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Reading Patterns in L2 Dyslexic Italian Learners of Chinese: An Eye Tracking Perspective

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Abstract

The study investigates the reading patterns of dyslexic learners of Chinese through the lens of eye-tracking technology, focusing on the differences in cognitive processing when engaging with two types of Chinese characters: ideo-phonetic compounds and pictographs.

Dyslexia, a specific learning disorder, significantly impacts reading abilities, leading to challenges in word recognition, spelling, and comprehension. The research aims to enhance understanding of how visual stimuli can aid dyslexic students in learning Chinese, a language characterized by its unique writing system.

The study involved ten Italian university students, including six diagnosed with dyslexia, who participated in a 100-hour online Chinese language course. Eye movements were recorded using a Tobii Pro Spectrum eye tracker, allowing for an analysis of fixation patterns and durations as participants engaged with the characters. The research questions focused on whether the type of character influenced the average number and duration of fixations, and whether there were significant differences in fixation patterns between dyslexic and non-dyslexic readers.

Results indicated that both dyslexic and non-dyslexic participants exhibited longer fixation durations on pictographs compared to ideo-phonetic compounds, suggesting a more complex cognitive processing for pictographic characters. However, contrary to initial hypotheses, dyslexic participants did not demonstrate a greater number of fixations on ideo-phonetic compounds. The findings highlight the importance of understanding character structures and suggest that knowledge of basic character components may be more beneficial for dyslexic learners than visual aids alone.

This research represents a significant step in exploring the intersection of dyslexia and Chinese language acquisition in Italy, providing empirical data that can inform educational strategies tailored for dyslexic students. The study concludes that while visual stimuli can support learning, a deeper understanding of character structures is crucial for improving reading comprehension among dyslexic learners.

Keywords: Dyslexia, CFL-Chinese as foreign language, Eye tracking, Ideo-phonetic compounds vs pictographs, Reading patterns.

1. State of the Art

Dyslexia is a specific learning disorder that primarily affects the ability to read and process written language. It is characterized by difficulties in word recognition, spelling, and decoding, which can lead to problems with reading comprehension and vocabulary. Dyslexia is not related to intelligence, hearing, or vision issues, but rather to differences in how the brain processes language. The biological origin of dyslexia involves an interaction of genetic, epigenetic, and environmental factors that affect the brain's ability to perceive or process verbal or non-verbal information effectively and accurately. This complex interplay can lead to the specific difficulties in reading and language processing that are characteristic of dyslexia (American Psychiatric Association 2023:78).

In Italy, research on dyslexia and Chinese language is still at an embryonic stage. However, the national indications for inclusive education recommend the use of personalized teaching in order to enhance the different characteristics of each student and favor their learning. This work therefore aims to take a step forward from the state of the art, not only by investigating the characteristics of the acquisition of two types of Chinese characters, the ones derived from pictograms and ideo-phonetic compounds, in Italia students with dyslexia, but also by delving, for the first time in Italy, into the importance of the presentation of visual stimuli in order to maximize their learning.

To date, there are two studies that have addressed this issue. The first is the study by Formica (2018), a secondary school teacher, who proposed a series of practical activities to improve phonological and orthographic awareness. In particular, Formica focuses on metalinguistic skills to stimulate meaningful and active learning, aimed exclusively at understanding the grapheme-phoneme relationship in the pinyin transcription system. Although of great value, this study mainly concerned experimentations on teaching methodologies. The other research in Italy that collected and analyzed data on the characteristics of dyslexic students learning Chinese as a second language (LS) is the one conducted at the University of Macerata by Giaconi and colleagues (2019), which Gesù, who collaborated on the project, also discussed in one of his contributions (2019). This research involved a group of ten students, five with dyslexia and five normal readers, for a 30-hour course in Italy and a summer school at Beijing Normal University. The study focused on mapping the students' errors to define their characteristics and highlight learning difficulties.

The experimental work of this research moves from a study conducted by Liu Han-Chin and described within the article “Using Eye-Tracking Technology to Explore the Impact of Instructional Multimedia on CFL Learners Chinese Character Recognition” (2021). However, some changes have been made, the most important of which concerns the introduction of dyslexic participants which the known study did not include. In addition, while Liu's study included photographs next to pictographs, this research included the original pictograms, highly iconic and absolutely specific to the typeface being investigated.

This work aims to take a step forward from the current state of the art and represents the first study in Italy to relate research on dyslexia and the Chinese language using eye-tracking technology. Furthermore it will lay the groundwork to understand, based on empirical data, the characteristics of Chinese language acquisition in Italian-speaking dyslexic students.

In selecting characters, the categorization presented by Xu Shen in the *Shuōwén jiězì* 说文解字 was taken into account, and thus reference was made to *xiàngxíng* 象形 (pictograms) and *xíngshēng* 形声 (ideo-phonetic compounds).

The former are graphemes that represent referents (physical objects, people, animals, and so on) in a more or less stylized way (Lavagnino, Pozzi 2013; Abbiati, 2012) whose ancient representations can be likened to images. These include characters such as *nǚ* 女 (woman), *mù* 木 (wood), *rì* 日 (sun). Although these characters represent only a small percentage of Chinese characters (Taylor, Taylor 1995), they are common radicals, that is, basic components of compound characters.

Ideo-phonetic compounds, on the other hand, are characters consisting of two components, one of which gives clues to the meaning of the character and the other to its pronunciation (Lavagnino, Pozzi 2013; Wang, 2000). They account for more than 90 percent of Chinese characters (De Francis 1984; Wang 2000).

Research conducted with eye-tracking on dyslexic subjects suggests that visual support in the form of images related to the text can facilitate comprehension during reading (Holmqvist 2017), as well as the initial processing of words within a sentence, allowing readers to predict the contents of the subsequent sentence (Rivero-Contreras et al. 2021).

Given the difficulties with the decodification of written words, dyslexic subjects tend to rely more on the visual-non verbal modality during the comprehension processes (Daloiso 2014). As described, dyslexia is a disorder that primarily affects reading and writing dimension, while not compromising other cognitive abilities, such as those related to non-verbal aspects (Berton *et al*. 2006). Consider, for example, the evidence from the psychology of thinking and learning, which states that much of our knowledge is mentally encoded not in logical-formal structures, but in forms that preserve the physical-perceptual characteristics of reality (Antonietti 1998). Using visual representations such as pictures, diagrams, vignettes and cartoons can then prove to be useful teaching support in the context of dyslexia as they provide an anchor to the perceptual datum of what is being represented and form the basis for multisensory learning (Berton *et al*. 2006).

Eye mind theory (Just, Carpenter 1980) according to which "there is a clear correspondence between what is fixed and what is cognitively elaborated"; in other words, when a subject looks at a word or an object, he also thinks about it (cognitive process) and that process is measurable in the "window" (temporal and metaphorical) of the eye's fixation.

1.1 Aims

As described in the previous paragraphs, we know that eye movements represent a 'window to the mind' and that studies using *eye-tracking* technology allow us to investigate the cognitive processes underlying reading and comprehension.

Eye movements are a crucial indicator of cognitive processes during reading, acting as a 'window to the mind.' Research utilizing eye-tracking technology has illuminated how individuals engage with text, revealing that more complex stimuli necessitate a higher frequency of fixations and prolonged fixation durations. This phenomenon is particularly pronounced in dyslexic readers, who exhibit longer fixations and shorter saccades, indicating distinct cognitive processing patterns compared to typical readers.

The research questions emerging from these observations focus on the implications of using characters derived from pictograms, which are inherently more visual and iconographic in nature. Specifically, the inquiries aim to explore whether these pictogram-based characters can facilitate improved reading comprehension and cognitive processing among various reader groups, including those with dyslexia.

By investigating the relationship between eye movements and the cognitive load associated with different types of textual stimuli, we attempt to understand how visual representations influence reading efficiency and comprehension. This line of inquiry not only aims to enhance our understanding of reading processes but also has the potential to inform educational strategies and interventions tailored for individuals with reading difficulties.

In summary, the research questions center on the effectiveness of pictogram-derived characters in enhancing reading comprehension and the associated eye movement patterns that reflect underlying cognitive processes.

It was decided to restrict the Area of Interest (Note 1) to the single character. In order to identify the readers' cognitive effort on the characters viewed, it was decided to use measures of the number and average duration of fixations.

Research question 1

Are the average number and duration of fixations influenced by the type of stimulus?

Hypothesis: with regard to subjects with dyslexia only, the average number and duration of fixations are expected to be significantly different between ideo-phonetic compounds and pictograms. It is hypothesized that dyslexic participants will generate a greater number and longer average duration of fixations with regard to ideo-phonetic compounds.

Research question 2

Do the number and duration of fixations differ significantly between subjects with dyslexia and normo-readers?

Hypothesis: subjects with dyslexia are generally expected to make a greater number and longer average duration of fixations than non-dyslexics.

2. Method

2.1 Participants

Given the exploratory nature of this research, special care was taken in selecting a small but homogeneous group of participants. Ten Italian university students (mean age = 22.2), of whom six with dyslexia (three males and three females) and six normal readers (six females), participated in the study. Of the students with dyslexia, four were pure dyslexics (diagnosis code F81), while the others presented comorbidities with other specific learning disorders (diagnosis code F83): dyscalculia (1); dysgraphia, dysorthographia and dyscalculia (1).

The participants, all absolute beginners, were offered a free 100-hour Chinese language course, in return for their participation in the experimental activity. The course, which was held online to allow students from different cities in Italy to participate, enabled them to reach the A1 level of the Chinese language (HSK1).

During the course, participants were introduced to pictographic characters and ideo-phonetic compounds. With regard to the first type of characters, they were able to see the oldest forms of pictograms and their evolution over time, through the images taken from the *Hanyu Da Cidian* 汉语大词典 (Luo 1986-1994) and the text 'Evolution de l'écriture chinoise' (Li 1993). The presentation of ideo-phonetic compounds, on the other hand, was conducted by adopting the analytical method in order to identify and highlight the semantic and phonetic components within them. The *Hanyu Da Cidian* and the *Hanzi Tuanjie Zidian* 汉字团解字典 (Gu 2008) were adopted to provide this type of explanation.

Before starting the experimental activity, all participants were asked to fill in a questionnaire with some basic personal information for screening purposes (name, age, languages known). None of the participants had knowledge of Oriental languages. Instead, the languages studied and known were: English (10); Spanish (5); French (4); German (3).

2.2 Stimuli

The visual stimuli of the present experimental activity consist of 50 Chinese characters, of which 25 characters derived from pictograms and 25 ideo-phonetic compounds, completely unknown to the participants.

The stimuli had a specific layout. They present on the left, from top to bottom, the Italian translation, the character and the *pinyin*; while on the right, there is the original pictogram for the first type of characters and a metalinguistic analytical explanation for the second one.

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In order not to alter the data regarding the duration and number of fixations, the complexity of the characters was kept constant and character pairs (pictogram/compound) that were selected diverge by a maximum of two strokes, as in the examples shown in Figures 1 and 2 (*ěr* 耳 ear: 7 strokes, *yuǎn* 远 far: 6 strokes).

Figure 1. Pictograph 耳 (ear) and its original pictogram

Figure 2. Ideo-phonetic compound 远 (far) and its metalinguistic explanation

The characters and the class to which they belong have been identified within the *Hanyu Da Cidian*, as have the images relating to the original pictograms; as for the metalinguistic description, this has been taken and translated from the *Hanyu Da Cidian* and the *Hànzì Tújiě Zìdiǎn*. The digital representation of the original pictograms was taken from https://hanziyuan.net/.

As far as ideo-phonetic compounds are concerned, mainly characters with left/right construction were presented. They are the most numerous among those contained in the HSK1 programme, as well as the most familiar to the students who participated in the project. As for their pronunciation, regular, semi-regular and irregular characters were chosen. However, *pinyin* was not the focus of this experimental activity.

2.3 Procedure

A Tobii Pro Spectrum (screen-based eye tracker) with a binocular sampling rate of 1200 Hz was used to record eye movements. Stimuli were presented on a 23.8″ colour screen (EIZO [Ishikawa, Japan] FlexScan EV2451) with a resolution of 1920 × 1080 pixels (52.8 × 29.7 cm). The recorded data were filtered through the Tobii Identification by velocity threshold algorithm that identifies fixations and saccades in the raw gaze data according to a velocity criterion. For the detection of saccades, a default value of 30 °/s was used for the velocity threshold. Gaze parameters were based on the averages of the left and right eyes, but when only one eye was found for a data sample, that was used in the calculation.

Each AOI was defined using the AOI tool of the Tobii Pro Lab software (vers. 1.940). The duration and number of fixations on each AOI were analysed. The fixation radius was defined as 35 pixels. Tobii did not have the text analysis tool at the time of data processing, implying that the visual stimuli used corresponded to a fixed image. Consequently, the technical analyses were conducted as if an image had been presented. However, even if the tool had been available, the particularity of the Chinese writing system would not have allowed it to be transcribed as standard text. This suggests that the reading process differs in technical, perceptual and methodological terms. The text tool usually calculates data on the basis of the configuration of the alphabets, which is uniform, but in this case it could not be applied.

Participants were given informed consent and a questionnaire to collect some basic data, which has already been described above.

Before starting the reading test, the *eye-tracker* was calibrated with the participants' eye movements. Next, a slide was shown on the screen briefly explaining to the subjects what they had to do during the experiment. This explanation was given in written Italian, we give here a translation of it:

Hello, you are about to start the test. This is not an exam. In the slides that follow, there will be Chinese characters that we ask you to observe and understand. The characters will be accompanied by a picture of their pictograms or an explanation. Read the whole slide in your head until you think you have understood. When you think, you have finished understanding the slide, go to the next page by clicking on the mouse. Pay attention because at the end you will have to take a short test and recognise 16 of the characters you will now see. Click on the mouse to begin!

This was followed by four stimuli containing known characters, in order to give the participants a factual understanding of the contents and tasks relating to the test which were not considered in the data analysis. During the viewing of the stimuli containing known characters, the participants were allowed to ask questions about what was still unclear about the test. Afterwards, with a new message written in Italian, the participants were informed of the start of the actual test:

The test run has ended. Now the actual test begins. Click on the mouse to start!

As there were people with dyslexia among the participants, the inclusion of fillers was avoided, which would have burdened the test. It was decided to keep the subjects' attention by telling them that at the end of the eye-tracker activity they would do a test on the characters seen on the screen. There was no time limit and they could freely decide, with a click of the mouse, when to move on to the next stimulus.

The tests were administered individually with each participant in a single meeting.

After the eye-tracking test was finished, each participant was administered the post-test, at the end of which they were asked to answer a short interview about the experimental activity they had participated in and the stimuli they had seen.

3. Results

In this section, we present the results of the quantitative analysis conducted to answer the research questions outlined above. The main objective of this analysis was to explore and compare different aspects of reading behavior between dyslexic and non-dyslexic participants, in relation to two types of visual stimuli: ideo-phonetic compounds, accompanied by a metalinguistic explanation and characters derived from pictograms, flanked by the image of the original pictogram. The following subsections present in detail the data collected, the statistical methodologies used and the main observations that emerged from the data analysis.

Number and average duration of fixations

Number of fixations refers to the number of times the participant fixates an AOI; duration of fixations refers to the time each individual fixation lasts within AOI. In this case, the AOI is represented by the individual Chinese characters.

The data regarding the number of fixations are graphically represented in Figure 3. The average values are rather uniform both between groups and within the same group: however, one dyslexic participant stands out for a particularly high number of fixations.

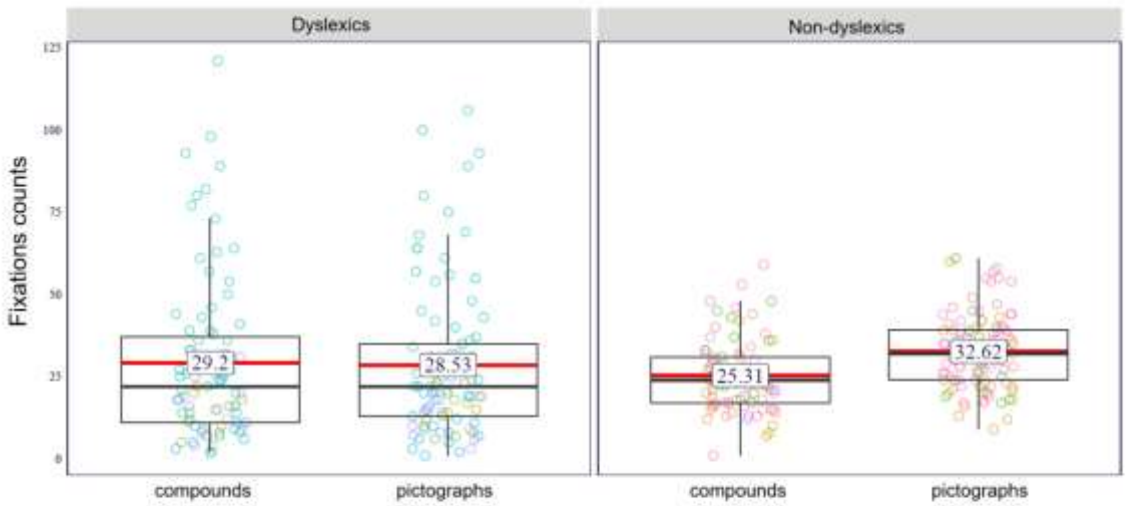

Figure 3. Fixations counts

The data were analysed using a linear mixed model postulating a normal distribution. The linear effects are represented by the interaction between presence or absence of dyslexia, on the one hand, and stimulus type, on the other, for a total of four values (D_compounds, D_pittograms, ND_compounds, ND_pittograms, where D indicates the group of dyslexic participants, ND that of non-dyslexic participants). The model also predicts a random intercept for each participant and stimulus.

The coefficients estimated by the model are shown in Table 1 in the Appendix. Coefficients significant at the 95% threshold are highlighted in grey.

None of the fixed effects considered reach statistical significance at the 95% threshold and this is probably due to the small number of participants. However, some stimuli are associated with moderate statistically significant effects.

For example, a statistically significant contrast opposes the two stimulus types in the non-dyslexic group (7.96, CI = 4.34 - 11.65). DR1 is therefore partially answered in the affirmative: a difference in the number of fixations between the two stimulus types exists, but it does not affect the dyslexic participants, as predicted by the working hypothesis. Indeed, the data show that non-dyslexics perform a greater number of fixations on pictograms. The hypothesis concerning DR2, on the other hand, is not confirmed by the data: subjects with dyslexia do not perform a greater overall number of fixations than non-dyslexics. However, data also show that there is a tendency in the first group to fixate less on both the visual stimuli.

The data concerning the average duration of fixations are graphically represented in Figure 4. (Note 2)

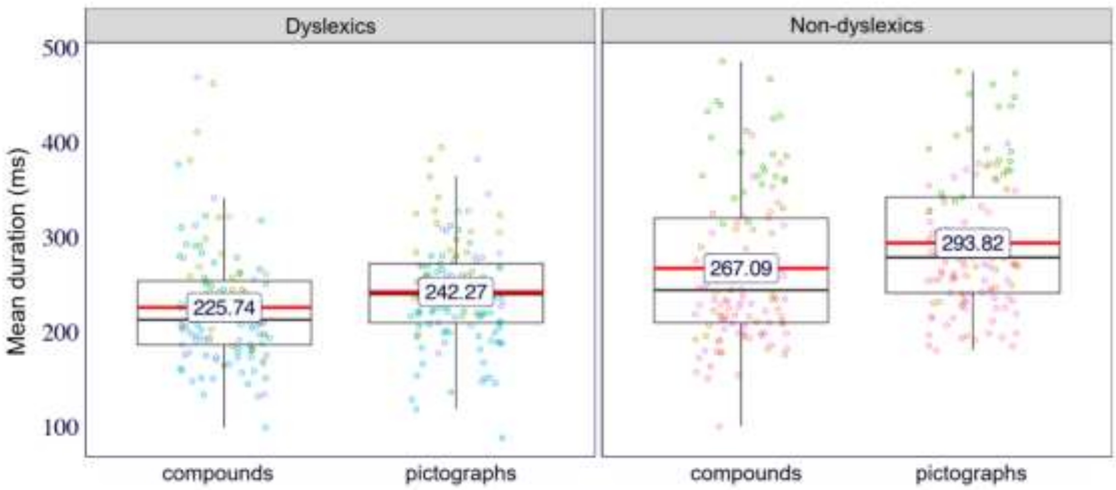

Figure 4. Mean duration (of fixations)

It can be seen that pictograms cause longer fixation times on average in both groups of participants. One participant in the non-dyslexic group also stands out as particularly conspicuous.

Again, a linear mixed model postulating a normal distribution was set up to verify the above observations. The linear effects are represented by the interaction between the presence or absence of dyslexia, on the one hand, and the type of stimulus, on the other hand, for a total of four values (D_compounds, D_pittograms, ND_compounds, ND_pittograms, where D indicates the group of dyslexic participants, ND that of non-dyslexic participants). As before, the model also predicts a random intercept for each participant and stimulus, respectively correlated with the random coefficient of stimulus type and participant group.

As can be seen, DR1, which assesses the influence of stimulus type on the average duration of fixations, is answered in the affirmative, with the specification that the same trend applies to both groups. However, contrary to initial expectations, participants recorded longer fixations on pictograms and not on ideo-phonetic compounds.

As for DR2, as for the number of fixations, again, there were no significant differences between dyslexics and non-dyslexics for either type of stimulus, again contrary to the initial hypothesis. However, even in this case, data show that there is a tendency in the first group to fixate shorter than the normo-reader on both the visual stimuli.

It can be seen that pictograms cause longer fixation times on average in both groups of participants. One participant in the non-dyslexic group also stands out as particularly conspicuous.

As the Table 2 shows that the credibility interval (95%) of the post hoc contrasts does not include the value 0 only in the case where the type of stimulus varies within the same group (dyslexics: mean = 16,63, CI = -33,19 – 0.95; non-dyslexics: mean = -26,77, CI = - 43,20 – -9,84): the RQ1 is therefore answered in the affirmative, with the clarification that the same trend applies to both groups. On the other hand there are no significant differences between dyslexics and non-dyslexics for either of the two stimulus types: the response to RQ2 is negative (reading times differ significantly between dyslexics and non-dyslexics?), although there is a tendency for dyslexics to have shorter reading times, contrary to the working hypothesis.

4. Discussion and Conclusions

In reference to the first research question we explored, the analysis of eye movements shows that the number of fixations is affected by the type of stimulus, but this difference only affects the non-dyslexic group. Indeed, the data show that non-dyslexics perform a greater number of fixations on pictographs.

As for the duration of fixations, the results indicate that the average duration of fixations tends to be influenced by the type of stimulus, but contrary to the initial hypothesis, both groups fixate longer on characters derived from pictograms than on ideo-phonetic compounds.

It is known that a high number of fixations reveals the reader's behavior in exploring the visual stimulus and also which visual elements captured the reader's attention (Rayner 1998; Godfroid 2020). Furthermore, according to the eye-mind hypothesis they can also reveal a higher cognitive load in understanding the visual stimulus. Based on these assumptions, it is possible to speculate that non-dyslexics had been more interested in reconstructing meanings by making comparisons between the contemporary pictographs and the original pictograms, as we can see in the Figure 5, 6, 7 and 8.

Furthermore, it is also possible to suppose that they found it more difficult to convey the same meanings through an image rather than a metalinguistic explanation. This hypothesis directly leads us to the analysis of the second metric.

Figure 5. Night: fixation counts of dyslexic participants

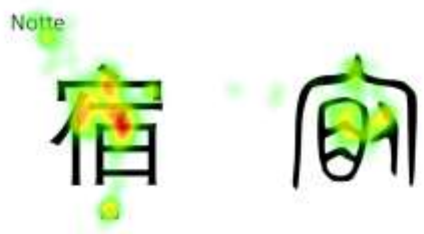

Figure 6. Night: fixation counts of non-dyslexic participants

Figure 7. Night: fixation duration of dyslexic participants

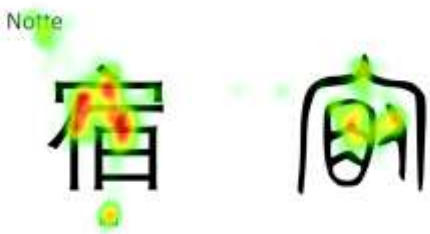

Figure 8. Night: fixation duration of non-dyslexic participants

As stated, again, by the Eye-mind hypothesis, the duration of fixation correlates more directly with cognitive load. Since both groups have been shown to fixate more and longer on characters derived from pictograms, it is possible to suppose that they benefited from knowledge of the sublexical components of the characters that make up the ideo-phonetic compounds. We hypothesize that these subcomponents were easier to identify within the characters because the metalinguistic explanation recalled prior knowledge of them in all the participants. Studies on Chinese characters acquisition confirm that the sub-lexical information contained in the semantic and phonetic components of the character is crucial to the overall understanding of the character and facilitates its recognition (Shen 2000; Shen, Ke 2007).

Thus, the greater cognitive effort would have been linked to the impossibility, in the case of characters derived from pictograms, of being able to break them down into smaller orthographic units and be able to identify the known components. This would have exposed the readers to a greater visual complexity of the characters (Yin, 2007; Zhang, 2001) and their more difficult processing.

The hypothesis concerning DR2, on the other hand, is not confirmed by the data: subjects with dyslexia do not perform a greater overall number of fixations than non-dyslexics. This is probably attributable to the level of Chinese language possessed, that is, a basic level, which was the same for all participants in the study (HSK1). It can be related also to the fact that the characters were unfamiliar to all the participants. In his studies, in fact, Rayner (1986) also showed that the eye movements of normal readers can take on the characteristics of readers with dyslexia when subjected to a text too complex for their ability.

However, even if there were no significant differences between dyslexics and non-dyslexics for either type of stimulus, contrary to working hypotheses, it is possible to see a tendency for the dyslexics participants to fixate less and for a shorter time both the pictographs and the ideo-phonetic compounds, if compared with the non-dyslexic group. Furthermore, the latter performed a greater number and longer duration of fixations particularly on characters derived from pictograms.

The data analysis results lead us to propose one main interpretative hypothesis. It is known that dyslexics tend to suffer from a visual-spatial attention deficit, which research has confirmed originates in abnormalities of the eye's magnocells (Galaburda 2014; Stein 2008). This deficit has also been found in studies on dyslexia and Chinese, which have shown that it is an increasingly important factor in reading difficulties in this language as well, so much so that its role seems to have been shown to outweigh that of several other already known reading-related skills (Chen *et al*. 2019).

The sample of participants involved is not representative of the general population and therefore the reported conclusions need further study in the field to lead to more complete definitions. It was not possible to involve a much larger number of students as the Chinese language course to be completed in order to participate in the experimental activity posed a major challenge for students with dyslexia and many decided not to add further study load to their university course. However, this is the first study conducted in Italy on dyslexic Italian-speaking students learning Chinese language by using the eye-tracking technology, so it is hoped that this research can be expanded in the future.

References

Alessandra, L., & Silvia, P. (2013). *Cultura cinese. Segno, scrittura e civiltà*. Roma, Carocci.

American Psychiatric Association. (2023). *DSM-5-TR. Manuale diagnostico e statistico dei disturbi mentali*. Milano, Raffaello Cortina Editore.

Antonietti, A. (1998). Valutare il software: che cosa offre di realmente diverso. *Informatica & Scuola*, *IV*(3).

Berton, M. A., Ciceri, F., Craighero, M., Dazzi, V., Grandi, L., Lampugnani, G., ... Stella, G. (2006). Strategie e tecnologie per l'apprendimento: risorse educative per famiglia e scuola. *Dislessia*, *3*(3), 295-307.

Chen, N. T., Zheng, M., & Ho, C. S. H. (2019). Examining the visual attention span deficit hypothesis in Chinese developmental dyslexia. *Reading and Writing*, *32*, 639-662. https://doi.org/10.1007/s11145-018-9882-1

Daloiso, M. (2014). *Lingue straniere e disturbi specifici dell'apprendimento: un quadro di riferimento per la progettazione di materiali glottodidattici accessibili*. Torino: Loescher Editore.

DeFrancis, J. (1984). *The Chinese Language: Fact and Fantasy*. Honolulu: University of Hawaii Press. https://doi.org/10.1515/9780824840303

Formica, A. (2018). La didattica della lingua cinese con alunni con disturbi specifici dell’apprendimento. In A. Brezzi, & T. Lioi (Eds.), *La didattica del cinese nella scuola secondaria di secondo grado. Esperienze e prospettive* (pp. 67-76). Roma, Sapienza Università Editrice.

Galaburda, A. (2014). Dyslexia and genetics, paper presented at the Learning Difference Convention. Sydney, Australia.

Gesù, F. (2019). La sfida della lingua cinese per studenti con dislessia: nuove metodologie didattiche, obiettivi e prospettive. *Limine. Frontiere e Integrazioni, 18*, 191-197.

Giaconi, C., Simone Aparecida Capellini, S., & Trentin, G., *et al.*. (2019). Inclusione e Università: il progetto "dislessia e lingua cinese. *Education, Science and Society*, 120-134. https://doi.org/10.3280/ess1-2019oa8075

Godfroid, A., (2020). *Eye-tracking in second language acquisition and bilingualism*. New York, Routledge. https://doi.org/10.4324/9781315775616

Holmqvist Olander, M., Wennås Brante, E., & Nyström, M. (2017). The Effect of Illustration on Improving Text Comprehension in Dyslexic Adults. *Dyslexia*, *23*(1), 42-65. https://doi.org/10.1002/dys.1545

Just, M. A., & Carpenter, P. A. (1980). A theory of reading: From eye fixations to comprehension. *Psychological Review*, *87*(4), 329-354. https://doi.org/10.1037/0033-295X.87.4.329

Liu, H.-C. (2021). Using Eye-Tracking Technology to Explore the Impact of Instructional Multimedia on CFL Learners’ Chinese Character Recognition. *Asia-Pacific Educational Resources, 30,* 33-46. https://doi.org/10.1007/s40299-020-00512-2

Rayner, K. (1986). Eye movements and the perceptual span in beginning and skilled readers. *Journal of Experimental Child Psychology*, *41*(2), 211-236. HTTPS://DOI.ORG/10.1016/0022-0965(86)90037-8

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, *124*(3), 372-422. https://doi.org/10.1037/0033-2909.124.3.372

Rivero-Contreras, M., Engelhardt, P. E., & Saldaña, D. (2021). An experimental eye-tracking study of text adaptation for readers with dyslexia: effects of visual support and word frequency. *Annals of Dyslexia, 71*, 170-187. https://doi.org/10.1007/s11881-021-00217-1

Shen, H. H. (2000). Radical knowledge and character learning among learners of Chinese as a foreign language. *Linguistic Studies, 6,* 85-93.

Shen, H. H. (2004). Level of cognitive processing: Effects on character learning among non-native learners of Chinese as a foreign language. *Language and Education*, *18*(2), 167-182. https://doi.org/10.1080/09500780408666873

Shen, H., & Ke, C. (2007). Radical awareness and word acquisition among non-native learners of Chinese. *The Modern Language Journal*, *91*(1), 97-111. https://doi.org/10.1111/j.1540-4781.2007.00511.x

Stein, J. (2008). The neurobiological basis of dyslexia. In G. Reid, A. Fawcett, F. Manis, & L. Siegel (Eds.), *The Sage Handbook of Dyslexia*. London: Sage. https://doi.org/10.4135/9780857020987.n4

Taylor, I., & Taylor, M. M. (1995). *Writing and literacy in Chinese, Korean, and Japanese*. Philadelphia: John Benjamins Publishing. https://doi.org/10.1075/swll.3

Wang, L. (2000). Tan xingshengzi tedian ji zucheng [Reflection on the peculiarities and grouping of ideo-phonetic characters]. *Waijiao xueyuan xuebao*, *1*, 91-95.

Yin, J. J. (2007). Meiguo daxue rumen jieduan hanzi kecheng de sheji [Curriculum design for an entry course on Chinese characters at an American university]. *Journal of the Chinese Language Teachers Association*, *42*(2), 67-76.

Zhang, M. (2001). Hanyu rumen jieduan de hanzi jiaoxue [Beginning-level Chinese character instruction]. *Journal of the Chinese Language Teachers Association*, *36*(2), 55-62.

Appendix A

Table 1. Statistical Model, Number of Fixations

Parametro	Mean	Sd	2,75 %	97,5%
Dyslexics_ ideo-phonetic compounds	–1,18	9,99	–20,69	17,98
Dyslexics_ pittographs	–0,03	10,02	–19,22	19,17
Non-Dyslexics_ ideo-phonetic compounds	–2,49	9,93	–21,17	17,25
Non-Dyslexics_ pittographs	5,48	9,95	–13,33	25,23
Sigma	11,10	0,37	10,42	11,88
Dys_Participant [1]	0,90	6,79	–11,99	14,72
Dys_Participant [2]	–4,06	6,83	–16,79	9,47
Non-Dys_participant [3]	–11,55	6,63	–24,08	1,97
Non-Dys_participant [4]	1,80	6,85	–11,24	15,19
Non-Dys_participant [5]	1,68	6,65	–10,94	14,96
Non-Dys participant [6]	33,28	6,61	20,55	46,78
Dys participant [7]	–15,91	6,60	–28,66	–2,33
Dys_participant [8]	–8,29	6,62	–20,97	5,26
Non-dys_participant [9]	3,48	6,86	–9,49	17,11

Dys_participant [10]	1,84	6,82	–10,77	15,35
[1] Maple 枫	0,56	2,72	–4,89	5,92
[2] Wide 阔	–3,15	2,81	–8,69	2,09
[3] Rainbow 虹	1,33	2,77	–3,93	6,87
[4] Remote 缅	–0,15	2,64	–5,17	5,10
[5] Ride 骑	–1,30	2,72	–6,45	4,13
[6] Chivalrous 侠	2,32	2,73	–3,06	7,76
[7] Deer 鹿	2,34	2,71	–2,82	7,80
[8] Grain 粒	–2,84	2,72	–8,14	2,49
[9] Shell 贝	–5,18	2,84	–10,88	0,13
[10] Horn 角	–3,18	2,78	–8,66	2,18
[11] Distant 辽	–1,18	2,68	–6,46	3,93
[12] Elephant 象	–4,75	2,77	–10,25	0,60
[13] Exam 试	–4,81	2,85	–10,44	0,49
[14] Extreme 极	–1,50	2,78	–6,91	3,74
[15] Granary 廪	–0,17	2,67	–5,16	5,23
[16] Busy 忙	1,60	2,68	–3,45	6,75
[17] Teach 教	0,17	2,66	–4,94	5,26
[18] Insect 虫	5,66	2,87	0,34	11,40
[19] Inhale 吸	0,97	2,84	–4,49	6,61
[20] Slowly 徐	–2,28	2,73	–7,54	3,16
[21] Far 远	3,64	2,78	–1,66	9,05
[22] Night 宿	–1,58	2,66	–6,84	3,63
[23] Swim 泳	–1,98	2,75	–7,36	3,28
[24] Eye 睛	–1,29	2,75	–6,96	3,90
[25] Ear 耳	–2,56	2,72	–7,97	2,70
[26] Imperial palace 宫	2,69	2,72	–2,37	8,30
[27] Sparrow 雀	–1,88	2,72	–7,22	3,38

[28] Step 步	–6,25	2,94	–12,07	–0,56
[29] Fish 鱼	–2,73	2,74	–8,21	2,57
[30] Bridge 桥	–0,06	2,67	–5,20	5,15
[31] Reason 理	0,31	2,73	–4,85	5,72
[32] Remember 记	–2,59	2,76	–7,81	2,81
[33] Reflect 映	0,86	2,72	–4,35	6,17
[34] Breast 奶	4,20	2,86	–1,13	10,04
[35] Silk 丝	0,77	2,71	–4,36	6,12
[36] eyebrow 尾	4,78	2,83	–0,65	10,34
[37] Elder sister 姐	5,51	2,88	0,17	11,35
[38] Younger Sister 妹	3,82	2,82	–1,52	9,49
[39] Spring 泉	5,01	2,84	–0,23	10,86
[40] Supervise 监	5,33	2,80	0,07	11,00
[41] Turtle 龟	0,90	2,70	–4,12	6,16
[42] Plank 板	0,36	2,73	–4,87	5,63
[43]Head 首	2,89	2,81	–2,37	8,45
[44] Tiger 虎	0,13	2,66	–4,92	5,44
[45] Mouse 鼠	–1,75	2,74	–7,23	3,39
[46] Thunder 雷	–0,53	2,73	–5,76	4,79
[47] Bird 鸟	–3,89	2,78	–9,42	1,42
[48] Man 夫	2,38	2,73	–2,84	7,85
[49] Vast 浩	–2,47	2,79	–7,80	2,89
[50] Vegetables 蔬	2,11	2,77	–3,12	7,68

Table 2. Statistical Model, Mean Duration of Fixations

variable	Mean	Sd	2.5%	97.5%
Dys_ideo-phonetic compound	224.22	28.59	166.89	280.67
Dys_pictographs	240.85	27.94	185.53	296.78
Non-dys_ideo-phonetic compound	264.85	27.36	210.94	318.26
Non-dys_pictographs	291.62	26.67	239.18	342.99
sigma	44.78	1.51	41.95	47.8
Intercept	255.38	18.47	217.58	291.68
Non-Dys_participant [1]	12.7	27.72	-41.27	67.57
Non-Dys_participant [2]	-27.82	27.71	-82.45	26.76
Dys_participant [3]	37.84	29.26	-19.47	95.77
Non-Dys_participant [4]	113.72	27.94	59.79	169.59
Dys_participant [5]	30.55	28.99	-26.77	89.32
Dys_participant [6]	-20.46	29.2	-78.62	37.7
Dys_participant [7]	-51.26	29.09	-107.84	6.58
Dys_participant [8]	10.93	29.09	-46.28	68.51
Non-Dys_participant [9]	-18.28	27.7	-73.66	35.27
Non-Dys_participant [10]	-69.17	27.84	-123.44	-14.39
[1] Maple 枫	4.17	7.38	-6.45	22.53
[2] Wide 阔	-0.35	5.55	-12.9	11.49
[3] Rainbow 虹	-0.67	5.58	-13.7	10.66
[4] Remote 缅	1.66	5.86	-9.03	16.14
[5] Ride 骑	-0.68	5.55	-13.91	10.08
[6] Chivalrous 侠	-2	5.75	-16.23	7.76
[7] Deer 鹿	-1.1	5.59	-13.7	9.98
[8] Grain 粒	-2.64	6.17	-18.75	7.23
[9] Shell 贝	-1.03	5.22	-13.38	9.55
[10] Horn 角	-0.99	5.73	-13.67	11.03
[11] Distant 辽	1.08	6	-10.75	15.81
[12] Elephant 象	0.76	5.39	-10.12	13.16
[13] Exam 试	-1.92	5.84	-16.08	8.56
[14] Extreme 极	0.06	5.53	-11.65	12.45
[14] Extreme 极	-0.11	5.67	-12.56	11.82
[16] Busy 忙	-0.58	5.35	-13.13	10.24

[17] Teach 教	-1.26	5.65	-14.76	9.13
[18] Insect 虫	-0.99	5.29	-13.66	9.63
[19] Inhale 吸	2.34	6	-7.87	17.3
[20] Slowly 徐	0.35	5.47	-11.31	12.62
[21] Far 远	-1.92	5.64	-16.5	8.05
[22] Night 宿	-1.32	5.73	-15.37	9.34
[23] Swim 泳	2.75	6.59	-7.51	19.87
[24] Eye 睛	-0.3	5.5	-12.52	11.56
[25] Ear 耳	0.16	5.46	-11.47	12.16
[26] Imperial palace 宫	-0.51	5.43	-12.78	10.86
[27] Sparrow 雀	-0.82	5.55	-13.64	10.23
[28] Step 步	0.69	5.33	-10.01	12.76
[29] Fish 鱼	-1.57	5.87	-15.86	8.91
[30] Bridge 桥	2.34	6.15	-8.29	16.91
[31] Reason 理	0.77	5.54	-10.17	14.19
[32] Remember 记	-1.23	5.51	-14.58	9.14
[33] Reflect 映	-2.39	5.98	-17.58	7.45
[34] Breast 奶	1.35	5.72	-8.66	14.82
[35] Silk 丝	-0.43	5.75	-13.7	11.4
[36] eyebrow 尾	3	6.59	-7.34	19.8
[37] Elder sister 姐	-3.3	6.46	-20.11	6.23
[38] Younger Sister 妹	-0.89	5.52	-13.61	9.94
[39] Spring 泉	1.43	5.63	-9.03	14.67
[40] Supervise 监	-0.36	5.7	-13.23	11.58
[41] Turtle 龟	2.81	6.16	-6.8	17.83
[42] Plank 板	-1.85	5.6	-15.68	7.56
[43]Head 首	0.22	6.06	-13.32	13.19
[44] Tiger 虎	1.52	5.86	-9.6	15.53
[45] Mouse 鼠	0.37	5.64	-11.52	13.01
[46] Thunder 雷	1.63	5.7	-8.89	15.3
[47] Bird 鸟	1.05	5.49	-9.59	13.93
[48] Man 夫	-2.21	5.82	-16.7	7.79
[49] Vast 浩	0.69	5.38	-9.7	13.24
[50] Vegetables 蔬	3	6.67	-8.06	19.36

Notes

Note 1. The Area of Interest (AOI) in eye tracking refers to a predefined area within the visual environment that is deemed particularly relevant for the purpose of the study. Researchers manually delineate these areas on the stimulus material to focus their analysis on specific parts of the visual field.

Note 2. Each point corresponds to the average fixation duration of a participant, which in turn is uniquely identified by the corresponding color. For each combination of variables, the group mean (red segment and numerical label) as well as the first, second (median) and third quartile (lower, middle and upper segment of the rectangle, respectively) are indicated. The vertical arms extend to values at most 1.5 times the interquartile distance from the first and third quartile.

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