Greek and other languages (Cao & Fang, 2024; Protopappas & Gerakaki, 2008). However, as expected, no significant improvement in segmental processing and fluency was observed following the experimental visual single-session exposure. This could be attributed to the stimuli, which were specifically targeted to fine-grained visual processing (e.g., discrimination and crowding), rather than broader linguistic and phonological skills.

In the present study, ORF was found to be related to stress errors, suggesting that students with higher oral reading fluency tend to produce fewer lexical stress errors. This correlation indicates that lexical stress can influence reading fluency, affecting both speed, accuracy and comprehension (Goswami, Gerson, & Astruc, 2010). Incorrect stress assignment in Greek can interfere with lexical retrieval, leading to re-readings, unsuccessful word and text comprehension, and pauses, slowing down reading fluency. The results suggest that correct stress pattern may contribute to fluency and faster word recognition. Thus, visual intervention could have improved readers' visual and attentional processing and, consequently, boosted their reading speed and overall reading fluency. However, this needs to be further tested with a longer intervention that goes beyond single-session exposure.

While the current study data may not be conclusive about the universality of specific visual deficit theories, it suggests trends that future research with larger samples can potentially test further. Nevertheless, research on the level of visual or auditory perception in dyslexia is still not well developed (Vellutino et al., 2004), and further research should be conducted longitudinally to examine long-term outcomes, as this exploratory study consisted of a shorterterm exposure. The observed immediate effects provide a strong basis for continued exploration of visual interventions in dyslexia support, and future research should examine whether the gains in stress assignment and reading fluency are maintained over time (potentially with more than one follow-up test session). Moreover, while previous studies have explored visual and auditory interventions, to our knowledge, no attempt has been made to directly compare these modalities. Although the visual and auditory conditions were matched across core design principles, for example, the duration and structure of the trials, the non-linguistic nature, the perceptual discrimination demands, the attentional engagement, they differed in terms of the sequential and simultaneous processing.

Nevertheless, the effectiveness of visual single session exposure in improving lexical stress assignment among Greek-speaking children with dyslexia validates the importance of visual processing mechanisms in reading acquisition especially in languages with transparent orthographies. Greek, with its consistent grapheme-phoneme correspondence and stress marking, requires attention to fine orthographic details, making it an ideal language to test the impact of visual-based interventions. These findings may have cross-linguistic relevance, as other transparent languages (e.g., Italian, Spanish, Finnish) also depend on visual markers that contribute to reading fluency. Thus, visual components may be a promising complement or alternative to phonologically focused interventions, especially in educational contexts where decoding accuracy is not solely reliant on phonological skills. Considering the relative simplicity of the tasks, with further validation through repeated-session and longitudinal research, structured visual interventions may have the potential to inform classroom practice and speech and language therapy. These strategies could potentially be integrated into classroom or clinical settings to support students with dyslexia or with other learning difficulties in improving the processing of fine linguistic features during reading. The visual task is also a fun activity that can complement traditional phonological training tools.

Conclusion

In the present study, a unique characteristic of Greek orthography was employed as the focus of research, revealing a new angle on how processing of fine linguistic features can be improved after the use of an exploratory single-session intervention. Improvement in the stress assignment was observed once the participants were trained in visual tasks, contrary to the auditory modality, and the control group, in which no improvement was observed. Regarding oral reading fluency, findings suggest that students with higher fluency tend to produce fewer lexical stress errors. By addressing an underexplored area, the present study contributes to the ongoing discussion of the role of visual features in reading performance among students with dyslexia. Goodman, Ziegler and Goswami (2005) have highlighted that, for students to learn a language, they must first familiarise themselves with the 'code' of each writing system, including its visual symbols. Our findings provide a theoretically grounded and empirically supported basis for the development of broader multimodal approaches to reading training/interventions, especially in languages where lexical stress plays a key role. Consequently, it offers new insights with potential educational and clinical implications focused on students with dyslexia and reading difficulties.

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Appendix

Κείμενο 1

Το γαϊτανάκι

Μια φορά, δεν πάει καιρός, ζούσε σ’ ένα μικρό χωριό, κάπου εδώ κοντά, ένας άνθρωπος πολύ σοφός και πολύ γέρος. Η πλάτη του ήταν σκυφτή, τόσο σκυφτή, που η άσπρη του γενειάδα άγγιζε τη γη. Είχε διαβάσει τα βιβλία όλου του κόσμου και είχε μάθει τις γλώσσες όλων των ανθρώπων. Ζούσε απόμερα, σ’ ένα μικρό σπιτάκι, ολομόναχος. Στον κήπο του φύτρωναν κι άνθιζαν όλων των λογιών τα λουλούδια: τριαντάφυλλα, τουλίπες, μαργαρίτες, κυκλάμινα, ζουμπούλια κι όμορφα κατακόκκινα γαρίφαλα. Οι συχωριανοί του πολύ τον αγαπούσαν κι όλοι τον φώναζαν: ο κυρ Νικόλας ο Γαρίφαλος. Όταν τέλειωσε το πότισμα, ο κυρ Νικόλας μπήκε στο σπίτι του και κάθισε στο γραφείο του. Μια στοίβα χοντρά βιβλία τον περίμενε. Έπρεπε να τα διαβάσει… Τι παράξενο όμως, εκείνο το βράδυ, όσο κι αν πάσχιζε να συγκεντρωθεί, δεν τα κατάφερνε. Ο λογισμός του έτρεχε αλλού: στα τρία κοριτσάκια, στο τραγούδι τους. Χρόνια τώρα ζούσε ευτυχισμένος με τα βιβλία του, τα λουλούδια του, ολομόναχος, και ξάφνου η μοναξιά τού φάνηκε αβάσταχτη. Κατάλαβε πως η ζωή του έφτανε στο τέρμα της, νοστάλγησε τα νιάτα του. Ήταν πολύ λυπημένος εκείνο το βράδυ ο καλός κυρ Νικόλας. Κουνούσε το χιονισμένο του κεφάλι και μιλούσε δυνατά: «Είμαι μόνος, κανένας δεν μπορεί να με βοηθήσει, κανέναν δεν μπορώ να βοηθήσω με τις χίλιες γνώσεις μου. Είμαι άχρηστος. Ας ήμουν τουλάχιστο νέος, ας είχα τη δύναμη να ξανάρχιζα τη ζωή μου, θα μπορούσα…» Μονομιάς το πρόσωπο του κυρ Νικόλα φωτίστηκε. Σηκώθηκε από την πολυθρόνα κι άρχισε να χώνει βιαστικά κι ανάκατα μέσα σε μια βαλίτσα τα πράματά του.

Το γαϊτανάκι της Ζωρζ Σαρή
http://www.snhell.gr/kids/content.asp?id=234&cat_id=10

Once upon a time, not long ago, there lived in a small village, somewhere near here, a very wise and very old man. His back was bent, so bent that his white beard touched the ground. He had read all the books of the world and had learned the languages of all people. He lived alone, in a small house, all alone. In his garden, flowers of all kinds grew and bloomed: roses, tulips, daisies, cyclamens, hyacinths and beautiful scarlet carnations. His villagers loved him very much and everyone called him: Mr. Nicholas the Carnation. When the watering was finished, Mr. Nicholas went into his house and sat down at his desk. A stack of thick books was waiting for him. He had to read them… But strangely enough, that night, no matter how hard he tried to concentrate, he couldn't. His thoughts were elsewhere: on the three little girls, on their song. For years now he had lived happily with his books, his flowers, all alone, and suddenly the loneliness seemed unbearable to him. He understood that his life was coming to an end, he longed for his youth. Good Sir Nicholas was very sad that night. He shook his snowy head and spoke loudly: "I am alone, no one can help me, I cannot help anyone with my thousand knowledge. I am useless. Suddenly, Mr. Nikolas' face lit up. He got up from his armchair and began to hurriedly and haphazardly stuff his things into a suitcase.

Κείμενο 2

Μια γειτονιά, δύο εποχές.

Πρέπει να σου μιλήσω για τη γειτονιά μου. Έφυγα και φοβάμαι πως θα την ξεχάσω. Πρέπει να διαλέξω τις σωστές εικόνες για να μπορείς να κάνεις μια βόλτα με το νου στις μυρωδιές και στις εικόνες της γειτονιάς μου. Στη γειτονιά μου υπήρχαν, όπως σε όλες τις γειτονιές της πόλης, πολλοί φούρνοι, πέντε σε δύο τετράγωνα. Για να είμαστε δίκαιοι ως προς τους φουρνάρηδες, πηγαίναμε μια στον ένα, μια στον άλλο. Μετά ήταν το πάρκο απέναντι από το σταθμό. Παίζαμε, και τι δεν παίζαμε εκεί, όλα εκείνα τα παιχνίδια που τώρα δεν υπάρχουν πια. Κοντά στη γειτονιά μου είναι και το λιμάνι, και καμιά φορά ο βόρειος άνεμος, ο βαρδάρης – το όνομα του οποίου έχει και η γειτονιά - έφερνε μυρωδιές ωραίες, θαλασσινές, μια νότα αλατισμένου αέρα. Μετά ήταν η κυρά Μαρίκα και ο κυρ Νικόλας, που πέθανε πια εδώ και χρόνια, με το μπακάλικό τους. Έβρισκες και του πουλιού το γάλα, πραγματικά. Φαντάσου ένα γωνιακό μπακάλικο, με τρεις εισόδους, πέντε διαδρόμους, αποθήκες πολλές, γεμάτο με πράγματα. Τώρα, ο σοφός τους εγγονός, το έκανε κανονική επιχείρηση. Σημαντική εικόνα της γειτονιάς, στο νότιο άκρο της, είναι το δικαστικό μέγαρο. Μετακινήσεις συνεχείς στη γειτονιά, γιατί είναι εμπορική το πρωί, και έχει ησυχία το βράδυ. Η γειτονιά μου προσπαθεί, δηλαδή, να είναι ήσυχη, μα δεν την αφήνουν και τόσο. Είναι αυτό που λέμε «κέντρο-απόκεντρο». Ένα μελίσσι με δεκάδες διαφορετικούς ήχους και αλλαγή διάφορων ανθρώπων κατά τη διάρκεια του εικοσιτετράωρου. Η γειτονιά κλείνει για να ανοίξει ξανά σε λίγες ώρες, ενώ ένα κομμάτι της ψυχής μου κοιμάται και ξυπνά με όλα αυτά.

I need to talk to you about my neighborhood. I left and I'm afraid I'll forget it. I need to choose the right images so you can take a mental stroll through the smells and images of my neighborhood. In my neighborhood, like in all neighborhoods in the city, there were many bakeries, five in two blocks. To be fair to the bakers, we went to one, then to the other. Then there was the park across from the station. We played, and what not, there, all those games that don't exist anymore. The port is also close to my neighborhood, and sometimes the north wind, the Vardaris - after which the neighborhood is named - would bring beautiful, sea-like scents, a hint of salty air. Then there were Mrs. Marika and Mr. Nikolas, who died years ago, with their grocery store. You could even find the bird's milk, really. Imagine a corner grocery store, with three entrances, five aisles, many warehouses, full of things. Now, their wise grandson, made it a regular business. An important image of the neighborhood, at its southern end, is the courthouse. Constant commuting in the neighborhood, because it's commercial in the morning, and quiet at night. My neighborhood tries to be quiet, but they don't let it be that quiet. It's what we call "center-outskirts." A beehive with dozens of different sounds and a change of people throughout the day. The neighborhood closes to reopen in a few hours, while a part of my soul sleeps and wakes up with all of this.