Rev. Estud. Ling., Belo Horizonte, v. 31, n. 3, p. 1447-1484, 2023.

Morphological Processing in Developing Readers: A Systematic Review

Processamento morfológico em leitores em desenvolvimento: uma revisão sistemática

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Abstract: This study investigated morphological processing in developing readers and which factors can modulate this process. Following the PRISMA guidelines, the search was carried out in the Web of Science, Scielo and PsycInfo databases, with no time limits. A total of 192 studies were identified. After the eligibility criteria were applied, 34 articles were included in the final sample, including 28 articles from the references of the sample studies. There is evidence that morphological processing occurs, in different languages, around eight years old, with discrepancies depending on individual, linguistic and psycholinguistic variables. Our findings suggest that, initially, morphological decomposition may be restricted to those complex words where there is orthographic and phonological overlap with another monomorphemic word, with activation of the latter driving the decomposition process. The study contributes to a better understanding of how morphological processing occurs during visual word recognition in children, identifying and discussing variables that can modulate this process. We hope that the results of this study can guide future research on the development of reading.

Keywords: morphological processing; visual word recognition; morphological decomposition; reading; morphology.

eISSN: 2237-2083 | DOI: 10.17851/2237-2083.31.3.1447-1484

Resumo: Este estudo investigou o processamento morfológico em leitores em desenvolvimento e quais fatores podem modular este processo. Seguindo as orientações PRISMA, a busca foi realizada nas bases de dados Web of Science, Scielo e PsycInfo, sem delimitação de tempo. Um total de 192 estudos foram identificados. Após os critérios de elegibilidade serem aplicados, 34 artigos foram incluídos para a amostra final, com a inclusão de 28 artigos a partir das referências dos estudos da amostra. Há evidências de que o processamento morfológico ocorra, em diferentes idiomas, por volta dos oito anos de idade, havendo discrepâncias a depender de variáveis individuais, linguísticas e psicolinguísticas. Nossos achados sugerem que, inicialmente, a decomposição morfológica pode estar restrita àquelas palavras complexas em que há sobreposição ortográfica e fonológica com outra palavra monomorfêmica, com a ativação desta última conduzindo o processo de decomposição. O estudo contribui para a melhor compreensão de como ocorre o processamento morfológico durante o reconhecimento visual de palavras em crianças, identificando e discutindo variáveis que possam modular esse processo. Esperamos que os resultados deste estudo possam orientar pesquisas futuras sobre o desenvolvimento da leitura.

Palavras-chave: processamento morfológico; reconhecimento visual de palavras; decomposição morfológica; leitura; morfologia.

Recebido em 15 de março de 2023.

Aceito em 28 de julho de 2023.

1 Introduction

Most words we encounter daily are composed of meaningful units, known as morphemes, which help in understanding the meaning of the words. For example, “teacher” consists of the morphemes “teach” and “-er”. Children reading such words rely on morphological processing, which aids in word recognition, enhancing accuracy and reading fluency. Gaining insights into the development of morphological processing can inform effective teaching strategies that enhance reading abilities. Morphological processing can be defined as the implicit use of the morphological structures of words during reading (Law *et al.*, 2018) and has been the subject of many investigations in recent decades (cf. Amenta; Crepaldi, 2012). Studies on morphological processing in reading usually employ reading aloud isolated words, lexical decision and priming tasks. In lexical decision tasks (LDTs), the participant is asked to indicate whether the stimulus presented on a computer screen is a word or not. Priming tasks, in turn, involve the brief presentation of a

prime and the subsequent presentation of a target stimulus. In this task, the time interval between the prime and the target can be manipulated in such a way that the prime is not consciously perceived, using intervals of approximately 50 ms or longer intervals that facilitate its conscious detection (Oliveira; Justi, 2017).

Studies using priming have shown that in adult readers, morphological decomposition occurs in the early stages of reading (cf. Amenta; Crepaldi, 2012; Rastle; Davis, 2008). This decomposition would be based on orthographically defined morphemes because, in addition to facilitation being observed when the prime-target pair is composed of morpho-semantically related words (e.g. farmer - FARM), facilitation is also observed for pairs that do not share a morpho-semantic relationship but have a pseudo-suffix. For example, in the pair corner - CORN, the –er in "corner" is a pseudo-suffix that would elicit the morphological decomposition. Importantly, this facilitation for pseudo-suffix pairs is higher than that observed for pairs with only an orthographic overlap (e.g. cashew - CASH) in which the final sequence of letters of the prime is not a morphological structure. Given this, Rastle and Davis (2008) propose that morphological processing in reading occurs in two hierarchical stages, with the first characterized by morpho-orthographic decomposition (which is blind to the morpho-semantic nature or pseudo-suffix nature of the primes) and the second related to morpho-semantic decomposition.

Despite the results for adult readers, some studies suggest that this effect is not observed in developing readers who exhibits a priming effect only for morpho-semantically related word pairs (Beyersmann *et al.*, 2015; Beyersmann; Castles; Coltheart, 2012; Hasenäcker; Beyersmann; Schroeder, 2016). It is therefore possible that in beginning readers, the morpho-orthographic patterns are not fully developed and do not allow morpho-orthographic decomposition in the early stages of word recognition. Other studies, however, have suggested that developing readers may exhibit some level of sensitivity to morphological structures. In a study by Burani, Marcolini and Stella (2002), children between the ages of 8 and 10 who speak Italian, a language with transparent grapheme-phoneme regularity, were asked to read pseudowords formed by morphemes (e.g. donnista, "womanist") and pseudowords with no stem or suffix (e.g. dennosto) as well as to perform a lexical decision task with pseudowords constructed in the same way as in the naming task. The authors observed that pseudowords constituted by morphemes were more often classified as

real words and named more quickly and accurately than were pseudowords without morphological structures. These results suggest that children may, to a certain extent, possess representations of morphological structures and use these representations during visual word recognition, a hypothesis that has been supported by the findings of other studies (Beyersmann; Grainger; Castles, 2019; Casalis; Quémart; Duncan, 2015; Dawson; Rastle; Ricketts, 2018; Hasenäcker; Schröter; Schroeder, 2017; Lázaro *et al.*, 2017).

Regarding the development of morphological processing, the results of the study by Hasenäcker, Schröter and Schroeder (2017) are of particular interest. The authors gave a lexical decision task to a sample of German-speaking 2nd, 3rd, 4th and 6th grade children and to adults, using 1,152 words classified into monomorphemic (e.g. lantern), compound (e.g. sunflower) and derived (e.g. farmer) words, which were further divided into prefixed and suffixed words. For the purposes of the lexical decision task, 1,152 pseudowords divided into the same categories as the real words were added. A facilitation effect was observed for compound words compared to monomorphemic words by the end of 2nd grade, indicating that by this age, children would exhibit a sensitivity to stems present in words. Furthermore, compared to the monomorphemic condition, a facilitation effect was observed for suffixed words by the end of 3rd grade and for prefixed words by the end of 4th grade. These results support the hypothesis of a sequential order for the emergence of morphology effects on word reading: first the stem effect, followed by the suffix effect and then the prefix effect. This development may be interconnected with reading acquisition because as children progress through grade levels, their access to morphologically complex words increases.

Nevertheless, the findings by Hasenäcker, Schröter and Schroeder (2017) may not be universal, as a study by Mousikou et al. (2020) provides evidence that sensitivity to morphology may vary according to the level of transparency of the language. The authors created four groups of pseudowords that varied in their morphological structure, namely, stem + suffix (e.g. nightness), stem + non-suffix (e.g. nightlude), non-stem + suffix (e.g. nishtness) and non-stem + non-suffix (e.g. nishtlude). English-, French-, German- and Italian-speaking 3rd grade children were asked to read aloud the items appearing on the screen as quickly and as accurately as possible. The results showed that the stem and suffix effects were greater in English-speaking children than in French, German and Italian speakers,

indicating that the consistency of the letter-sound relationship may interfere with the extent to which morphology is used when reading aloud.

The edge-aligned embedded word activation mechanism, described by Grainger and Beyersmann (2017), suggests that the initial factor for the morpho-orthographic segmentation process is the activation of stems embedded in words. Accordingly, words such as "farmer" and "corner" would activate both their respective representations as well as those of the words embedded in them, in this case, "farm" and "corn". Grainger and Beyersmann propose a developmental perspective for morphological processing in four stages. Initially, reading would occur through grapheme-phoneme conversion, which according to the self-teaching hypothesis[1] (Share, 1995, 1999) would enable the acquisition of detailed orthographic representations of each successfully decoded word. Free stems (e.g. farm) would be learned before the derived forms (e.g. farmer), such that when the orthographic representations of the latter were established, they would facilitate the activation of the stem embedded in the word with which the child would already be familiar, and this would be the starting point of morpho-orthographic segmentation. Subsequently, the formation of orthographic representations of affixes for morphologically complex words with a semantically transparent relationship would occur (e.g. -er, in teach/teacher). Finally, the influence of these affix representations would also be observed in words that appear to have a morpho-orthographic structure but have no real morphological relationship (e.g. corner – corn). However, the orthographic representations of affixes that enable morpho-orthographic segmentation in the early stages of visual word recognition in adults (Amenta; Crepaldi, 2012; Rastle; Davis, 2008) would not be present in beginning readers but would develop as they accumulate experience with reading (Rastle, 2019).

Although the information presented above indicates an increased interest in studies on morphological processing in children, the extent to which morphology is used during visual word recognition in children and when the patterns observed in skilled readers become stable in developing readers are not yet known. Moreover, it has been suggested that the grapheme-phoneme regularity of writing systems influences the

[1] According to the self-teaching hypothesis (Share, 1995), phonological decoding (print-to-sound translation) would have a self-teaching function because, after each successful decoding, the reader would have the opportunity to establish a detailed orthographic representation of the decoded word.

development of morphological processing in children (Mousikou *et al*., 2020). Accordingly, this research aims to answer the following questions: How does morphological processing occur in developing readers, and what factors can modulate this process? By addressing these questions, the present study carried out a systematic review of studies on morphological processing in children following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher *et al.*, 2009). The methodology used in the systematic review is presented in the method section. Afterwards, it was decided to present the results and the discussion in a single section that was subdivided according to the following evaluated effects: a) surface frequency, base frequency, morphological family size and family frequency effects; b) allomorphy and morphological processing; c) presence of morphological structures; d) individual and linguistic variations and; e) morpho-orthographic processing in children.

2 Method

The PRISMA guidelines (Moher *et al*., 2009) were adopted to carry out this systematic review. The search was conducted using the Web of Science, PsycINFO (American Psychological Association) and SciELO databases until January 2022. The following set of terms were used for the searches: "morphological processing" OR "morpho-orthographic priming" OR "morphological decomposition" OR "compound word processing" OR "embedded stems" OR "embedded stems priming" AND "masked priming" OR "word recognition" OR "visual word recognition" OR "visual priming" OR "lexical decision" OR reading AND "school-age" OR children OR "developing readers" in the title, keyword and abstract fields. These terms were selected from the keywords and/or titles of the articles consulted when constructing the objectives of the present review.

The following inclusion criteria were adopted: a) empirical studies published in English, Portuguese or Spanish; b) studies with participants between 7 and 12 years old; and c) studies that employed visual word recognition tasks. The decision was made to restrict the age range to 12 years, as after four years of experience with reading, the eye movements of children already resemble those observed in adults, except for the greater number of regressions performed by children (Rayner; Juhasz; Pollatsek, 2013). As to the exclusion criteria, the following were adopted: a) studies with participants with atypical development or learning disorders; b)

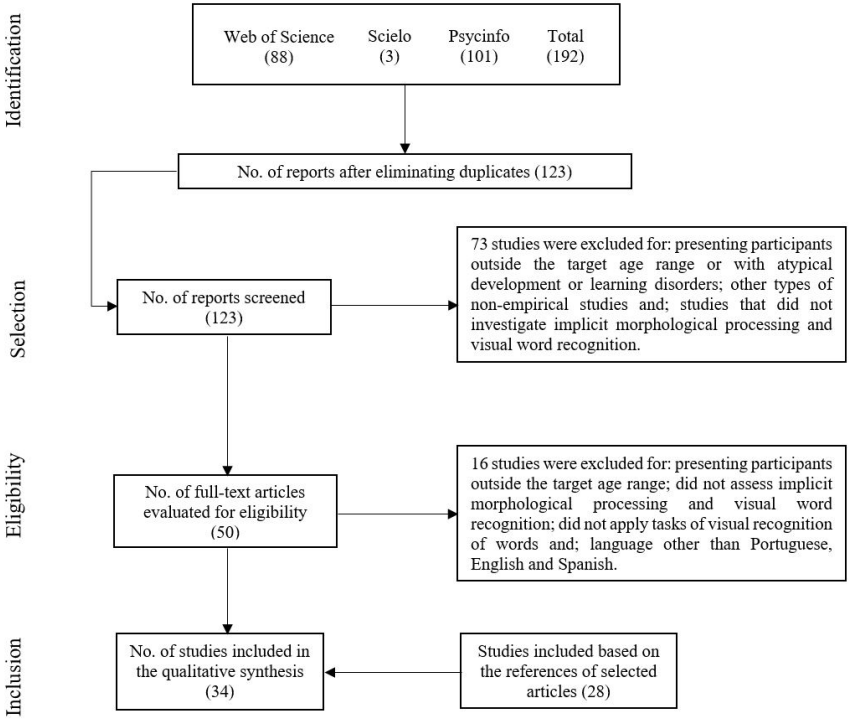
studies that did not report how the stimuli and tasks were constructed and manipulated; and c) no full text available. Duplicate studies were excluded.

After applying the inclusion and exclusion criteria, the sample of studies for the qualitative synthesis was defined. As recommended by Siddaway, Wood and Hedges (2019), the references of the studies found in the electronic database searches that were eligible for inclusion were analyzed, as the searched databases may not contain all of the published papers, and thus, some studies may not be retrieved. The inclusion of studies identified by consulting the references was based on the same inclusion and exclusion criteria adopted above. The analysis and discussion of the studies that compose the final sample focused on the place and date of publication, objectives, sample, stimuli and tasks employed, and results found.

3 Results and discussion

After reading the title, abstract and keywords, 50 articles were selected to be read in full. Upon reading the full text, 34 articles were selected, including 28 papers from the references of the studies selected to compose the sample. The steps performed can be seen in Figure 1.

Figure 1 – Flow Chart of Selection Process for Eligible Studies



Source: Elaborated by the authors.

Studies in 11 different languages were identified, including three cross-linguistic studies (Beyersmann *et al*., 2021; Casalis; Quémart; Duncan, 2015; Mousikou *et al.*, 2020), which compared two or more languages simultaneously. Despite the variety of languages, the majority of studies were conducted with speakers of English (20.97%), followed by Spanish (14.51%) and Italian (14.51%). There is also a high concentration of studies conducted on the European continent, accounting for 72.58% of the studies in the sample, with North America representing 9.68% and Latin America representing 6.45% of the studies.

Table 1 – Number of Studies by Language

Language	Frequency
German	5
Basque	1
Bosnian	1
Danish	1
Spanish	9
French	7
Hebrew	4
Dutch	8
English	13
Italian	9
Portuguese	1
Translinguistic*	3
Total	62

Note. *3 studies involved more than one language: 1) English and French (Casalis; Quémart; Duncan, 2015); 2) German and French (Beyersmann *et al.*, 2021) and; 3) German, French, English and Italian (Mousikou *et al.*, 2020).

Source: Elaborated by the authors.

As for the tasks employed, 23 of the studies used the reading aloud task, 15 used the lexical decision task, 18 used the lexical decision task or reading aloud with priming, four used the lexical decision task and the reading aloud task and two used the semantic categorization task. In the latter task, the items are presented in a specific block of a given semantic category (e.g. animals, body parts, household items, vehicles or clothing). The category is presented at the beginning of each block. Participants must indicate whether or not the presented word is part of the semantic category of the block (e.g. category: animal, item: CROWN, where the embedded word CROW would be activated, leading the participant to exhibit a longer reaction time for this item) (Hasenäcker; Solaja; Crepaldi, 2021; Nation; Cocksey, 2009).

With regard to the participants, in addition to children in the age range targeted by the present review, the studies evaluated children with a hearing impairment (n = 2) and reading deficits/difficulties (n = 16) as well as adolescents (n = 8) and adults (n = 20), mostly university students, who were intended to compose a control group. As for the experimental conditions and manipulations, in addition to the presence or absence of a morphological structure in the stimuli, variables such as surface frequency, base frequency, morphological family size and phonological and orthographic transparency were also manipulated.

The primary objective of this systematic review was to evaluate the results of the studies that investigated morphological processing in developing readers and variables that influence this process. Next, we will address these variables and their implications for the visual recognition of morphologically complex stimuli. Finally, we will present the main findings concerning morphological and morpho-orthographic processing during visual word recognition in children.

3.1 Surface frequency, base frequency, morphological family size and family frequency effects

The frequency effect, in which higher frequency words are processed more efficiently than lower frequency words, was first described eight decades ago and has been demonstrated in reading aloud, lexical decision and semantic decision tasks (Brysbaert; Mandera; Keuleers, 2018). Nevertheless, a phenomenon cited by Brysbaert, Mandera and Keuleers (2018) as a challenge to the frequency effect is the fact that some low frequency words are responded to quickly and accurately. Among this set of words are items that are related to other words by inflection, derivation and composition, such that their recognition could be accomplished through their decomposition. This brings us to the discussion regarding the frequency effects of the root/base of a derived word. In the present study, root is defined as the nuclear morpheme, which is the irreducible element that concentrates the meaning of the word common to all words in the same morphological family (Gonçalves, 2019), such as farm, a root of words like farmer and farming. Roots that are well represented in memory would facilitate the recognition of words from the same morphological family (Carlisle; Katz, 2006), and thus, one would expect that words in which the root has a high frequency

would be recognized more easily. However, review studies have shown that the root frequency effect in children tends to manifest itself only in low frequency words (Angelelli; Marinelli; Burani, 2014;Angelelli *et al*., 2017; Deacon; Francis, 2017; Deacon; Whalen; Kirby, 2011; Lázaro; Camacho; Burani, 2013; Marcolini *et al*., 2011; Suárez-coalla; Martínez-garcía; Cuetos, 2017; Verhoeven; Schreuder, 2011), with this effect appearing in children with a mean age of 8.92 years in English (Deacon; Francis, 2017) and Dutch (Verhoeven; Schreuder, 2011), 8.65 years in Italian (Angelelli; Marinelli; Burani, 2014) and 7.8 years in Spanish (Lázaro; Camacho; Burani, 2013). One possible explanation for this is that high frequency words already have well-established orthographic representations in the lexicon, enabling them to be accessed quickly and accurately. Conversely, low frequency words would not have such well-established representations and thus could benefit from their constituents in order to facilitate access to their meaning (D'Alessio; Wilson; Jaichenco, 2019).

Accordingly, as Carlisle and Katz (2006) suggest, to understand the impact of morphology on the recognition of derived words, it is important to consider not only word frequency but also root frequency as well as morphological family size (number of words derived from a root) and average family frequency, as each would contribute to morphological processing in a different way. However, the results of the studies in our review indicate mixed findings for the morphological family size effect on reading time and accuracy, with facilitation effects on reaction time being observed in children in 2nd (mean age = 8.1 years) but not 4th (mean age = 10.1 years) grade in Dutch (Perdijk *et al.*, 2012), higher reading accuracy in children in 4th and 6th grades in English (Carlisle; Katz, 2006) and no contribution to reaction time in children with a mean age of 11.7 years in Italian (Burani *et al.*, 2018). The morphological family size effect should be viewed with caution, both because of the number of studies that aimed to evaluate the morphological family size and average family frequency effects and because of the age groups investigated (only the study of Perdijk *et al.*, 2012 evaluated children at the beginning of literacy) but primarily due to the lack of control over the base frequency of the words used. As shown by the study by Deacon and Francis (2017), with children in 3rd and 5th grades, only the base frequency effect contributed to reading accuracy, independent of the number of orthographic neighbors of the word and root, word frequency,

family size and family frequency. According to the authors, this suggests that exposure to the base word would influence the development of sensitivity to morphological patterns in reading.

In short, we observed that children around the age of eight also exhibit the frequency effects observed in adult readers, with base frequency facilitation effects also appearing in this period, but only when the word frequency is low. These findings may indicate access to morphological constituents during lexical access, such that frequent bases would have a well-established orthographic representation, thus aiding in the visual recognition of infrequent words. Another hypothesis would be that the use of morphological constituents would facilitate lexical access to infrequent words due to greater feedback from the semantic system because multiple units could be activated by the base/root, such that words with a larger morphological family size would be responded to more quickly and accurately. However, it is not possible to determine whether this effect is real, given the mixed results found as well as the small number of studies and the lack of control over the base frequency.

3.2 Allomorphy and morphological processing

Derived words may or may not present orthographic and/or phonological alterations in relation to their base, for example, divide/division and direct/direction. This phenomenon is called allomorphy and occurs when a morpheme can be represented by phonetically different forms, which may occur in prefixes, nominal and verbal bases, suffixes, inflections and other morphological types (Gonçalves, 2019). Studies with adults suggest that these alterations do not interfere with morphological processing during visual word recognition (Crepaldi *et al.*, 2010; Mccormick; Rastle; Davis, 2008). This may occur because experienced readers have had numerous encounters with derived words that exhibit orthographic alterations but have relationships of morphology and meaning, enabling them to abstract the relationship between the root and the derived word, whereas for children this relationship may be more difficult to identify due to the small number of exposures to written words (Lázaro; García; Burani, 2015).

The results of this review tend to support the above position, with children in 3rd grade who speak English (Carlisle, 2000; Mann; Singson, 2003), French (Quémart; Casalis, 2014) and Spanish (Lázaro;

García; Burani, 2015) reading more accurately and exhibiting shorter reaction times for derived words that do not present orthographic and/or phonological alterations in relation to the root. However, some observations must be made. In a study by Deacon, Whalen and Kirby (2011), in 4th grade children, no orthographic/phonological transparency effect was observed for words with a high frequency base, unlike what was observed for low frequency words, when words without orthographic/phonological alterations in relation to the base were read more accurately. This may have occurred because high frequency words have a well-established representation in the lexicon that is accessed automatically, and there is no time for it to experience the effects of the morphological decomposition of its constituents. Furthermore, in a study by Quémart and Casalis (2015), although the group of children (mean age = 9 years and 8 months) exhibited the transparency effect (priming only in the morphological condition without phonological and orthographic alterations), the group of adolescents (mean age = 13 years and 1 month) exhibited priming for both the morphological conditions without alterations and the morphological condition with only phonological alterations but not for the condition with phonological and orthographic alterations. In comparison, the group of adults exhibited priming effects in all these conditions.

The embedded word activation model proposed by Grainger and Beyersmann (2017), cited in the introduction of this paper, assumes that the initial stage of morpho-orthographic processing would occur through the activation of embedded bases, which are learned in their free forms and form orthographic representations resulting from repeated decoding. These orthographic representations would be activated during the reading of complex words that contain them. What we observed, however, is that embedded word activation in the early years of literacy seems to be influenced by whether or not there are orthographic and/or phonological alterations in relation to the base. This assumption may explain the results observed by Quémart and Casalis (2014) in 3rd, 4th and 5th grade children, who demonstrated the orthographic/phonological transparency effect during short exposures (60 ms) to the derived word but not in long exposures (250 ms). This may have occurred because the children have not yet established flexible orthographic representations of the base, such that embedded word activation in the early stages of visual recognition is dependent on orthographic and phonological overlaps. In later stages,

it is possible that children use morpho-semantic representations to facilitate target word recognition. As children age, they may establish more flexible base representations, which coupled with the emergence of affix representations enable the activation of bases embedded in allomorphs. Another explanation proposed by the authors, which aligns with our own, suggests that two processing routes are initially activated in parallel: a morpho-orthographic and a morpho-semantic procedure. The morpho-orthographic procedure is faster in processing the form properties of morphemes, but its effectiveness depends on the degree of orthographic and phonological overlap between the prime and the target. On the other hand, the morpho-semantic procedure operates on semantic representations and can be activated both in the presence of phonological and orthographic changes, but its effects are observed only in the later stages of recognition.

The results seem to indicate that in the early years, children perform morphological decomposition processes based primarily on orthographic overlap between the derived word and its root, such that phonological and orthographic alterations would prevent the decomposition of the derived word into its constituents, thus observing the role not only of orthography but also the influence of phonology during the early stages of visual word recognition. As the child progresses through grade levels and has more exposure to written words, they would form more flexible representations of the base and establish relationships between different members of the same morphological family, including members with phonological and orthographic alterations, which would enable decomposition in the early stages independent of orthographic and phonological overlap, similar to what is observed in experienced readers. Nevertheless, we observed, as in the previous section, that few studies sought to investigate the role of phonological and orthographic alterations in the recognition of complex words. In addition, of the seven studies that addressed this topic, only three adopted a cross-sectional methodology, evaluating children from different school grades, including 2nd or 3rd grade, making it impossible to draw solid conclusions about the influences of base alterations on visual word recognition throughout development.

3.3 Presence of morphological structures

As Levesque, Breadmore and Deacon (2021) suggest, there are two essential reasons why morphemes can provide useful building blocks for reading words. The first would be the fact that they enable direct access from writing to meaning, while the second would be that morphemes carry multidimensional information, acting as a glue between phonology, orthography and meaning. Morphemes could therefore lead to a more accurate and faster reading of words constituted by them because they would provide representations with overlapping phonological, orthographic and semantic information.

The results observed in the review largely demonstrate the facilitation effect of morphological structures on the visual recognition of morphologically complex words in different languages. These effects were shown in reading aloud tasks as higher reading accuracy and speed for morphologically complex words than for monomorphemic words and pseudowords composed of morphemes than for pseudowords without morphemic constituents beginning in the 3rd grade in English, French, Italian, Spanish, German and Basque (Angelelli *et al.*, 2017; Angelelli; Marinelli; Burani, 2014; Antzaka *et al*., 2019; Burani *et al*., 2008; D'Alessio; Jaichenco; Wilson, 2018; Laxon; Rickard; Coltheart, 1992; Marcolini *et al*., 2011; Mousikou *et al*., 2020; Suárez-coalla; Cuetos, 2013; Suárez-coalla; Martínez-garcía; Cuetos, 2017; Traficante *et al.*, 2011). This effect was also evident in the choice of how to pronounce ambiguous letter sequences, i.e. those that could be read in more than one way, during the reading aloud of pseudowords in Dutch and Hebrew beginning in the 3rd grade (Bar-on; Ravid, 2011; Verhoeven; Schreuder; Baayen, 2003; Verhoeven; Schreuder; Haarman, 2006).

In LDTs, it was observed that participants had a shorter reaction time and higher accuracy for morphologically complex words than morphologically simple words and a longer reaction time and lower accuracy for pseudowords constituted by morphemes than pseudowords not constituted by morphemes starting at the age of eight in English, Spanish, French, Dutch, Italian and German (Assink; Vooijs; Knuijt, 2000; Burani; Marcolini; Stella, 2002; Carlisle; Stone, 2005; Casalis; Quémart; Duncan, 2015; D'Alessio; Wilson; Jaichenco, 2019; Dawson; Rastle; Ricketts, 2018; Duncan *et al.*, 2011; Hasenäcker; Schröter; Schroeder, 2017; Jaichenco; Wilson, 2013; Quémart; Casalis; Duncan, 2012; Van Hoogmoed *et al.*, 2011; Verhoeven; Schreuder, 2011). Importantly,

this effect occurred even in studies that controlled for word frequency, length and number of orthographic neighbors. Furthermore, most studies controlled for these variables, extending even further to others such as base and affix frequency and bigram frequency, with some studies also controlling for the number of phonological neighbors, concreteness, trigram frequency, age of acquisition and morphological family size.

As for the semantic categorization tasks, a lower accuracy and longer reaction time were observed in 7- and 8-year-old children when the embedded word was congruent with the semantic category of the block, for example, when the stimulus was the word SHIP (which contains the sequence HIP) and the block was of words related to body parts compared to when it was related to animals (Hasenäcker; Solaja; Crepaldi, 2021; Nation; Cocksey, 2009). In these tasks, it is important to observe variables such as frequency and embedded word frequency because these can affect reaction time. Items that present low surface frequency but high embedded word frequency may produce results that are difficult to interpret because it is difficult to identify whether the interference effect was due to the activation of the embedded word through its morpho-orthographic representations or due to its greater familiarity. Another important factor is the phonological similarity between the stimulus and the embedded word, as items that have the same pronunciation as the embedded word may result in the activation of the latter through phonological retrieval, i.e. lexical access to the embedded word would be mediated by phonology. That being said, we observed that in the study by Nation and Cocksey (2009) that included the role of these variables in its analysis, a greater effect was observed when the embedded word was high frequency than when it was low frequency, but no statistically significant difference was observed. Furthermore, there was no difference between items that shared or did not share a pronunciation with the embedded word, suggesting that the activation of semantic representations of the embedded word is independent of phonology and can be accessed directly through orthography.

Finally, with regard to the tasks that used priming, facilitation was observed in the early stages of visual recognition, when the prime and target words were morphologically related in terms of an orthographic condition and a control where the prime and target words were not related at all (Beyersmann; Castles; Coltheart, 2012; Casalis *et al.*, 2009; Casalis; Quémart; Duncan, 2015; Dawson; Rastle; Ricketts, 2021; Duranovic

et al., 2020; Fleischhauer; Bruns; Grosche, 2021; Law; Ghesquière, 2021; Lázaro *et al.*, 2018; Oliveira; Justi, 2017; Quémart *et al.*, 2011; Quémart; Casalis, 2015; Schiff; Raveh; Fighel, 2012; Schiff; Raveh; Kahta, 2008), with studies reporting this effect in children as early as the 3rd (Beyersmann; Castles; Coltheart, 2012; Fleischhauer; Bruns; Grosche, 2021; Quémart; Casalis, 2014; Quémart; Casalis; Colé, 2011; Schiff; Raveh; Kahta, 2008) and 4th grade (Duranovic *et al.*, 2020; Schiff; Raveh; Fighel, 2012). However, some studies have observed effects only beginning in the 5th grade (Lázaro *et al*., 2018; Oliveira; Justi, 2017). With regard to the morpho-orthographic condition, studies observed a facilitation effect in relation to an orthographic and control condition in children aged approximately 9 (Dawson; Rastle; Ricketts, 2021; Quémart; Casalis, 2015; Quémart; Casalis; Colé, 2011) and 10 years old (Fleischhauer; Bruns; Grosche, 2021; Law; Ghesquière, 2021).

Nevertheless, we should make an observation about the tasks that used priming. When we evaluate morphological processing in priming tasks, we must keep in mind that the prime-target pairs used in the morphological condition, which are usually related through a derivation process (e.g. farm – farmer), share not only a morphological relationship but also a semantic and orthographic relationship, and thus, when we observe facilitations in the visual recognition of the target word, it is difficult to determine whether this facilitation occurred because of the morphological structure, because of the semantic relationship or simply because of the orthographic similarity between the stimuli. As such, to investigate the role of morphological processing, it is important to also use an unrelated control condition (e.g. program – boot), a condition with a purely semantic relationship (e.g. bee – honey) and one with a purely orthographic relationship (e.g. spinach – spin). Based on this observation, we note that although all the studies employed the orthographic and unrelated conditions, only four studies employed all the conditions mentioned (Fleischhauer; Bruns; Grosche, 2021; Law; Ghesquière, 2021; Quémart; Casalis, 2015; Quémart; Casalis; Colé, 2011), of which only the studies by Fleischhauer, Bruns and Grosche (2021), Quémart and Casalis (2015) and Quémart, Casalis and Colé (2011) assessed children in different school grades. Only the study by Fleischhauer, Bruns and Grosche (2021) evaluated children in 1st, 2nd, 3rd and 4th grades, finding morphological priming effects beginning in 3rd grade (mean age = 9.83 years) and morpho-orthographic priming effects beginning only in 4th

grade (mean age = 10.52 years). As for the two other studies (Quémart; Casalis, 2015; Quémart; Casalis; Colé, 2011), which observed children at approximately 9, 11 and 12 years of age, morphological and morpho-orthographic priming effects were observed at all ages. However, while the study by Fleischhauer, Bruns and Grosche (2021) was conducted with German-speaking children, the studies by Quémart and Casalis (2015) and Quémart, Casalis and Colé (2011) were conducted with French speakers, and the discrepancy between the results may be linked to cross-linguistic factors, which are discussed in the following section.

Another group of studies that used priming to investigate morpho-orthographic processing specifically analyzed the effect of the target word's presence in the prime, contrasting four prime conditions: affixed words (e.g. farmer – farm), affixed pseudowords (formed by a real stem and a real affix, but which together do not form a word, e.g. farmity – farm), non-affixed pseudowords (real stem and non-real affix, e.g. farmald – farm) and a condition where the prime has no relationship to the target word (e.g. workald – farm) (Beyersmann *et al.*, 2015, 2021; Beyersmann; Grainger; Castles, 2019; Hasenäcker; Beyersmann; Schroeder, 2016, 2020). In these studies, in comparisons with the unrelated condition, facilitation effects were observed when the prime contained the target word, regardless of the presence of the affix, in 8-year-old children. We should emphasize, however, that although these findings demonstrate an embedded word activation effect, they do not employ a semantic condition to compare to the suffixed word condition. Furthermore, despite using stimuli constituted by a pseudo-stem as primes of a pseudoword (e.g. nishtness – nish), in order to enable the lexical decision task, they have not been considered in the analysis as an orthographic condition, making it difficult to state whether the effect attributed to embedded word activation is actually due to the activation of their morpho-orthographic patterns or to a more general orthographic overlap effect. One exception to this is the study by Hasenäcker, Beyersmann and Schroeder (2020), who also evaluated the condition of stimuli constituted by a pseudo-stem (e.g. nishtness – nish), observing no priming effect as a result of the presence of the pseudo-stem in the prime compared to the control condition. This leads us to conclude that the priming effect due to the presence of a real word embedded in the prime is not due to general orthographic overlap effects.

In short, the results found suggest that children employ a morphological decoding process during visual word recognition. In this

respect, the use of implicit morphological processing during reading already seems to be present in the early years, with studies reporting effects of the presence of morphological structures on word and pseudoword reading in 2nd grade children (approximately 8 years old) (Beyersmann; Castles; Coltheart, 2012; Burani *et al*., 2008; Burani; Marcolini; Stella, 2002; Colé *et al*., 2012; D'Alessio; Jaichenco; Wilson, 2018; D'Alessio; Wilson; Jaichenco, 2019; Dawson; Rastle; Ricketts, 2018; Jaichenco; Wilson, 2013). However, it is not yet clear whether the observed effects resulting from the presence of morphological structures are due to the activation of morpho-semantic or morpho-orthographic representations. Furthermore, based on priming studies, it is difficult to say when the use of morphological structures begins in the early stages of visual word recognition, as most studies begin to evaluate children in the 3rd grade, at about 9 years of age, and do not use conditions that make it possible to distinguish the morphological effect from orthographic and semantic effects. We thus observed that although some studies report facilitation effects on word recognition due to the presence of morphemes as early as the 3rd grade, others suggest that these effects appear only in the 4th and 5th grades, in children around 10 years old. One possible explanation for the differences observed between some studies may be related to linguistic and individual variables, a topic that we will address below.

Finally, it is important to distinguish between the effects discussed above in priming tasks and those observed in simple lexical decision tasks. Priming tasks aim to assess whether the features of the prime stimulus can be rapidly decoded and influence the recognition of the target word. On the other hand, simple lexical decision tasks investigate how specific characteristics of the presented stimuli facilitate or hinder their recognition compared to other stimuli. In this type of task, the response to an item is based on its resemblance to a real word rather than its intrinsic properties (cf. Dufau; Grainger; Ziegler, 2012; Norris, 2006; Ratcliff, Mckoon, Gomez, 2004).

3.4 Individual and linguistic variations

As described above, although most studies concur in supporting the role of morphological processing in visual word recognition, some variations may occur due to individual and/or linguistic variables. With regard to individual variables, reading proficiency, evaluated by

tests that measure accuracy and fluency in reading isolated words and pseudowords, is the main predictor of complex word processing, with children who have higher reading levels exhibiting greater effects of the presence of morphological structures (Beyersmann *et al*., 2015; Dawson; Rastle; Ricketts, 2021; Mousikou *et al.*, 2020). Based on this, it is possible to assume that the variations resulting from an increase in age or school grade are actually a consequence of changes in reading proficiency because as children progress in their education, they are more exposed to written words and particularly to complex words, thus explaining a possible lack of differences between school grades, as observed in Quémart and Casalis (2014) and Beyersmann *et al*. (2015). In turn, children with reading difficulties or dyslexia seem to use morphological structures as a compensatory strategy to overcome the deficit in phonological decoding, as they exhibit a greater effect of the presence of morphemes on reading accuracy and time, an effect observed in Italian, Danish, Spanish and English, with studies reporting this effect in children as young as 8 years old (Angelelli *et al*., 2017; Burani et al., 2008; Duncan *et a*l., 2011; Elbro; Arnbak, 1996; Marcolini *et al.*, 2011; Suárez-coalla; Cuetos, 2013; Suárez-coalla; Martínez-garcía; Cuetos, 2017; Traficante *et al*., 2011).

According to Grainger and Beyersmann (2017), with frequent exposure to reading and increased visual vocabulary, children would begin to discover relationships between morphologically related units (e.g. a painter is someone who paints; an artist is someone who works with art), making connections between words related in form (orthography and phonology) and meaning (e.g. farm, farmer, farming) that would serve as a foundation for the development of morpho-semantic representations. These morpho-semantic representations would develop rapidly in the early years, as they would be supported by the relationships already established in the spoken language. Later, with increased repeated exposure to written words, morpho-orthographic representations would be established. With this in mind, it is possible to hypothesize that morphological processing occurs through different pathways during the acquisition of reading skills. Initially, it would occur through morpho-semantic representations, facilitating the effects observed in the reading aloud task and LDT in 8-year-old children. With increased reading experience, the reader would use not only morpho-semantic representations but also morpho-orthographic representations.

It is these morpho-orthographic representations that would enable the effects observed in priming tasks due to the presence of morphological structures in the early stages of visual recognition, generally observed only in children over the age of 9 years.

With regard to linguistic variables, in addition to the grapheme-phoneme transparency of writing systems that was discussed in the introduction of this article, other variables may play a role in the development of morphological processing and word recognition, such as morphological productivity, morphological complexity and syllabic complexity (Beyersmann *et al*., 2020; Borleffs *et al.*, 2017). Accordingly, as Fleischhauer, Bruns and Grosche (2021) argue, the detection of morphemes during visual word recognition may be more efficient in morphologically rich and productive languages, such as French and German, than in English. In adult readers, the morphological processing effect appears to be associated with morphological productivity, with larger magnitudes being observed in more productive languages (Beyersmann et al., 2020). However, the results of the cross-linguistic studies found in our review that evaluated children between 3rd and 4th grade indicate different directions. In the study by Mousikou et al. (2020), greater morphological processing effects were observed in English, a writing system with an opaque grapheme-phoneme relationship, and the results of Casalis, Quémart and Duncan (2015) and Beyersmann et al. (2021) suggest a greater efficiency of morphological processing in French. It is therefore still unclear whether morphological productivity and/or the degree of opacity in the grapheme-phoneme mapping of an orthography can modulate morphological processing.

Finally, with regard to linguistic variables, we will briefly present the results found for Hebrew. This language is different from Portuguese, French or English, for example, in which the word formation process usually occurs through the linear concatenation of the affix (suffix or prefix) with the root. In Hebrew, affixes (here called transfixes) are discontinuous units that attach to a discontinuous stem (Gonçalves, 2019). Thus, a triconsonantal stem (e.g. GDL / "grow"), which carries the shared meaning between words with this stem, is interspersed with a set of vowels that carry the semantic and morphosyntactic information (e.g. CaCoC) thus forming the word (e.g. GaDoL / "big") (Schiff; Raveh; Kahta, 2008). The studies in our review (Bar-on; Ravid, 2011; Haddad *et al*., 2018; Schiff; Raveh; Fighel, 2012; Schiff; Raveh; Kahta,

2008) demonstrated that children speaking this language show similar results to children who speak other languages, i.e., a faster reading speed for complex words than monomorphemic words, morphological priming effects compared to orthographic priming and an absence of morphological priming when there were orthographic alterations between the stem and the derived word. These results suggest that morphological processing occurs independent of the linear arrangement of morphemes.

3.5 Morpho-orthographic processing in children

In this final section, we will address the studies that employed a morpho-orthographically related stimulus condition in LDTs with short primes (50-67 ms) (Beyersmann *et al.*, 2015, 2021; Beyersmann; Castles; Coltheart, 2012; Beyersmann; Grainger; Castles, 2019; Dawson; Rastle; Ricketts, 2021; Fleischhauer; Bruns; Grosche, 2021; Hasenäcker; Beyersmann; Schroeder, 2016, 2020; Law; Ghesquière, 2021; Quémart; Casalis, 2015; Quémart; Casalis; Colé, 2011; Schiff; Raveh; Fighel, 2012). Returning to the discussion in the section "Presence of morphological structures", we can separate the studies that investigated morpho-orthographic processing in children into two groups. The first group usually employs four conditions: morphological, morpho-orthographic, orthographic and unrelated, with some also employing a semantic condition. In these studies, all the conditions use real words as primes and targets. The second group, in turn, employs four different prime conditions: affixed words, affixed pseudowords, pseudowords with a non-existent affix and words unrelated to the target word; in the first three conditions, the target word is embedded in the prime.

Looking at the results of the first group of studies, we noticed a greater heterogeneity in the results, observing a facilitation of the morpho-orthographic condition compared to the unrelated condition in children with an average age of 8 years and 10 months for French (Quémart; Casalis, 2015; Quémart; Casalis; Colé, 2011) and only after the age of ten years for German (Fleischhauer; Bruns; Grosche, 2021) and 12 years for Hebrew (Schiff; Raveh; Fighel, 2012). As for English, we found studies that identified an effect of the morpho-orthographic condition compared to the unrelated condition in children around the age of 10 years (Dawson; Rastle; Ricketts, 2021; Law; Ghesquière, 2021); no effect was identified in children aged 8 and 10 years on average (Beyersmann; Castles; Coltheart, 2012). We also

emphasize that in the previous studies, when the effect of the morpho-orthographic condition was observed, a priming effect was also observed in the morphological condition but not in the orthographic and semantic conditions compared to the unrelated condition. Looking at the second group of studies, we observed a greater consistency in the findings, noting facilitation effects on the recognition of the target word when it is present in the prime, regardless of whether it is an affixed word, an affixed pseudoword or a pseudoword with a non-real affix, beginning at the age of eight years in English, German and French (Beyersmann *et al.*, 2021; Beyersmann; Grainger; Castles, 2019; Hasenäcker; Beyersmann; Schroeder, 2016, 2020).

The results of the second group of studies support the hypothesis of Grainger and Beyersmann (2017), suggesting that in the early years, the morphological decomposition process begins through the activation of embedded words. Accordingly, both affixed and non-affixed stimuli would generate a priming effect, provided that the target word was embedded in the prime. The results observed in semantic categorization tasks (Hasenäcker; Solaja; Crepaldi, 2021; Nation; Cocksey, 2009) are in line with this theory, demonstrating that embedded words congruent with the semantic category of the block caused greater interference in responses. Interestingly, studies employing the semantic categorization task found effects in children as young as 8 (Hasenäcker; Solaja; Crepaldi, 2021) and 7 years old (Nation; Cocksey, 2009). Furthermore, as presented in the study by Hasenäcker, Schröter and Schroeder (2017), 2nd grade children already exhibit facilitation in the lexical decision task for compound words, i.e. those that have two embedded words, whereas facilitation due to the presence of affixes appears only after the 3rd grade.

With regard to the studies in the first group, one possible explanation may be linked to reading proficiency. As proposed in the model developed by Grainger and Beyersmann (2017), the extraction of embedded words can be hindered when the prime itself is a real word because when it is presented, both its orthographic and semantic representation are activated, which causes a lateral inhibition in the activation of the embedded word. Because morpho-orthographic pairs do not share morpho-semantic representations, they cannot be used to aid in the extraction of the embedded word. Affix representations can then assist in extracting the embedded word, but these are established only after long exposure to reading. That being said, it is possible that children with poor reading proficiency may have greater difficulty extracting

embedded words, making it impossible for priming effects to occur in the morpho-orthographic conditions. Following this logic, Dawson, Rastle and Ricketts (2021) evaluated children and adolescents and observed that morpho-orthographic priming increased with reading proficiency.

In short, we observed that children around the age of eight years exhibit facilitations due to the presence of the stem, which may be the key element for the beginning of morpho-orthographic processing. However, facilitations such as those observed in adults, where both the target word and the prime are real words, tend to appear later, from age 9-10 years, possibly related to an increase in reading proficiency. We emphasize, however, that only two of the studies found were longitudinal (Beyersmann *et al.*, 2021; Hasenäcker; Beyersmann; Schroeder, 2020), making it possible to control for individual variations. In addition, most studies did not involve a comprehensive period of school grades, which coupled with the small number of studies of this nature make it impossible to determine a more exact period for the emergence of morpho-orthographic processing resulting from real word primes.

3.6 Limitations and future studies

A first limitation of our review is that it did not include theses, dissertations and research reports and was confined to published scientific papers. We believe, however, that this has not biased our sample, as studies based on dissertations and theses, as well as those presented at conferences, tend to be published later in peer-reviewed journals. Another limitation concerns the fact that we sought to analyze morphological processing in its complexity. Although this approach provides an overview of morphological processing in developing readers, the specific evaluation of the role of each variable (the role of linguistic, individual and psycholinguistic variables, phonological and orthographic transparency effects and morpho-orthographic processing) in the magnitude of the observed effects would require a further breakdown into different categories, which we have only touched upon in this study.

We recommend that future studies investigate morphological processing in different school grades simultaneously, encompassing the first years of reading development, rather than being restricted to specific school grades, thus making it possible to identify when the different effects presented here begin to appear. We also emphasize the importance of

conducting cross-linguistic studies, not only because of the small number of studies we found but also because they make it possible to create equivalent stimuli and tasks across different languages and enable broader comparisons. Similarly, we recommend conducting longitudinal studies, as they make it possible to track changes in morphological processing by controlling for individual variations. We also recommend employing different experimental conditions in addition to an unrelated control condition, such as orthographic and semantic conditions, which would make it possible to distinguish the effects of morpho-orthographic structures on complex word processing. Finally, we recommend studying morphological processing using other morphological structures, such as prefixes and compounds, given the small number of studies that have evaluated these categories.

4 Conclusion

The results of this review highlight some consistent findings regarding the utilization of morphological structures in visual word recognition by children. However, it is important to make a few observations. First, the use of morphological structures appears to be context-dependent, being particularly pronounced when the presented word is unfamiliar or infrequent. In such cases, words with frequent bases are recognized faster than words with lower frequency bases, suggesting that a low-frequency word undergoes decomposition and that its constituent morphemes contribute to visual recognition (Angelelli *et al*., 2017; Angelelli; Marinelli; Burani, 2014; Deacon; Francis, 2017; Deacon; Whalen; Kirby, 2011; Lázaro; Camacho; Burani, 2013; Marcolini *et a*l., 2011; Suárez-coalla; Martínez-garcía; Cuetos, 2017; Verhoeven; Schreuder, 2011). Second, in the early years, children perform morphological decomposition processes based primarily on orthographic overlap between the derived word and its root, such that phonological and orthographic alterations would prevent the decomposition of the derived word into its constituents (Carlisle, 2000; Mann; Singson, 2003; Quémart; Casalis, 2014; Lázaro; García; Burani, 2015). It is only in adolescence and adulthood that these alterations do not interfere with morphological processing during visual word recognition (Quémart; Casalis, 2015).

Another consistent finding has to do with the processing of embedded words. In a variety of tasks ranging from reading aloud to lexical and semantic decision tasks, children as early as eight years old

show differences in accuracy and reaction time for morphologically complex words in comparison with monomorphemic words and for pseudowords composed of morphemes in comparison with pseudowords without morphemic constituents (Angelelli *et al*., 2017; Angelelli; Marinelli; Burani, 2014; Antzaka *et al.*, 2019; Burani *et al.*, 2008; D'Alessio; Jaichenco; Wilson, 2018; Laxon; Rickard; Coltheart, 1992; MarcolinI et al., 2011; Mousikou et al., 2020; Suárez-coalla; Cuetos, 2013; Suárez-coalla; Martínez-garcía; Cuetos, 2017; Traficante *et al*., 2011). However, it is not yet clear whether the observed effects resulting from the presence of morphological structures are due to the activation of morpho-semantic or morpho-orthographic representations because the results of priming studies which could help elucidate this issue are mixed. Although, there are suggestions that morpho-orthographic effects occur later than morpho-semantic ones (Fleischhauer; Bruns; Grosche, 2021; Grainger; Beyersmann, 2017).

Given the results presented, it is interesting to analyze them in the light of theoretical models that address morphological processing. One of the first models introduced in the literature was proposed by Taft and Forster (1975) and posits a mandatory morphological decomposition mechanism for any stimulus with a complex morphological structure. In subsequent years, Caramazza, Laudani, and Romani (1988) proposed a hybrid processing model, introducing two parallel pathways for recognizing suffixed words. The first pathway involves direct access to lexical representations, treating the word holistically. Conversely, the second pathway accesses lexical representations through their morphological structures. Another model is the hybrid model of morphological processing by Diependaele, Sandra and Grainger (2009). This model takes into account that priming effects in word pairs with transparent morphological relationships generally exhibit larger magnitudes than morpho-orthographic pairs. The authors argue that the morphological structure of words is represented in the lexicon at two levels. A first level, in which the interaction of the morphological structure with the orthography occurs (morpho-orthographic level), and a second level, in which the interaction of the morphological structure with the semantics occurs (morpho-semantic level). The words would be mapped simultaneously in the morpho-orthographic and morpho-semantic levels, the latter occurring through the orthographic representation of the complete word. Although the models above provide essential insights into morphological processing during visual word recognition, it is important to

highlight that all of them were built based on data observed in adult readers and represent end states of lexical organization. Therefore, throughout this article and in this section, we rely on the embedded word activation mechanism described by Grainger and Beyersmann (2017) as a starting point to discuss how morphological decomposition occurs in developing readers.

According to Grainger and Beyersmann's (2017) model, children, through regular exposure to reading and an expanding visual vocabulary, begin to recognize associations between morphologically related units (e.g. a teacher is someone who teaches). By linking words that share similarities in form (orthography and phonology) and meaning (e.g. farm, farmer, farming), these connections lay the foundation for the development of morpho-semantic representations. During the early years, these representations progress rapidly, benefiting from the existing linguistic relationships already established in spoken language. Thus, the activation of the word embedded within a stimulus appears to be a crucial factor in the Grainger and Beyersmann model for initiating morphological decomposition processes, which is in accordance with the above results showing an advantage in the processing of morphologically complex words over monomorphemic words and also with base frequency effects.

Grainger and Beyersmann (2017) also posit that morpho-orthographic representations would be established with increased repeated exposure to written words. Thus, the model has the potential to explain why the extraction of the embedded word seems to be hindered in cases of allomorphy. In the initial stages of literacy, extracting the embedded word would only occur when there is phonological and orthographic overlap with the word in its simple form. As children increase their visual vocabulary over the years, they develop orthographic representations of affixes, which help them to extract embedded words in cases of allomorphy. As proposed by Grainger and Beyersmann, children with more advanced levels of reading are more competent in extracting embedded words since they have greater exposure to reading and, therefore, more opportunities to establish orthographic representations of bases and affixes, facilitating visual recognition of morphologically complex words. Consequently, the Grainger and Beyersmann model also predicts that morpho-semantic effects shall be present earlier in development than morpho-orthographic effects, which is in accordance with the revised results.

Summing up, in the Grainger and Beyersmann (2017) model, it is possible to hypothesize that morphological processing occurs through different pathways during the acquisition of reading skills. Initially, it would occur through morpho-semantic representations activated by extracting the embedded word. It would explain the effects of base frequency and morphological complexity observed in reading aloud and lexical decision tasks in children about eight years old. As reading experience increases, readers would not only rely on morpho-semantic representations but also on morpho-orthographic representations. These morpho-orthographic representations would account for the effects observed in priming tasks, reflecting the presence of morphological structures in the early stages of visual recognition, typically observed in older children.

Credit Author Statement

The authors declare that the text was jointly conceived, and the tasks were divided as follows: Humberto dos Reis Pereira: Conception and design; Analysis and interpretation of data; Discussion of results; Composition, and review of the final version for publication, in accordance with the standards established by the Journal. Francis Ricardo dos Reis Justi: Conception and design; Analysis and interpretation of data; Discussion of results; Review of the final version for publication, in accordance with the standards established by the Journal.

Acknowledgments

The authors are grateful to the Minas Gerais State Agency for Research and Development (FAPEMIG) for providing financial support to the first author.

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