MORPHOLOGICAL PROCESSING IN ITALIAN L2 DEVELOPING READERS: A PILOT STUDY

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ABSTRACT: In this paper we focus on the morphological competence and awareness of 23 Italian second-language (L2) school children, by comparing the reading profiles of Italian L1 and L2 children attending primary school from 2^{nd} to 5^{th} grades. Reading data were collected through the experimental *finger-tracking* protocol developed within the *ReadLet* project, which supports collecting and structuring behavioural reading data of short narrative texts displayed on a tablet touch-screen. The analyses reproduced the main effects that are well-attested in the developmental literature, and pointed out some differences in the behavioural profile of L2 versus L1 children, with the former being more affected by word length and frequency effects, as well as by the aloud reading task than the latter. Interestingly, however, a functional morphological segmentation strategy emerges in L2 readers processing complex inflected forms during the aloud reading task. We interpret it as a possible strategy to alleviate the extra cognitive load associated with the overt articulation of morphologically complex words within the context of a connected text.

KEYWORDS: reading, bilingualism, morphological awareness, developing readers, word processing.

1. INTRODUCTION[1]

Reading demands a complex cognitive process that includes recognition of each written words, access to their meaning, and semantic integration into larger-than-word units. The most influential approach describing the functional architecture of the mechanisms underlying reading skill is the Dual Route Model (Coltheart *et al.* 1993, 2001), which suggests a lexical strategy that

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involves recognition of the written word and access to its pronunciation and meaning, and a sub-lexical route activating the grapheme-phoneme conversion. In a developmental perspective, the interaction between the sub-lexical route and the lexical frequency-based route sheds some light on morpho-lexical effects on reading, since an early effect of morpheme-based lexical reading may suggest an emergence of morphemes that can efficiently help to process and access unknown or low-frequency complex words (Burani *et al.* 2008), as well as inflected or derived words (Bertram *et al.* 2000). Specifically, in the aloud reading modality, the sub-lexical route may involve three stages, with (i) an initial phonological reading of a few already familiar words, (ii) an intermediate phonological reading in which the child manages to merge phonemes into syllables and concatenate syllables with each other, and (iii) the final stage where the child articulates the whole word after a sub-vocal syllabic reading.

In the silent modality, the recognition of a word as a whole – via the lexical route – is based on the strategy of recognition of the most salient graphemes; a sub-lexical route would be in place for those words where only a serial decoding of graphemes may discriminate the target word. High-frequent co-occurring graphemes may speed-up word recognition and meaning access (Grainger & Ziegler 2011).

Accordingly, the frequency of both word and sub-constituents plays a key role in favouring a fluent reading strategy, as well as the degree of discriminability of such (sub)structures: the greater the transparency of the grapheme-phoneme mapping – especially in a shallow orthography such as Italian – the easier the assignment of a unique phonological representation. Particularly in shallow orthographies, developmental readers are supposed to initially follow a sub-lexical route to then successfully integrate both the sub-lexical and the lexical reading strategy (Burani *et al.* 2002). With transparent scripts, high levels of reading accuracy may be reached quite rapidly; however, reading speed may improve slowly, especially in atypically developing children (see, on Italian, Barca *et al.* 2006; De Luca *et al.* 2008; Marzi *et al.* 2020).

1.1 Factors affecting reading

Many factors are reported to affect reading performance, such as word length, word frequency, lexicality and neighbourhood size (Barca *et al.* 2002, 2006; Zoccolotti *et al.* 2009).

Word length may induce longer latencies before long words are articulated, as well as longer articulation time. Its effect is shown to decrease considerably for high-frequency words as well as for increasing reading abilities in a developmental perspective. Likewise, the word frequency effect is shown to reach its fully potency in 3rd grade (Zoccolotti *et al.* 2009). The lexicality effect – grapheme strings stored in the mental lexicon as words, as opposed to strings that are not represented in the reader's mental lexicon – is reported to influence reading at all ages for high-frequency words and by 3rd grade for low-frequency ones, progressively increasing with age. Interestingly, it has been shown a facilitatory effect of morpheme lexicality (Job *et al.* 1998), as well as a neighbourhood lexical effect (Arduino & Burani 2004) on reading aloud tasks of non-words.

Additionally, the reading modality may have an impact on comprehension, with higher comprehension rates for text read orally by children entering middle school (Dickens & Meisinger 2016). Developmental children are shown to take benefit from aloud reading as it allows for grapheme-phoneme mapping reinforcement (Kuhn & Schwanenflugel 2007). The two modalities, in fact, involve different cognitive processes. In reading aloud, readers must articulate words and follow between and within sentence-punctuation, notably taking significantly more time to complete text reading compared to silent reading (McCallum *et al.* 2004). Interestingly, silent reading fluency has been shown to be a good predictor of reading comprehension for skilled readers, but not for poor/struggling readers (Kim *et al.* 2011).

1.2 Reading in a second language

Reading fluency appears to support accurate text comprehension (Kuhn & Stahl 2003); however, when reading in a second language (henceforth L2), lower-level process difficulties may prevent higher-level processes, thus resulting in slower and less accurate reading as compared to grade/age peers (Grabe 2009). The mutual relation between vocabulary knowledge and reading comprehension, and their reciprocal growth in a developmental perspective, may be challenged by decoding difficulties (Grabe 2009; Jeon & Yamashita 2014). There is, in fact, broad consensus that successful reading comprehension should rely on both highly automatised word recognition and syntactic parsing (for a systematic review, see Jeon & Yamashita 2014). The general comprehension of a connected text may be challenged by an inefficient integration at the word-level (Perfetti 2007), although contextual information may play a role in facilitating word recognition.

Factors affecting reading in monolingual (henceforth L1) readers have been reported for L2 readers too. Children with Italian as either L1 or L2 read words better than non-words, preferring the lexical strategy where possible, and relying on the sub-lexical strategy for unknown or non-words. A strong frequency effect is reported in Italian *late bilinguals*, whereas a comparable effect to L1 is shown in *early bilinguals* (Bellocchi *et al.* 2016). These effects have been recently confirmed for English L1 children reading in Spanish as L2 (López 2021). Although the developmental interaction of reading strategies and the effect of specific lexical factors on L1 and L2 reading performance result in a similar picture, L2 children experience more difficulties in literacy acquisition and word reading accuracy than L1 grade-peers (Melloni *et al.* 2022). All in all, poor linguistic skills in L2 children are suggested to explain limited performance in reading comprehension (Jeon & Yamashita 2014; Melby-Lervåg & Lervåg 2014).

1.3 Morphological competence

In experimental studies with English children from 3rd to 4th school grades (Jarmulowicz *et al.* 2008; Deacon *et al.* 2014), it has been shown that children exhibit a direct effect of morphological awareness on reading comprehension. Morphological awareness (henceforth MA) is referred to as the ability to reflect on and manipulate correctly morphemic structure (Ehri 2005). Interestingly for our present concerns, convergent evidence has been shown for L2 learners (see, for example, Deacon *et al.* 2007; Zhang *et al.* 2010) and minority-language readers (Kieffer & Lesaux 2008; Kieffer *et al.* 2013). MA points directly to the explicit understanding of word structure and to the ability to combine or decompose words into their different morphemes (Carlisle 1995, 2000; Kirby & Bowers 2018).

The debate on how morphemes are represented in the mental lexicon, and how morphemic representations are accessed in word processing, has focused on the investigation of how morphological information unfolds in processing a morphologically-complex word (for a recent overview focussing on the role of morpfological competence on reading acquisition, see, Marelli *et al.* 2020). Notably, the ability of recognising familiar morphemes in unknown complex words, be they derived or compound words, helps in understanding their meaning (Bertram *et al.* 2000). At early stages for typically developing children, MA is suggested to play an important role in achieving accuracy and fluency in decoding, thus enhancing reading comprehension (Deacon *et al.* 2014). Conversely, in proficient readers, MA can help in establishing connections between different sections of a text and making inferences, no longer affecting accuracy and fluency of decoding. A large body of evidence suggests the importance of MA to reading, since it develops with exposure to oral and written language (Berko 1958; Mann & Singson 2003; Jarmulowicz *et al.* 2008; Kieffer & Lesaux 2012; Kirby *et al.* 2012). MA is suggested to be a late emerging competence connected to orthographic skills (Ehri 2005), based on the increasing exposure to less frequent complex words. In fact, high frequent stems have been shown to facilitate decoding of complex derived words since the fourth school grade (Mann & Singson 2003).

Interestingly, it has been shown that a combination of morphological and semantic processing can help children with reading difficulties, such as dyslexics or poor readers, as a compensating mechanism for specific phonological deficits (on French, Casalis *et al.* 2004; on English, Catts *et al.* 2006; Deacon *et al.* 2014; on Italian, Burani *et al.* 2008; on Spanish, Suárez-Coalla & Cuetos 2013). The cross-linguistic experimental evidence suggests that both typically and atypically developing children are able to detect sublexical chunks corresponding to morphemes and take advantage from them. Put together, the evidence supports the idea that children with dyslexia may develop representations of reading units larger than the grapheme, and use sublexical, morphemic constituents to overcome their difficulties in phonological decoding. However, a developmental reader is not always able to take advantage from the morphemic structure of complex words. This facilitation is more effective when stems and affixes are easily detectable. Languages with shallow orthographies such as Italian, Spanish, and German, allow children to easily use a morphological strategy and benefiting from access to them, thus achieving higher levels of accuracy and overcome possible reading difficulties (Marelli *et al.* 2020). It has been shown (Spinelli *et al.* 2005; Zoccolotti *et al.* 2005) that children with dyslexia are more sensitive to length effects than control children, with more difficulties in reading aloud and reading non-words. Using a morphological reading strategy, therefore, may help them in processing long complex words that are not yet fully-memorised in their mental lexicon (Burani 2010). MA and morphological reading are shown to be effective in L2 readers as well, in phonetic decoding, listening comprehension and reading fluency (Kieffer *et al.* 2013).

1.4 Objective of the pilot study

With our focus on morphological competence in L2 children attending primary schools in Italy, we investigated the serial processing of morphologically-complex words during reading, both silently and aloud. Our approach capitalises on recent evidence that finger and eye movements may provide highly congruent dynamic patterns during exploration of images that are displayed on a computer's touchscreen (Lio *et al.* 2019), and on synergistic behaviour of fingers and eyes in tasks requiring synchronisation of fast eye movements and the slower motor system controlling the fine coordination of finger movements (Inhoff & Gordon 1997; Furneaux & Land 1999).

We propose, here, a quantitative analysis of reading dynamics in a group of 115 primary school children engaged in a task of reading connected texts – silently and aloud – while *finger-pointing* to the narrative text displayed on a tablet touch-screen. Based on a web application interfaced with an ordinary tablet, finger-tracking results show to replicate significant psycholinguistic benchmarks in the literature on word visual recognition and reading. Pace of word reading and text comprehension in L2 Italian children, attending primary school in Italy, are compared to those of grade-matched Italian monolingual children, by focussing on morphologically-complex verb forms as our specific objective.

2. METHODS

2.1 Participants

115 children were included in this study, by sampling children from entire primary school classes from 2nd to 5th grade, in two schools in the city and province of Pisa. Participants' parents were asked to give written informed consent for their children involvement, as well as some information about the child's first language and the language mostly spoken at home.[2] At the end, the experimental sample was composed by a total of 115 participants, with 92 Italian L1 speakers (mean age = 9.28, sd = 1.21) and 23 Italian L2 ones (mean age = 9.20, sd = 1.32). All of them had with normal or corrected-to-normal vision. None of them were reported by parents to have learning difficulties. L1 and L2 groups of participants are not of comparable size, since entire classes have been recruited in two schools – one in the city centre of Pisa, Italy, and one in a small town of the province of Pisa, Italy – with a consequent reduced number of L2 subjects.

For the L2 experimental group, all were reported by parents to be first-generation children, with different mother languages, namely Albanian, Arabic, Chinese, English, French, German, Russian, Spanish.

2.2 Materials

Children were presented with two fantasy narrative texts, to be read one silently and one aloud. The order of reading modality and the texts to be read were counterbalanced across participants to have text stimuli equally distributed among participants and across modalities.

[2] The study was approved by the Ethics Committee of the National Research Council of Italy (approval number CNR 0037523/2021) and was conducted according to the ethical standards of the Declaration of Helsinki and the Italian Association of Psychology.

Four different fantasy texts were created by controlling and classifying each of them in episodes of increasing levels of readability. Natural Language Processing methods and techniques (Dell'Orletta *et al.* 2011) made it possible to annotate all words in the texts for levels of linguistic analysis – from part-of-speech tagging to token's syntactic role in a sentence – thus controlling the overall complexity of each episode. Texts were broken down into five episodes each, of increasing length and complexity, with a mean number of tokens ranging from 157.26 (sd 1.92) for the 1st episode up to 201.12 (sd 9.89) for the 5th one (173.76 (1.64) for the 2nd one, 187.32 (4.46) for the 3rd one, 188.09 (5.88) for the 4th one). Token length range increased as well, from 1–10 up to 1–15, while the mean word (log)frequency[3] decreased for both content and function words for increasing episodes. In this way, the four texts – of five episodes each – are of comparable increasing complexity, as confirmed by their statistical non-significance as random effects in the regression models that will be reported in Section 3.

At the end of each episode children were presented with a written questionnaire with multiple-choice answers controlling for reading comprehension. In detail, two *wh*-questions with multiple-choice answers were presented at the end of each episode to verify children's ability to retrieve the general content and identify temporal or cause-effect relations of the stories told in the texts.

Children attending different school grades were presented with a different number of episodes, with 2nd graders being presented with the first 2 episodes, 3rd graders with 3 episodes, up to 5th graders with all the 5 episodes. Accordingly, for each reading session a child had to be engaged no longer than twenty minutes.

2.3 Procedures

A common tablet and a web application (Ferro *et al.* 2018; Taxitari *et al.* 2021) were used to record the finger movements of Italian developing readers when they concurrently read and finger-point to a text displayed on a tablet touch-screen. Despite the inherently different dynamics of ocular and tactile movements, finger movements were shown to highly correlate with eye-tracking data (Crepaldi *et al.* 2022) and to replicate established reading effects in a language with a transparent orthography such as Italian (Marzi *et al.* 2020). The innovative method of *finger-tracking* has been developed to capture the processing behaviour of readers while reading a text displayed on a touch-screen, either silently or aloud. Finger-tracking consists in recording the time-series of finger movements on a tablet, thus capturing the serial processing of mor-

[3] Token frequencies were extracted from the Italian *Subtlex* corpus (Crepaldi *et al.* 2013).

phologically complex words, such as inflected verb forms and derived words. Pointing to the text while reading is highly familiar to children learning to read, since it helps them to focus their attention and to serially scan letters and syllables (Uhry 2002; Mesmer & Lake 2010).

The finger-tracking technology is based on an ICT infrastructure[4] with a cloud-based back-end exposing a battery of web services that act as an interface between a central repository and the users. As new data are collected and stored in the repository, cloud services start processing text and audio streams off-line, by aligning them in time, so that each word in the text is associated with its text-to-speech rendering by the reader – in the aloud reading modality – and with a time-stamped series of finger touch events. Recorded encrypted and pseudo-anonymised data are made available for off-line data processing.

The experimental campaign has been conducted in two primary schools in the Province and city of Pisa, Italy, respectively in February and May 2021. During their usual schooling activities, children were presented with two fantasy narrative texts by being preliminary instructed to finger-track the text on the touch-screen of a common tablet in both reading conditions.[5] A practice reading excerpt taken from Collodi's *Pinocchio* tale was preliminary shown to each child, together with a multiple choice practice question.

3. EXPERIMENTAL ANALYSIS

Statistical analyses of reading data were modelled with R (R Core Team 2022) as generalised additive models (*gam* function), and graphed with (non-)linear regression plots and distribution plots (*ggplot* package, *geom_smooth* and *ggbetweenstats* functions).

In spite of the different size in our two experimental groups, we observe a comparable distribution of word tracking times for the two reading modalities in both L1 and L2 children, as shown in Figure 1. Here, distributions of tracking time for each word token are reported for L1 (left panel) and L2 (right panel) children by reading modalities. Both groups exhibit a significant longer tracking time in the aloud reading modality than in the silent one (see the within-group *t* test-statistic significance reported on the top of both panels). In fact, a full overt articulation is supposed to be slower than a covert

[4] The architecture has been developed by the *ComphysLab* at CNR-ILC within the frame of the *ReadLet* project, whose goal is to investigate and validate the correlation patterns between the movement of a reader's finger pointing to a text during reading and eye-tracking data.

[5] A 10.1 inches Samsung tablet (1.8 GHz Octa-Core, 3 GB RAM, 64 GB eMMC, Android 10) was used, with a screen of 14.9cm x 24.5cm in a resolution of 1920 x 1200 pixels. Texts were presented in Arial (21.25pt). Participants were tested in their school building, while sitting at a desk where the tablet was placed on a stand to prevent accidental movements.

articulation, thus slowing the overall aloud reading. However, there is a statistically significant difference (p-value $< 2.2e-16$) in the tracking times *between* groups, with a mean token tracking-time for L1 children of 0.38 seconds and of 0.43 seconds for L2 children. The same pattern is observed when comparing tracking-times between groups *within* reading modality, with a significant shorter time for L1 children in both modalities than L2 ones (0.41 vs. 0.46, p-value < 0.001 for aloud reading, 0.35 vs. 0.40, p-value < 0.001 for silent reading).

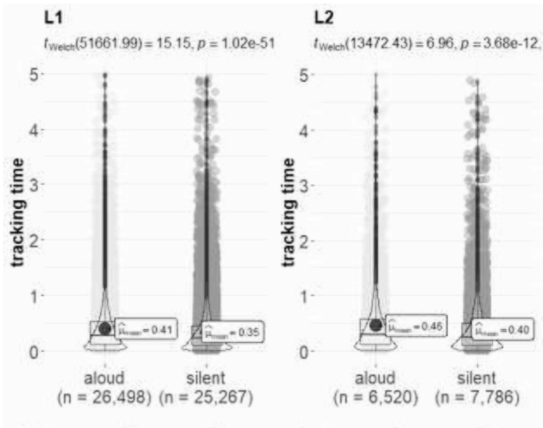

FIGURE 1: DISTRIBUTIONS OF WORD TRACKING TIME (IN SECONDS) FOR ALOUD AND SILENT READING FOR L1 (LEFT PANEL) AND L2 CHILDREN (RIGHT PANEL).

3.1 Word length and word frequency effects

In replicating the well established behavioural evidence for developmental readers (Bates *et al.* 2001; Zoccolotti *et al.* 2005, 2009; Kliegl *et al.* 2004; Burani *et al.* 2007), we observe the basic word length and word frequency effects on reading time by measuring the tracking time for each words in a text as a proxy of reading behaviours, usually captured with eye-tracking.

In Figure 2, regression plots for increasing word length and increasing word frequency are shown for the two experimental groups in the two reading modalities. Tracking time are positively affected by word length and negatively by word frequency, as expected. Notably, from the pertinent regression models (i.e. generalised additive models, or GAMs) reported in Table 1 and Table 2, L2 children are significantly more affected by the two variables in their tracking/reading time than L1 children.

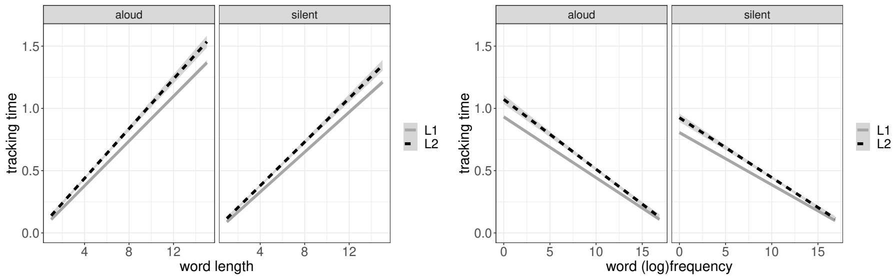

FIGURE 2: LINEAR REGRESSION PLOTS FOR TOKEN TRACKING TIME (IN SECONDS) AS A FUNCTION OF WORD LENGTH (LEFT PANEL) AND WORD LOG-FREQUENCY (RIGHT PANEL) FOR GROUPS (GREY LINE FOR L1 AND BLACK DASHED LINE FOR L2 CHILDREN) AND READING MODALITY. SHADED AREAS INDICATE 95% CONFIDENCE INTERVALS.

ALOUD READING	*Estimate*	*SE*	*t Value*	*Pr(>|t|)*
intercept (L1)	0.03	0.02	1.39	> 0.05
word length (L1)	0.09	0.01	110.67	$< 2e-16$
word length (L2)	0.10	0.01	7.06	< 0.001
participants (re)				$< 2e-16$
reading texts (re)				> 0.05
R^2	42.2%			
SILENT READING	*Estimate*	*SE*	*t Value*	*Pr(>|t|)*
intercept (L1)	0.04	0.02	1.97	< 0.05
word length (L1)	0.08	0.01	101.71	$< 2e-16$
word length (L2)	0.09	0.01	5.62	< 0.001
participants (re)				$< 2e-16$
reading texts (re)				> 0.05
R^2	43.2%			

TABLE 1: GAM COEFFICIENTS FOR MODELS FITTING TOKEN TRACKING TIME AS A FUNCTION OF WORD LENGTH IN INTERACTION WITH GROUPS, FOR ALOUD AND SILENT READING. PARTICIPANTS AND TEXTS ARE ADDED AS RANDOM EFFECTS (*re*).

When focussing on the two reading modalities *within* groups, a greater time difference between silent reading and aloud reading is observed in L2 children compared with L1 ones, with the former showing a mean by-token difference of 0.09 seconds, and the latter of 0.08 seconds. However, this difference is not statistical significant (p-value > 0.05 for the Welch *t* test).

3.2 A developmental perspective

In a developmental perspective – from 2^{nd} to 5^{th} school grade – both L1 and L2 children show a progressive decrease of average reading time per token, as well as a reducing effect of word length and word frequency, as shown by the regression plots in Figure 3 and Figure 4, where the slowing effect of length

ALOUD READING	*Estimate*	*SE*	*t Value*	*Pr(>|t|)*
intercept (L1)	0.96	0.02	45.74	$< 2e-16$
word frequency (L1)	-0.05	0.01	-78.47	$< 2e-16$
word frequency (L2)	-0.06	0.01	-6.77	< 0.001
participants (re)				$< 2e-16$
reading texts (re)				> 0.05
R^2	31.1%			
SILENT READING	*Estimate*	*SE*	*t Value*	*Pr(>|t|)*
intercept (L1)	0.86	0.02	38.10	$< 2e-16$
word frequency (L1)	-0.04	0.01	-70.87	$< 2e-16$
word frequency (L2)	-0.05	0.01	-5.73	< 0.001
participants (re)				$< 2e-16$
reading texts (re)				> 0.05
R^2	33.2%			

TABLE 2: GAM COEFFICIENTS FOR MODELS FITTING TOKEN TRACKING TIME AS A FUNCTION OF WORD (LOG)FREQUENCY IN INTERACTION WITH GROUPS, FOR ALOUD AND SILENT READING. PARTICIPANTS AND TEXTS ARE ADDED AS RANDOM EFFECTS (*re*).

and the accelerating effect of frequency are considered by reading modality for the two groups. Interestingly, in the L1 group, a different profile can be observed for the 2nd and 3rd graders as opposed to 4th and 5th ones. This pattern perfectly replicates the behavioural result reported in the literature (De Luca *et al.* 2008; Zoccolotti *et al.* 2005): the effect of length is stronger in the earliest stages of acquisition of reading skills, to then decrease starting from the 4th grade level. A similar effect may be observed for L2 children, with a less clear grouping effect for 2nd and 3rd school grades on the one side and 4th and 5th school grade on the other side.

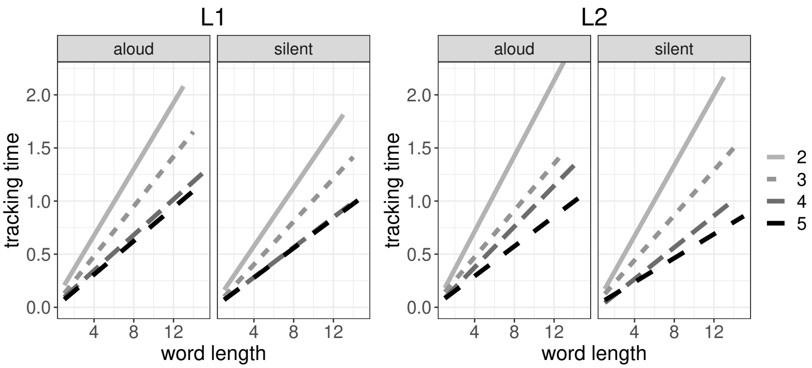

FIGURE 3: LINEAR REGRESSION PLOTS FOR TOKEN TRACKING TIME (IN SECONDS) AS A FUNCTION OF WORD LENGTH, GRADE LEVEL (FROM 2ND TO 5TH) AND READING MODALITY, FOR L1 (LEFT PANEL) AND L2 (RIGHT PANEL) CHILDREN.

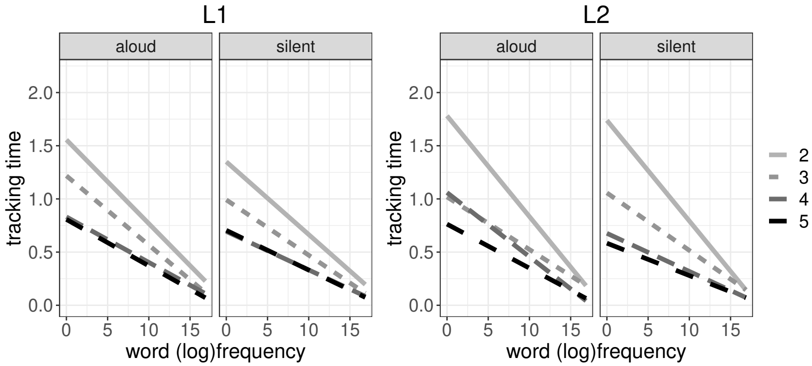

FIGURE 4: LINEAR REGRESSION PLOTS FOR TOKEN TRACKING TIME (IN SECONDS) AS A FUNCTION OF WORD LOG FREQUENCY, GRADE LEVEL (FROM 2ND TO 5TH) AND READING MODALITY, FOR L1 (LEFT PANEL) AND L2 (RIGHT PANEL) CHILDREN.

It is worth noting that, in the developmental perspective, the effects of word length and word frequency progressively decrease for increasing grade levels, in both reading modalities – see the regression models reported in Table 3 and Table 4, in particular the negative coefficient for the interaction of length and grade level, and the positive coefficient for the interaction of frequency and grade level. Once again, these results are consistent with the diminishing role that word length and word frequency are reported to play for increasing proficiency levels of reading (Burani *et al.* 2007; Zoccolotti *et al.* 2009; Davies *et al.* 2013).

Interestingly enough, lexical frequency and length effects do not seem to play a minor role in the reading of a connected text. A context-based effect of larger processing units is supposed to maximise fluency and to minimise reading effort and reading time. However, the effects reported here are comparable to those reported for words in isolation or in a small syntactic context of a single sentence (see among others, De Luca *et al.* 2008; Zoccolotti *et al.* 2009). In good accord with previous evidence, such an effect appears in our data to be an age-related developing ability emerging from increased exposure to written language and from increased reading ability.

3.3 Comprehension

The *finger-tracking* experimental protocol is comprehensive of a control for reading comprehension by administering a few multiple-choice questions at the end of each text episode – as described in Section 2.2. Notably, children of both L1 and L2 groups show a significant negative correlation between mean

ALOUD READING	*Estimate*	*SE*	*t Value*	*Pr(>|t|)*
intercept (L1)	0.09	0.07	1.30	> 0.05
word length (L1)	0.18	0.01	47.52	$< 2e-16$
word length (L2)	0.25	0.01	10.77	$< 2e-16$
word length * grade level (L1)	−0.02	0.01	−23.68	$< 2e-16$
word length * grade level (L2)	−0.01	0.01	−9.77	$< 2e-16$
participants (re)				$< 2e-16$
reading texts (re)				> 0.05
R^2	44.5%			
SILENT READING	*Estimate*	*SE*	*t Value*	*Pr(>|t|)*
intercept (L1)	0.11	0.07	1.49	> 0.05
word length (L1)	0.16	0.01	47.18	$< 2e-16$
word length (L2)	0.23	0.01	11.55	$< 2e-16$
word length * grade level (L1)	−0.02	0.01	−24.42	$< 2e-16$
word length * grade level (L2)	−0.02	0.01	−11.04	$< 2e-16$
participants (re)				$< 2e-16$
reading texts (re)				> 0.05
R^2	45.9%			

TABLE 3: GAM COEFFICIENTS FOR MODELS FITTING TOKEN TRACKING TIME AS A FUNCTION OF WORD LENGTH IN INTERACTION WITH GRADE LEVELS AND GROUPS, FOR BOTH READING MODALITIES. PARTICIPANTS AND TEXTS ARE ADDED AS RANDOM EFFECTS (*re*).

ALOUD READING	*Estimate*	*SE*	*t Value*	*Pr(>|t|)*
intercept (L1)	1.84	0.08	23.87	$< 2e-16$
word frequency (L1)	−0.09	0.01	−32.84	$< 2e-16$
word frequency (L2)	−0.13	0.01	−7.18	< 0.001
word frequency * grade level (L1)	0.01	0.01	15.62	$< 2e-16$
word frequency * grade level (L2)	0.01	0.01	5.93	< 0.001
participants (re)				$< 2e-16$
reading texts (re)				> 0.05
R^2	32.3%			
SILENT READING	*Estimate*	*SE*	*t Value*	*Pr(>|t|)*
intercept (L1)	1.72	0.08	21.79	$< 2e-16$
word frequency (L1)	−0.08	0.01	−31.56	$< 2e-16$
word frequency (L2)	−0.13	0.01	−11.63	$< 2e-16$
word frequency * grade level (L1)	0.01	0.01	15.65	$< 2e-16$
word frequency * grade level (L2)	0.01	0.01	10.93	$< 2e-16$
participants (re)				$< 2e-16$
reading texts (re)				> 0.05
R^2	34.9%			

TABLE 4: GAM COEFFICIENTS FOR MODELS FITTING TOKEN TRACKING TIME AS A FUNCTION OF WORD LOG FREQUENCY IN INTERACTION WITH GRADE LEVELS AND GROUPS, FOR BOTH READING MODALITIES. PARTICIPANTS AND TEXTS ARE ADDED AS RANDOM EFFECTS (*re*).

token reading/tracking time and accuracy in comprehension normalised in a $0-1$ range (p-value $< 2.2e-16$), as shown in Figure 5. Here, token tracking time is shown to get reduced for increasing scores of text comprehension, suggesting that reading speed and understanding ability are tightly connected issues in reading efficiency, in line with literature evidence on both children and adults (Bell 2001; Wallot *et al.* 2014). For a word to be read fluently, it needs to be memorised in the reader's mental lexicon with both its phonological and semantic representations. In such account, reading fluency, as part of a developmental process of decoding skills (Pikulski & Chard 2005), has been shown to correlate with reading comprehension in a developmental perspective (Pinnell *et al.* 1995), and in a bidirectional relationship supporting the idea that fluency facilitates comprehension and vice versa (Klauda & Guthrie 2008).

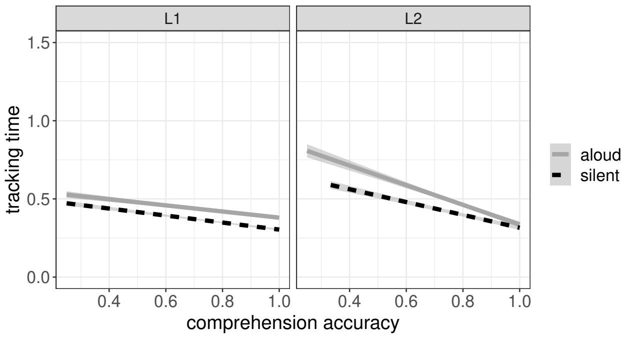

FIGURE 5: LINEAR REGRESSION PLOTS FOR TOKEN TRACKING TIME (IN SECONDS) AS A FUNCTION OF COMPREHENSION ACCURACY AND READING MODALITY, FOR L1 (LEFT PANEL) AND L2 (RIGHT PANEL) CHILDREN. SHADED AREAS INDICATE 95% CONFIDENCE INTERVALS.

Mean accuracy values for all graders are higher for L1 children than for L2 children in the aloud reading modality (respectively, 0.86 and 0.80, p-value $< 2.2e-16$ for the Welch t test); whereas there are comparable mean values in the silent reading modality (0.79 for both groups). Unsurprisingly, both L1 and L2 children show higher accuracies in comprehension when reading aloud: in fact, comprehension has been shown to be higher in oral reading as opposed to silently (Hale *et al.* 2007; Kim *et al.* 2011, 2014), although it requires additional cognitive resources to combine phonological decoding with prosody. In particular, it has been suggested that less skilled readers – be they early grade readers, dyslexic children or L2 children – may benefit from reading aloud as an attentional focus enhancing comprehension (Kragler 1995; Robinson *et al.* 2019), as well as a way to reinforce acquisition of grapheme-phoneme correspondence (Kuhn & Schwanenflugel 2007).

3.4 Word internal processing

To capture the serial processing of morphologically complex words, we shifted our attention from the word level to the *within*-word level. For each word in the texts, the *Readlet* infrastructure is able to align a touch-event to the bounding box coordinates of each character displayed on the tablet screen. Thus, it is possible to analyse speed changes within a word, and to take into account the predictive nature of word reading.

In Figure 6, non-linear regression plots for tracking time on symbols are shown as a function of the within-word symbol position and the reading modality, for L1 and L2 children. Notably, for both groups and for both reading modalities, we observe a serial decrease of symbol tracking times, suggesting that the reading pace for each word token tends to speed up when moving from the word onset to its end, as a predictive process – i.e. the ability to anticipate the end of a word as more of it is processed.

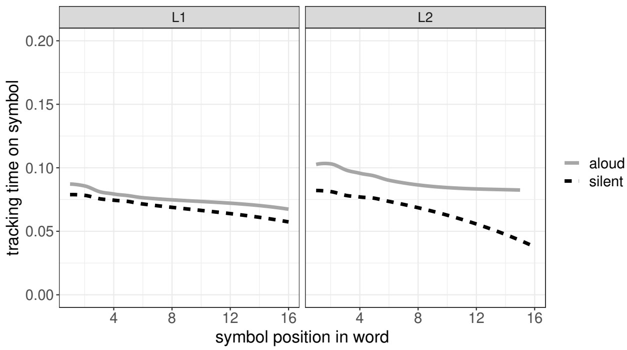

FIGURE 6: NON-LINEAR REGRESSION PLOTS FOR SYMBOL TRACKING TIME (IN SECONDS) AS A FUNCTION OF SYMBOL POSITION IN WORD AND READING MODALITY, FOR L1 (LEFT PANEL) AND L2 (RIGHT PANEL) CHILDREN.

Interestingly, there is no significant difference for L1 and L2 children in silent reading, whereas in aloud reading L2 children show a longer tracking time per symbol (p-value $< 2e-16$) but a greater accelerating effect (as confirmed by the negative slope, p-value < 0.05) as more of a word is processed.

In a developmental perspective, in Figure 7 tracking time on symbols is shown for grade levels for L1 and L2 children in both reading modalities. Here, for the 2nd graders, the non-linear tracking time is particularly evident, with an initial peak followed by a progressive acceleration (see the decreasing curve for incremental positions in the word), followed by a final incremental time on endings for very long words (for x values greater than 10). This confirms the difficulty for the youngest readers of our sample in reading long words, as already pointed out in Figure 3 for tracking time on the word level, in line with the developmental literature (among others, Kliegl *et al.* 2004; De Luca *et al.* 2008; Zoccolotti *et al.* 2009).

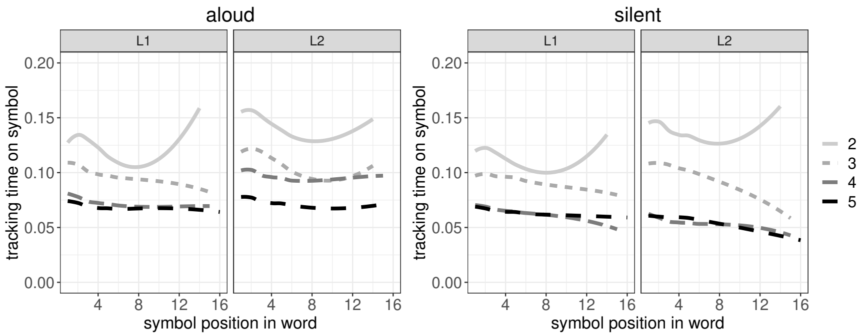

FIGURE 7: NON-LINEAR REGRESSION PLOTS FOR SYMBOL TRACKING TIME (IN SECONDS) AS A FUNCTION OF SYMBOL POSITION IN WORD, GRADE LEVEL (FROM 2^{ND} TO 5^{TH}) AND GROUPS, FOR ALOUD (LEFT PANEL) AND SILENT (RIGHT PANEL) READING MODALITIES.

At this stage of analysis, we focused on morphologically complex words, and in particular on verb forms only. To better analyse the non-linearity in tracking morphologically complex forms, we excluded from our data the shortest verb forms (length $1-3$), thus focussing on morphologically complex forms in the $4-15$ length range. In addition, each complex verb form has been manually segmented into stem+suffix patterns, with each symbol in the form being annotated for its relative position to the morpheme boundary (*MB* in the regression plots).[6] In Figure 8 the non-linear regression for symbol tracking-time on verb forms is presented for both groups and for the two reading modalities.

There is no significant difference in the reading profile of L1 and L2 children in the silent modality, as confirmed by a GAM fitted on symbol tracking time (p-value > 0.05). Conversely, there is a statistical significance in the aloud reading modality (p-value < 0.005), with a longer tracking time on symbol for L2 children.

Specifically, in the aloud modality, it should be noticed that L2 children show a more discontinuous pattern as compared to L1 ones. This serial reading strategy seems to suggest that L2 children may rely on a morphological processing for complex verb forms, with a first local minimum when a stem is recognised – as most of it is read – and a progressively reducing tracking

[6] Here, negative values index the verb stems and positive values index the inflectional endings, with 0 representing the first symbol of the ending.

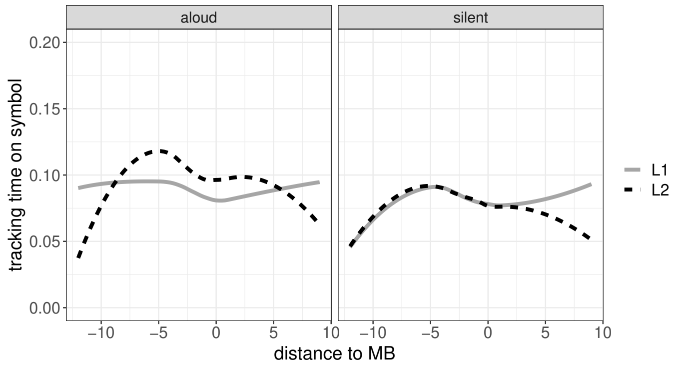

FIGURE 8: NON-LINEAR REGRESSION PLOTS FOR SYMBOL TRACKING TIME (IN SECONDS) ON VERB FORMS AS A FUNCTION OF THE DISTANCE TO THE MORPHEME BOUNDARY (*MB*) AND GROUPS, FOR ALOUD (LEFT PANEL) AND SILENT (RIGHT PANEL) READING MODALITIES.

time as more of the inflectional ending is read. Additionally, this discontinuous tracking pattern for morphologically-complex verb forms can be evaluated by measuring the time-lag at the morpheme boundary. In detail, for each verb form and for each child, we calculated the difference between the tracking time for the last character of stems and the tracking time for the first character of their inflectional ending. For the aloud reading modality, the distribution of lags between the two experimental groups are statistically different (p-value $< 2.2e-16$), with a positive value for L2 children (mean of lag $= 0.0003$) denoting an additional tracking-time on the first character of a suffix given the tracking-time on the last character of its stem. Conversely, L1 children show a negative value (mean of lag $= -0.009$) suggesting the progressive decreasing tracking-time as more of a print word is processed.

The progressively decreasing time observed in L1 children may account for an efficient anticipatory strategy in processing morphologically-complex words while reading a connected text. Here, effects of semantic integration and syntactic prediction are, in fact, required to interact to capture the general content of the text, as well as to retrieve word meaning from the context.

4. DISCUSSION AND CONCLUDING REMARKS

The current analysis shows that our sample of Italian L2 children presents higher reading time as compared to L1 school-grade peers, as well as slightly – though statistical significant – lower accuracy scores on comprehension. Notably, in a developmental perspective, reading pace results progressively less affected by word length and word frequency in both groups, with a clear break starting from the 4th school grade for L1 – as widely reported by the literature on highly transparent orthographies such as Italian (e.g., among many others, Burani *et al.* 2007; Zoccolotti *et al.* 2009). The same break is not shown by L2 children.

Both groups present higher tracking time in the aloud reading modality than in the silent one, since oral reading demands of additional cognitive resources for speech planning, articulation and eye-voice coordination (Vorstius *et al.* 2014). Notably, from our results, the aloud reading task seems to be a great challenge for our L2 children – more than L1 ones. Interestingly, however, results suggest a segmentation strategy adopted by L2 children as a way to alleviate the cognitive additional load due to the overt articulation of morphologically complex words. In fact, morpheme detection has been suggested as a way to improve fluency and accuracy in reading new or unfamiliar complex words (Burani 2010; Deacon *et al.* 2014). A sub-lexical reading strategy may rely on a morphemic processing when a lexical reading strategy is not viable and a context-based anticipatory strategy seems to fail. Accordingly, morphological awareness plays a crucial role for improving both accuracy and fluency in reading, in line with evidence reported for languages either with a shallow orthography or with an irregular phoneme-grapheme mapping (de Freitas *et al.* 2018; Marcolini *et al.* 2011).

From a theoretical perspective, our experimental evidence does not necessarily imply that morphemes represent a formal, fundamental unit of processing during a reading task – be it either aloud or silent. Rather, a morphological segmentation strategy that is usefully applied to support the processing load during a reading task of long, morphologically complex word forms – especially in the case of an oral reading task – implies a notion of morphological competence as a by-product emerging from language processing and learning (in line with Marelli *et al.* 2020).

From a methodological perspective, the focussing on word reading in context – as opposed to reading individual words in isolation – sheds light on the mutual interaction of word length, word frequency and morphological complexity with grade levels from a finer-grained perspective, as well as on how they affect access to the content of the whole text. There is, in fact, growing awareness that reading is grounded in more dynamic cognitive units than simple words, with both sub-lexical constituents and supra-word units having an effect on processing (see, among others, Snell & Grainger 2017; Yang *et al.* 2020).

Finally, the innovative *finger-tracking* protocol adopted for our experimental campaign proved to replicate established benchmark effects reported in the psycholinguistic literature on reading in a shallow orthography like Italian. By being able to capture the serial processing of morphologically complex words at the single character level, it was possible to analyse the word internal processing and its variability as a functional processing of morphological structure. In acknowledging the limitations of the present work, due to both the small number of children that took part in the pilot study and the uneven size of the two sample groups, we strongly believe that a large-scale assessment of reading abilities through the *Readlet* protocol would be of help in monitoring the development of efficient reading strategies in L2 children.

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