UNIVERSIDADE FEDERAL DE MINAS GERAIS

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Eduardo Moreira Dias

Revisitando *Souza and Dias (2018) – Considerações sobre o Ensino de Leitura em Inglês como L2 a partir de um Estudo Experimental sobre o Reconhecimento Visual de Palavras:* Questões para o Estudo Psicolinguístico do Reconhecimento Visual de Palavras por Bilíngues

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EDUARDO MOREIRA DIAS

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To Eliana Moreira, Ana Lúcia Moreira and Cecília Maria Moreira.

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“[...]Ninguém viu aquele brilho de manhã ainda seco
que anunciava - peremptório:
é que setembro chegou.
E seguimos juntos.
Perdemos muito,
no trabalho, na ausência.
Perdemos alguns parentes e, tristemente, outros amigos.
Mas, veja, seguimos juntos.
É que setembro chegou.
[...]
E, pois, daqui a pouco, o telefone irá tocar,
a hora do trabalho, com o preço do mundo, cobrando a nossa pressa,
e teremos de fazer compras, pagar o estacionamento,
ir ao dentista, levar o filho para algum lugar.
E, pois, daqui a pouco, o noticiário da tevê anunciará um desastre, um escândalo, o gol do ano.
Mas, veja, não me importam as feridas em suas mãos, os sonhos que alimenta.
Não me importa o que pensa da educação ou o tamanho de sua culpa.
Não me importa deus ou o diabo, nem as impressões metafísicas do dia. Veja apenas, repare bem, aquela luz adentrando a sala, quase no corredor. É o que importa:
Setembro chegou e seguimos juntos.” (Kaio Carmona)

ABSTRACT

Fully understanding the early processes involved in visual word recognition is not an easy feat. One of the main issues in this field of research is the role of sound in reading (Pollatsek et al., 2015; Rastle & Brysbaert, 2006). Importantly, theories of visual word recognition and reading in general have been heavily informed and, perhaps, biased toward results coming from research done with monolinguals of English (Randall, 2007). When one takes into account the intricacies inherent to bilingualism, new methodological issues arise. In that regard, Souza and Dias (2018) have recently reported findings from two lexical decision tasks with monolinguals of Brazilian Portuguese and Brazilian Portuguese – English bilinguals that corroborate a dual-route theory of visual word recognition. In the present study, I try to develop a discussion of the findings reported by Souza and Dias (2018) based on a review of the literature on visual word recognition. Finally, informed by the literature, I consider some aspects that might need attention in future experimental research.

Keywords: Visual Word Recognition. Lexical Decision. Masked Phonological Priming. Bilingualism.

RESUMO

Compreender plenamente os processos iniciais envolvidos no reconhecimento visual de palavras não é uma tarefa fácil. Uma das principais questões neste campo de pesquisa é o papel do som no processo da leitura (Pollatsek et al., 2015; Rastle & Brysbaert, 2006). Teorias sobre o reconhecimento visual de palavras e a leitura em geral têm sido bastante informadas e, provavelmente, enviesadas por resultados provenientes de pesquisas feitas com monolíngues do inglês (Randall, 2007). Nesse sentido, quando considerações sobre pesquisas em bilinguismo são contempladas, novas questões metodológicas surgem. A esse respeito, Souza e Dias (2018) relataram recentemente resultados de duas tarefas de decisão lexical com monolíngues do português brasileiro e bilíngues do par português brasileiro - inglês que corroboram teorias da dupla rota para o reconhecimento visual de palavras. No presente estudo, eu procuro desenvolver uma discussão sobre os achados relatados por Souza e Dias (2018) a partir de uma revisão da literatura sobre reconhecimento visual de palavras. Finalmente, informado pela literatura, considero alguns aspectos que podem requerer atenção em pesquisas experimentais futuras.

Palavras-chave: Reconhecimento visual de palavras. Decisão Lexical. Priming Fonológico Mascarado. Bilinguismo.

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SUMMARY

PREFACE

The present study, as it was originally conceptualized and submitted to the Graduate Program in Linguistic Studies (PosLin) at the Federal University of Minas Gerais (UFMG), included an experimental component through which I intended to verify and expand on the results reported by Souza and Dias (2018). However, on March 18th, 2020, all on-campus activities were suspended at UFGM in an effort to mitigate the spreading of the COVID-19 pandemic. This coincided with the period of time in which I had previously expected to start running experiments at the Laboratory of Psycholinguistics; hence it was not possible to carry out this part of the initial project.

The experimental component consisted of a lexical decision task in the paradigm of masked phonological priming, which is commonly used in the psycholinguistics literature to investigate early influences of phonological representations in visual word recognition. Under ordinary circumstances and, perhaps, with a different task design, it might have been possible to rapidly adapt the experiment to the virtual environment. Nevertheless, after a brief evaluation of the remarks made by Reips (2002), Grootswagers (2020) and Anwyl-Irvine et al. (2020) on the methodological implications of migrating to the virtual environment and on the accuracy issues specifically related to masked priming experiments in such setting, it was decided that this transposition should be postponed for now.

In accordance with the authors cited above, I believe that the future for online behavioural research is very promising, and most likely inevitable. However, also in agreement with the observations made by these researchers, it is my understanding that, due to the peculiar characteristics of the effects and predictions under investigation in this study, it would have been premature (and, at the very least, irresponsible) for me to take this step without carefully attending to the variables that come into play when one tries to conduct experiments on the internet. This rigorous analysis, coupled with the theoretical intricacies inherent to bilingual research, I believe, would not have been possible under the remaining time frame available for this project. Therefore, in its current version, this study comprises a literature review, fostered by the results reported by Souza and Dias (2018), concerning the role of sound in visual word recognition, by means of which I intend to deepen our understanding of the methodological aspects of the previous study.

INTRODUCTION

1.1 Preliminary observations

As disclosed in the previous section, the original version of the present study included an experimental component, which could not be brought to fruition due to the impacts of the COVID-19 pandemic. Consequently, the structure and main objectives of this thesis, have been reassessed. In its current version, the present work aims at expanding our understanding of the processes involved in visual word recognition, especially with regard to how bilinguals process individually presented written words. By means of a literature review, prompted by the findings of Souza and Dias (2018), I intend to identify elements that would allow the previous study to progress into an investigation of the interactions between abstract representations in the bilingual brain.

In this introductory section, I provide an overview of basic ideas that have been put forth by researchers interested in the processes of visual word recognition and reading in general. In Chapter 2, I explore how these and other issues have been analyzed in the context of bilingualism. Chapter 3 will be dedicated to an exposition of some of the main methodological issues that have been identified by other authors and that should inform our discussion of the results reported by Souza and Dias (2018) on the effect of masked phonological priming. Finally, in the last chapter of this thesis, I try to explore potential issues on which we may need to focus in future experimental research.

1.2 Reading and visual word recognition: basic notions

Reading has been recently described by researchers as “an impressive human achievement that requires coordinated mastery of a constellation of perceptual and cognitive processes” (Norris, 2013), “a remarkably complex and multifaceted behaviour, which relies on the recognition of individual words” (Yep and Balota, 2015). According to Coltheart (2006), “Little is known about how the most elaborate aspects of this system work, but much has been learned about its basic building blocks, such as letter identification, visual word recognition and knowledge of letter-sound rules.”. In fact, he argued that “It does not seem likely that much progress would be made if we started off by investigating ‘real reading’”. Alternatively, the cognitive scientist suggested that we should start by “breaking up ‘real reading’ into simpler component parts which are more immediately amenable to investigation" (Coltheart, 2006, p. 5).

The validity of Coltheart's proposition is attested by how some authors, such as Randall, (2007, ch.3), Balota, Yap and Cortese (2006), Yap and Balota (2015) and others, choose to tell the story of visual word recognition (henceforth referred to as VWR) research in introductory textbooks. Specifically, it seems to be common practice for authors to subdivide these revisional/introductory texts into sections dedicated to each of the "smaller component parts" and processes of reading that have been explored (i.e.: features, letters, words; visual word recognition; sublexical/lexical-level variables, etc.). Notwithstanding the substantial amount of work that has already been done, in an overview of the literature on computational models of visual work recognition, Norris (2013, p. 517) acknowledged the fact that "Understanding each of these processes is hard, but understanding how they operate as a whole presents an even greater challenge.", a perception which seems to be corroborated by all researchers cited above. In addition, and crucial to the purposes of the present study, when one factors into this complex equation the intricacies inherent to bilingual research, this task becomes even more methodologically and theoretically challenging.

In this regard, Randall (2007, p. 85) has identified the dual-route perspective (see section 1.3.2 of this thesis) on VWR as a central framework for understanding such processes, especially when research on languages other than English is taken into account. However, he also suggests that, even though there may be evidence to support a dual-route approach, there is also evidence that readers from different languages would use these routes to different degrees (Randall, 2007, p. 85). In addition, based on their analysis of current models of VWR and their respective predictions regarding this process, Balota et al. (2006, p. 346) have suggested that "Although some effects appear to be modeled quite well by interactive activation and parallel distributed processing systems, there have also been results that appear inconsistent with such systems." Importantly, in relation to behavioural research on this topic, they have argued that assuming a linear relation between response latencies and underlying cognitive processes is a simplifying assumption, "which will ultimately need to be faced by those studying the time-course of processes involved in visual word recognition, along with other cognitive operations." (Balota et al., 2006, p. 347). Accordingly, many authors have stressed the fact that the same set of stimuli might yield different results

As previously mentioned, a great deal of attention has been payed to the fundamental process of VWR. Importantly, in their review of this literature, Balota et.al. (2006) have indicated that research on this topic has been:

> […] central to work in cognitive psychology and psycholinguistics because words are relatively well-defined minimal units that carry many of the interesting codes of analysis (i.e., orthography, phonology, semantics, syntax) and processing distinctions (e.g., automatic vs. attentional) that have driven much of the work in cognitive psychology and psycholinguistics.

Furthermore, Balota et al. (2006) have also observed that "[…] because words have been a central unit of analysis in much of the verbal learning and memory research that dominated experimental psychology between the 1950's and the 1960's, there was considerable interest in developing norms that quantify different components of words". Some of these measurements and their implications for experimental research will be discussed in more detail in following sections of this thesis.

Also, it is important to mention that research on VWR has been identified by some of these authors as pivotal in the development of mathematical models of pattern recognition (Balota et al., 2006) and of models of reading in general (Randall, 2007, ch. 3). Moreover, (Yap and Balota, 2015, p. 26) have noted that although a number of writing systems exist, reading research has been dominated by the study of alphabetic systems, which, according to the authors, has led to the recognition of letters being a focal point for the development of early models of visual word processing. Finally, Randall's (2007) analysis of the literature on word recognition in English and his examination of theoretical models, considering other languages and the second language learner of English, highlights the fact that VWR theorization in general has been shaped by research with monolinguals of English.

Randall hints at the importance of considering results that come from research with second language (L2) learners whose native language (L1) is based on a different script (e.g.: Chinese, Arabic) and those whose native language differs from English concerning the psycholinguistic grain size, as defined by (Goswani et al. 1998, 2003) This idea is clearly stated on section 3.3 of his chapter "Decoding Print – Processes of word recognition in a second language":

> We thus need to be careful when using cognitive models which have been devised for English with other languages, but the examination of the mental processes involved in word recognition, especially cross-linguistically, is important in trying to understand the problems which second language learners face in trying to read in English. (Randall, 2007, pp. 78-79)

In this regard, based on an exhaustive literature review on the effect of masked phonological priming in English done by Rastle & Brysbaert (2006) and in line with their approach to the investigation of this phenomenon, Souza and Dias (2018) have investigated whether the same effect could be found for adult monolinguals of Brazilian Portuguese and highly proficient Brazilian Portuguese – English bilinguals when performing lexical decision tasks in their first and second language respectively. Rastle and Brysbaert (2006) had argued in favor of Based on the results from these experiments and following the researchers evaluated the descriptive adequacy of predictions made the dual-route cascaded model of visual word recognition and reading aloud (Coltheart et al., 2001) and concluded, in line with this perspective that:

> (1) “in the participant’s native language (Portuguese) the grapheme/phoneme association decoding mechanism is modulated by the frequency.”; (2) “in the visual recognition of words in the participants’ additional language (English), the mechanism is generally similar to the recognition of low frequency words in the mother tongue, but it is supported grapheme/phoneme associations available in the L1.” (Souza and Dias, 2018)

These observations will inform much of the discussion in this thesis. For now, having stablished the central role of letters and words as units of analysis that guided the theory on mental models of reading, we shall proceed to a brief discussion of some of these models.

1.3 Mental models of reading

According to Coltheart et al. (2001, p. 207), “Cognitive neuropsychologists of the 19th century held the view that the language was highly modular in structure, and they also held the view that an appropriate notation for describing hypothesized architectures of such systems was the box-and-arrow notation.” Importantly, they also observed that:

> Although this approach to modeling cognition […] was popular toward the end of the 19th century and remains popular in the 21st century, there was a long period during which both the modular modelling approach and the box-and-arrow notation for expressing theories had vanished from cognitive psychology – a period from perhaps 1900 to the mid-1950s. (Coltheart et al., 2001, p. 207)

In fact, as pointed out by Norris (2013, p. 517), “early models of reading were predominantly of the ‘box-and-arrow’ type.”. However, he argued, “even the most influential of these models – Morton’s logogen model – had very little to say about what exactly went on in the boxes or what information flowed along the arrows.” This, changed drastically with the development of computational models in the early 1980's (Norris, 2013), which revolutionized the psychology of reading (Coltheart et al., 2001). Yet, Norris (2013, p. 518) has identified that, even though there seems to be universal agreement that computational models should be preferred over older verbal or box-and-arrow ones, "there is a continuing debate about the most useful style of model.".

Norris (2013) identified sixteen major computational models of reading and organized them in terms of their primary focus. Table 1 shows each of these models, their style of modeling, the main tasks they can simulate and the phenomena they have been primarily designed to account for. In his exposition, the author focuses on more recent models of visual word recognition. Analysing each of these models, their different predictions and methods of implementation is, of course, beyond the scope of the present study.

Instead, in consonance with Souza and Dias (2018), Rastle and Brysbaert (2006) and many others, I will be grounding my discussion in the body of knowledge that has been accumulated with the development of the dual-route cascaded model of visual word recognition and reading aloud advanced by (Coltheart et al., 2001). Reasons for this choice will be provided throughout my exploration of some of the main effects that have been investigated in the literature on visual word recognition. For the moment, earlier work on computational modeling should be considered.

Model	Style	Task	Phenomena	Large lexicon
Models of visual word recognition				
IA [11,22]	IA	PI	Word-superiority effect	
Multiple read-out [3]	IA	PI, LD	Word-superiority effect	
SCM [2]	IA	LD, MP	Letter order	
BR [4–6]	Math/comp	LD, MP	Word frequency, letter order, RT distribution	√
LTRS [8]	Math/comp	MP, PI	Letter order	
Overlap [66]	Math/comp	PI	Letter order	
Diffusion model [30]	Math/comp	LD	RT distribution, word frequency	
SERIOL [7]	Math/comp	LD, MP	Letter order	
Models of reading aloud				
CDP++ [13]	Localist/symbolic	RA	Reading aloud	√
DRC [12]	IA	RA, LD	Reading aloud	
Triangle [24,25]	Distributed connectionist	RA	Reading aloud	
Sequence encoder [15]	Distributed connectionist	RA	Reading aloud	√
Junction model [50]	Distributed connectionist	RA	Reading aloud	√
Models of eye-movement control in reading				
E-Z reader [17,18]	Symbolic	R	Eye movements	
SWIFT [19]	Symbolic	R	Eye movements	
Model of morphology				
Amorphous discriminative learning [16]	Symbolic network	Self-paced reading, LD	Morphology	√

Table 1. Major computational models of reading organised in terms of their primary focus (extracted from Norris, 2013)

1.3.1 The interactive activation and competition model

The first computational model of reading was the highly influential interactive activation and competition (IAC) model, proposed by McClelland and Rumelhart (1981) and Rumelhart and McClleland (1982) (see Coltheart et al., 2001; for a review; but see also Yap and Balota, 2006; Balota et al., 2015, and Randall, 2007 for different approaches.). As stated in Randall (2007, p. 58), this model "[…]was designed to show how individual letter features could be used in combination to recognise a word.". Specifically, Yap and Balota (2015) assert that the development of the IAC model was influenced by what is currently known as the word-superiority effect (also known as the Reicher-Wheeler effect), which suggests that letters are better recognized when embedded in words. The problem here, as specified by Yap and Balota (2015), is that, due to the fact that most of the early research on reading was dominated by the study of alphabetic systems, it had been assumed by some that letter recognition was a necessary first step on route to VWR. Assuming that this is true, how would it be possible for word-level information influence the perception of its constituent letters? This and other issues concerning letter recognition, according to many of the authors consulted, trace back to ideas first proposed by Cattell (1885, 1886).

Importantly, Cattell seems to have been the first to argue that letters can be recognized and named by subjects more quickly if they are presented in the context of words, as compared to when they are presented embedded in nonwords. Additionally, Cattell (1885, 1886) found that some words can be named more quickly than single letters. Almost a century later, work by Reicher (1969) expanded on these findings and provided support for the word-superiority effect (but see Balota et al., 2006, p. 290-292 for a discussion on subsequent findings that constrained the interpretation of this effect and some important considerations on the paradigm employed by Reicher). In spite of these restrictions, as many have acknowledged, the theoretical importance of the Reicher-Wheeler effect is profound, hence its influence on the development o the IAC model (aforementioned).

This model of letter recognition has three representational levels, namely, the visual feature level, the letter level and the word level. There are two types of connections across representations: facilitatory (represented by lines that end in arrows) and inhibitory (represented by lines that end in circles) Additionally, within the letter level and the word level, there are inhibitory connections between nodes. Figure 1 shows the basic structure of this model.

When a word is presented to the model, all representations consistent with it will receive activation in an interactive and cascaded fashion, that is, each node will accumulate activation across time via the spread of activation across the connection paths (Yap and Balota, 2015).

Importantly, it is this characteristic of the model that allows it to account for the word superiority effect. Once activation at the lower levels begins, the individual nodes do not need to reach a threshold of activation to start influencing other levels of representation. Rather, as stated in Balota et al. (2006), “there is a relatively continuous transferal of activation and inhibition across and within levels as the stimulus is processed.”. Thus, when nodes at the word level become activated, they begin to provide feedback to the lower levels.

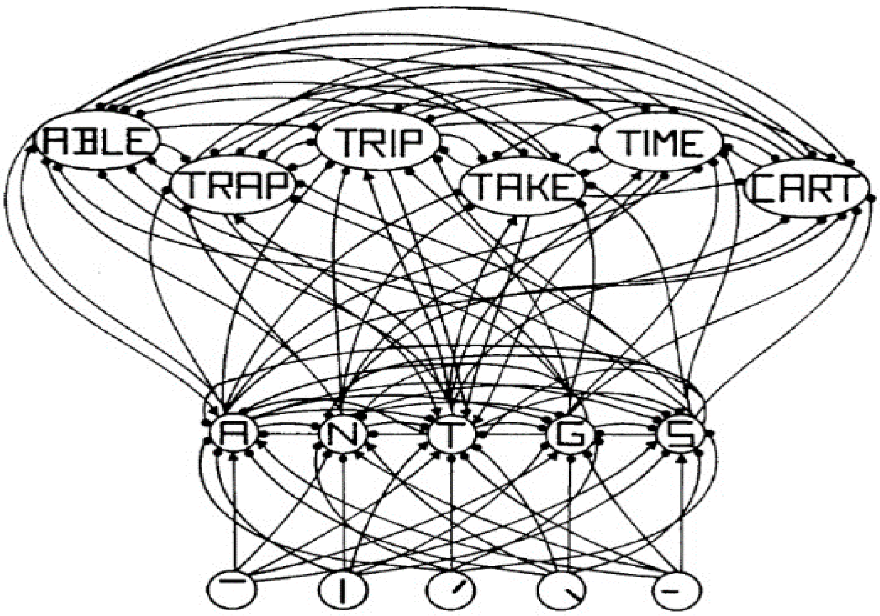

Figure 1. McClelland and Rumelhart’s (1981) interactive activation and competition model of letter recognition.

Curiously, as discussed by Balota et al. (2006, p. 292), there is another phenomenon in the literature known as the pseudoword superiority effect, which suggests that letters are also better detected when presented in the context of a pronounceable nonword, as opposed to when they are embedded in unpronounceable nonwords or presented in isolation. They explained that, initially, this effect would appear to challenge the IAC model. However, as clarified by the authors, the model can also accommodate this effect: “when letters are embedded in pronounceable nonwords, it is likely that there will be some overlap of spelling patterns between the pseudoword and acceptable lexical entries.”. For instance, if we consider the nonword MAVE (an example provided by Balota et al., 2006), we will find that “it activates 16 different four-letter words that share at least two letters within the McClelland and Rumelhart network.” This would, therefore, raise the overall levels of activation in the model through the connection paths.

Accordingly, "[…] the influence of orthographic regularity appears to naturally fall from the interaction across multiple lexical entries that share similar spelling patterns within the language." (Balota et al., 2006, p. 292). The relevance of this conclusion will be made evident in the section of this thesis dedicated to a review of recent findings reported by Souza and Dias (2018). Moreover, the contrast between words/nonwords, pronounceable/unpronounceable nonwords, regular/irregular spelling patterns and other issues debated in the VWR literature will also be contemplated. Meanwhile, some important considerations have to be made.

The fact that each node at each level produces inhibitory as well as excitatory connections was described by Randall (2007), as the innovatory approach taken in this model, which "allows for new information to either raise or lower the activity of other nodes at the same level, at the level above and at the level bellow.". Indeed, the activation dynamics of all units are constrained by the activation and inhibition of other similarly spelled words (Yap and Balota , 2015, p. 27). This has been pointed out as an important difference between the IAC model and the classic Logogen model developed by Morton (1970), mentioned above, in which the lexical representations (logogens) accumulate activation across time independently of each other (Yap and Balota, 2015).

An important idea we can derive from the debate fostered by the development of the IAC model, as highlighted by Balota et al. (2006, p. 293), is that "[…] letters and words appear to be recognized in the context of similar representations that either reinforce or diminish the activation at a given representation.". Essentially, the process of VWR is not passive; there are bottom-up (e.g.: from the marks on the page to the mental representations) well as top-down (eg.: from higher levels to lower levels of representation) influences at play. Finally, the historical importance of the IAC model is further attested by its influence on subsequent modelling enterprises. Relevant to this study is the impact that this model has had in the development of the previously mentioned DRC model of visual word recognition and reading aloud (Coltheart et al., 2001). It is to a brief description of this model that I turn to in the next section.

1.3.2 Reading aloud: strong vs weak phonological theories

In the previous sections, I made an effort to clarify that, although at first sight the process of reading might be seen as a straightforward sequence of events, this apparent simplicity is far from being the truth. Understanding how one manages to go from the visual apprehension of the marks on the page to accessing the representations of words is not simple. As we have seen above, the IAC model was first developed to explain letter recognition. If we move further into thinking about words, which have been, as we saw, a primary unit of analysis in the literature on VWR, many other issues start to arise. An important issue that has been at the center of debates concerning VWR, and reading in general, is to what extent phonology might be involved in these processes. Notedly, words and texts can be read silently or aloud, so, in theory, at least for latter process, knowledge of how words should be pronounced would have to play an important role.

The influence of sound in reading, however, as argued by Pollatsek (2015, p. 185), "has been a contentious issue, partly because there is never complete agreement about what coding into sound means". He pointed out that, if this meant coding letters and words into sound all the way up to saying them aloud as we read them, this would not be optimal, since it would "[…] slow down reading below the normal rate of about 300 words per minute for skilled readers.". Instead, he argues that "[…] there are many intermediate levels in which the auditory and speech systems could be involved in the reading process in skilled adult reading […]" (Pollatsek, 2015, p. 185).

In line with this viewpoint, Rastle and Brysbaert (2006), have said that there is a general agreement that VWR can be influenced by the computation on phonology. Yet, they also observed, as have many of the authors cited in this thesis, that "Perspectives differ considerably, however, with regard to the extent to which phonology influences the recognition of words." (Rastle and Brysbaert, 2006, p. 98). According to these researchers, there have been two major opposing theories on this matter, namely, a "strong phonological theory" and a "weak phonological theory". The former assumes that phonology plays a central role in VWR, and some of its proponents have even suggested that analysis of phonological information might be obligatory in this process. The latter, on the other hand, postulates that VWR can be accomplished either through a direct orthographic pathway or through an indirect phonologically mediated pathway. (Rastle and Brysbaert, 2006, p. 98). The different predictions made by these two conflicting theories and their respective implementations as models of reading are highly important to the ideas discussed in the present study and, as such, they will be revisited in the next sections.

Additionally, Pollatsek et al. (2015) has pointed out that the issue of phonological encoding (see Pollatsek, 2015, pp. 185-186 for further discussion on the different interpretations of this term) has been explored in many different paradigms, being "most extensively explored with adult normal readers processing single words, usually using either brief presentation paradigms or speeded classification tasks". He also indicates that many of the same tasks have been used in the study of different types of dyslexia. Findings from this second group of studies, as we shall see momentarily, have been appointed by many researchers as compelling evidence for dual-route theories of VWR, as opposed to single-route theories. (Coltheart et al., 1993, 2001; Gernsbacher, 2006; Randall, 2007; Rastle & Brysbaert, 2006; but see Pollatsek, 2015 for a discussion on more recent interpretations.)

A simple explanation of the dual-route theory viewpoint is provided in Rastle and Coltheart (1999, p. 482):

> The term 'dual-route theory' refers to a particular class of theories of visual word recognition and reading aloud. The defining feature of such theories is the postulate that there are two different procedures for converting print to speech, a dictionary-lookup or lexical procedure and a rule-based or nonlexical procedure.

This basic assumption has been extensively discussed by Coltheart and colleagues, across the years, and alternative accounts have also been analysed in minute detail (see Coltheart, 2005, 2006; Coltheart et al., 1993, 1999, 2001; Coltheart & Rastle, 1994; Rastle & Coltheart, 1999). In line with this theory, Coltheart et al. (1993, p. 589) explained that:

> The fundamental property of dual-route models of reading […] is the idea that skilled readers have at their disposal two different procedures for converting print to speech. These are, roughly speaking […] a dictionary lookup procedure and a letter-to-sound rule procedure.

In its final version, however, the DRC model of visual word recognition and reading aloud (Coltheart et al., 2001), consists of three routes, namely, the lexical semantic route, the lexical nonsemantic route, and the GPC (grapheme-to-phoneme conversion) route. This final version of the model is represented in figure 2.

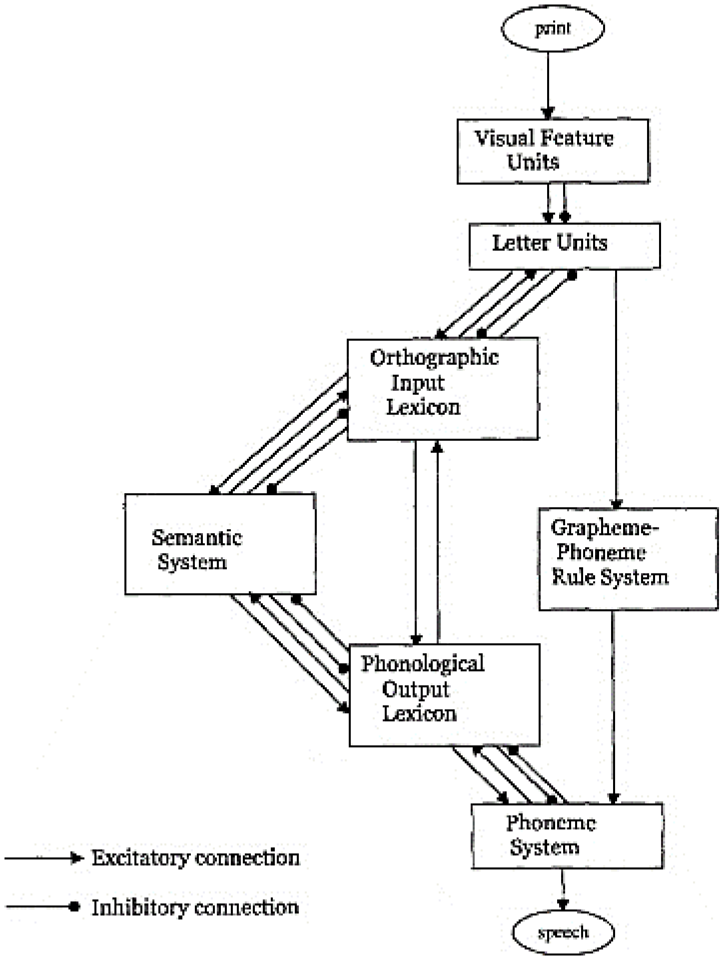

Figure 2. The dual-route cascaded model of visual word recognition and reading aloud (Extracted from Coltheart et al., 2001)

Similarly to what happens in the IAC, in the DRC, whose lexical route is an extension of the former, units of different levels interact both through inhibitory and excitatory connections. Moreover, also in line with how the IAC model works there are also within-level inhibitory connections between representational units (see Coltheart et al., 2001 for an in depth description of each route). Importantly, the DRC accounts for many findings in the VWR literature. In fact, Coltheart et al. (2001, p. 251) have provided a list of all the effects, as reported in studies of lexical decision and reading aloud tasks, that have been successfully simulated by the model. Having in mind that these are only the effects that have been explained by the DRC, I believe it is important to replicate the full list here (Figure 3), as a reminder of how deeply complex the process of skilled reading can be.

Reading Aloud

1. Frequency effect
2. Lexicality effect
3. Regularity effect
4. Interaction of regularity with frequency
5. Interaction of regularity with position of irregularity
6. Consistency effect
7. Pseudohomophony effect
8. Base word frequency effect on pseudohomophone reading
9. Absence of *N* effect on pseudohomophone reading
10. Presence of *N* effect on nonword reading
11. Whammy effect
12. Strategy effects
13. Homophone and pseudohomophone priming
14. Repetition priming
15. Onset effect in masked form priming
16. Triple interaction between regularity, frequency, and repetition
17. Length effect
18. Interaction between lexicality and letter length

Lexical Decision

1. Word frequency effect
2. Pseudohomophone effect
3. Interaction between pseudohomophone effect and orthographic similarity
4. *N* effect on NO responding
5. Interaction between *N* and frequency on YES responding

Acquired Dyslexias

1. Quantitative simulation of exception word, regular word, and nonword reading in surface dyslexia, and of the effect of frequency on surface dyslexic reading of exception words.
2. Quantitative simulation of the interaction between pseudohomophony and orthographic similarity in phonological dyslexia.

Other Effects

1. Stroop effect and its interaction with position of overlap
2. Prediction of regular-word reading accuracy from accuracy exception-word and nonword reading in normal, dyslexic, and brain-damaged children

Figure 3. List of effects that have been successfully simulated by the DRC model of visual word recognition and reading aloud. (Extracted from Coltheart et al., 2001)

An exposition as to how the DRC manages to simulate each of these effects is, of course, also beyond the scope of the present study. I will be treating the ones which are most relevant to my specific goals as the discussion unfolds. Critically, as acknowledged by many of researchers cited above, and even by the proponents of the model themselves, a major limitation of most current models of reading is that they can only account for the processing of individual monosyllabic words. This includes the IAC and the DRC (but see Norris, 2013 for a discussion of more recent models that have dealt with this problem). For now, let us consider how these and other issues have been treated in the context of bilingualism.

BILINGUALISM

2.1 The bilingual memory storage

For the past four decades, researchers have been trying to tackle the questions on how the bilingual brain processes, with such elegance and refinement, two or more possibly very different languages, and to which extent these languages interact with each other in the bilingual's lexicon. One of such researchers, and a reference in the field, is François Grosjean, who began exploring, in 1982, the embryonic notion that a bilingual's language behavior should be considered in two distinct contexts, that is, when they are interacting with monolinguals and when they are speaking with another bilingual.

A few years later, in 1985, the same researcher proposed a “situational continuum”, which ranged from a monolingual to a bilingual speech mode. According to Grosjean, bilinguals would navigate both states by “activating and deactivating” one or more of their languages to fulfill the demands of the linguistic situation. When speaking with a monolingual, a bilingual person would deactivate, though not completely, the languages the situation did not require. On the other hand, within a setting where bilinguals are speaking amongst themselves, one language would be chosen as the base language, while the others would remain constantly activated at a lower level, available to be called upon by the speaker at any time.

Nevertheless, the fact that bilinguals, very often, experience unwanted interferences of one language in the processing of another is well-known. So, in 1989, Grosjean introduced the ideas of intermediate modes and dynamic interferences. This concept of language modes evolved from a dichotomy to a spectrum, while these dynamic interferences were understood as the unwanted ones that occasionally happen without the speaker’s control. The concept would later unfold as the different levels of activation of the two languages were introduced in Grosjean (1997), and the theory would culminate with the publication of “The bilingual’s Language Modes” in 2001, with much more research being done on the topic ever since.

Concurrently, several models were put forth in an attempt to describe the organization of the bilingual lexicon and of human memory itself. Roberto R. Heredia provides an overview of the literature on mental models of bilingual memory in chapter 3 of “An introduction to Bilingualism: Processes and Principles” (Heredia, 2008). A more traditional view of the latter, proposed by Attikinson and Shiffrin (1968), suggests the classic distinction between short-term memory (STM) and long-term memory (LTM). STM would represent the temporary store for information that needs to be processed rapidly before being lost or being transferred to LTM. LTM would be the permanent store from which an individual could retrieve all sorts of information that they have about the world. Furthermore, this permanent store, according to the authors, could be further analyzed into more specialized parts, one of which would be responsible for the storage of language. This theory has been revised and discussed throughout the years, with concepts such as STM being replaced with the more modern idea of Working Memory (see Ardila, 2014, for further discussion), and some other adaptations made.

Linguists, in turn, have been pursuing a better understanding of how language is learned, stored and processed by the human brain. Moreover, researchers whose area of interest is bilingualism, have had the task of explaining the intricacies of how the bilingual brain manages to accommodate two or more languages into this sophisticated system. The Hierarchical Models of Word Association and Concept Mediation proposed by Potter et al. (1984), for instance, start with the assumption that bilinguals have their languages organized in levels of representation. In the Word Association model, the bilingual's languages would interact at a lexical level, whereas in the Concept Mediation model, they would work independently, being associated at a representational level. From this discussion on whether a bilingual's languages would interact with each other in different levels or work independently, emerged two hypothesis that have divided the field for many years: the Interdependence Memory Hypothesis and the Independence Memory Hypothesis (see Heredia, 2008, for a overview of the literature on mental models of bilingual memory). In the former, the bilingual's languages would be organized as a unit, one lexicon that would encompass both languages. In the latter, on the contrary, languages would be separately organized, with no direct interaction between them.

Many questions have yet to be answered about the architecture of the bilingual lexicon and the interactions among its abstract representations. Important to this study are the issues concerning the interactions that happen at the lexemic level of a lexical entry, as derived from Willem Levelt's interpretation of its structure (1989). Also pivotal to the genesis of the present study are the works of Rastle and Brysbaert (2006) on the phenomenon of phonological priming, the findings of Souza and Dias (2019) and their conclusions regarding the Dual Route Cascaded Model of Word Recognition and Reading Aloud (DRC), proposed by Coltheart et al. (2001).

Particularly, researchers have focused on interactions at the lexical level of a mental representation (see Lopez & Young, 1974; Glanzer & Duart, 1971), or on issues related to semantic categories (see Caramazza, & Brones, 1980; Schwanenflugel & Rey, 1986). However, not the same amount of attention has been given to phonological and morphological representations (the lexemic level of the lexical entry). In the past years, researchers at the Psycholinguistics Laboratory of the Federal University of Minas Gerais (UFMG) have tried to analyze these specific components, but further investigation is necessary. Thus, the present study was designed to shed some light on a few issues with respect to this facet of the lexical entry and the interactions that might happen among representations at this level during the process of VWR. It is to the discussion of these issues that I will turn to in the next sections.

2.2 Interactions between representations in the bilingual lexicon

Over the years, many linguists have devoted their time to the analysis of what was referred to by Groesjan (1989) as “dynamic interferences”. However, studies have tended to focus on interactions at the semantic-syntactic level (see Randall, 2007, ch. 3 for an extensive review of the literature). This conceptual level in which specifications of meaning and syntactic properties would be stored is what Levelt (1989, p. 182) called “lemma”, adhering to the term first proposed by Kempen and Huijbers (1983), when discussing the internal structure of the lexical entry in L1. The other half of the lexical entry, which, according to Levelt, contains morpho-phonological information, was later coined “lexeme”. Figure 1 shows the composition of a lexical entry as described by Levelt (1989).

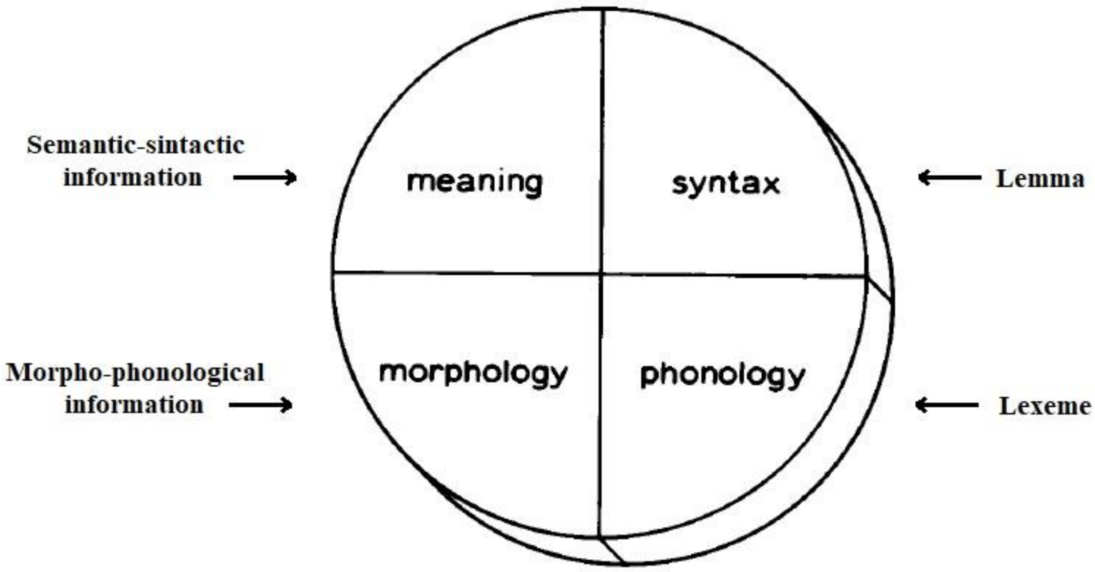

Figure 4: The internal structure of the lexical entry (adapted from Levelt 1989, p. 182)

Although Levelt’s representation shows each component of the lexical entry isolated from the others, these components are in fact highly integrated. This idea is well described in (Jiang, 2000)

> “An important feature of the lexical representation in L1 is that these different types of information are highly integrated within each entry, such that once the entry is opened, all the information automatically becomes available.”

Consequently, when a lexical entry becomes activated in an individual’s lexicon during the process of visual word recognition, for instance, information about the word’s semantic, syntactic and morphophonological representations are also accessed. Therefore, this is precisely where the effect of priming plays a part. According to the literature, those bits of information retrieved from the lexicon will remain active for a brief period of time, possibly affecting subsequent processing of input.

As previously observed, much work has been done concerning lemmatic interactions in the bilingual lexicon. However, it is important to say that controversial results supporting both, the Independence Hypothesis and the Interdependence Hypothesis, have been reported by different authors. For instance, as pointed out by Heredia (2008), Scarborough et. al. (1984) investigated the phenomenon of language transfer (more commonly referred to as priming in the literature) in Spanish-English bilinguals. By using a lexical decision task, they tried to observe if a bilingual would recognize a lexical item in the L2 faster, had its translation been shown previously to the subject. That condition was compared with an English-English one, in which the subject was exposed to the same word in the L2 twice. The results showed that priming only happened in the English-English condition. There was no language transfer in the Spanish-English condition, which supports the independence hypothesis.

Other studies, however, have presented findings that contradict the ones discussed above. Borodistky et. al. (2003) designed an experiment in which the subjects (German-English and Spanish-English bilinguals) were presented with words, which they were supposed to characterize with the three first adjectives that they could think of. Bearing in mind that the names for the same inanimate object may have different genders in different languages, the researchers wondered if a speaker would look for details in an object in order to associate their conceptual representations with the gender given by the language. The main goal, however, was to see if those representations of gendered words in L1 would affect adjective selection in L2. The words used in the experiment had opposite genders in German and Spanish, and were neutral in English, for example: der Schüssel (masc.), la llave (fem.) and the key. The results showed that speakers of German as L1 would systematically produce more adjectives with a masculine connotation when characterizing the genderless word in English, and opposite would happen with native speakers of Spanish. Their findings indicate that grammatical gender affects the conceptual representation of objects in L1, and also that conceptual transfer occurs from L1 to L2.

2.3 Masked phonological priming: Insights from Rastle and Brysbaert (2006) and Souza and Dias (2018)

Rastle and Brysbaert (2006) sought to clarify the discussion on the effect of facilitation caused by the phenomenon of phonological priming. According to the authors, phonological priming is:

> […] revealed when responses to a target word are faster or more accurate when those targets are preceded by phonologically identical nonword primes than when they are preceded by phonologically dissimilar orthographic control primes. (Rastle & Brysbaert, 2006)

The authors designed two lexical decision experiments so as to explore this effect by means of comparing the subjects' reaction time (RT) in relation to the conditions of pseudohomophone-target and graphemic control-target pairings. In both experiments, the words were recognized faster when preceded by the pseudohomophone primes. In the first, there was in average a 13ms facilitation effect, which means that the subjects, when exposed to a pseudohomophone prime, were faster to decide whether the target word was or not a real word of the English Language. However, as discussed by the authors, in the first experiment, pseudohomophone primes were always followed by a YES response, which could have caused the observed effect to arise due to participants' sensitivity to the status of the primes. Nevertheless, after controlling for this possible confounding variable in the second experiment, they found that responses to target words were also facilitated when they were preceded by pseudohomophone primes as compared to when they followed graphemic control primes.

Based on the results, the researchers evaluated the weak phonological theory of word recognition offered by Coltheart et al. (2001), implemented as the DRC. They wanted to identify the set of conditions under which there would be scope for a simulation of fast phonological priming. In simple lines, the procedure was to present the DRC model with the 112 phonological and 112 graphemic control primes used in their experiments under different sets of parameterizations and assess the influence of these parameter alterations over a 100-cycle period in activation of orthographic target words and the total activation of units in the orthographic lexicon. Rastle and Brysbaert ran a series of 6 simulations in order to assess the model's efficiency in describing the fast phonological priming effect found in their experiments. In the first simulation, they used the standard set of parameters of DRC for lexical decision as described by Coltheart et al. (2001), and the results showed no scope for producing a phonological priming effect. Phonological and graphemic control primes had similar influence on the activation of target words. Therefore, they concluded that modifications in the parameters should be made in order for more accurate responses to be achieved.

In simulation 2, they explored the possibility of a DRC model that processed phonology more rapidly, and whether that would provide scope for the simulation of the effect under analysis. Yet, the results showed that the alteration did not affect the results in a statistically significant manner. Therefore, in order to better understand the role of phonological assembly in word recognition, Rastle and Brysbaert decided to completely disable it in the third simulation. The outcome showed that, under the standard set of parameters adopted, phonological information had very little influence on the activation of orthographic lexical entries. Thus, the researchers concluded that more substantial changes in the balance between the two routes were required.

For simulation 4, the parameters that controlled the phonological route were adjusted in order to increase the role of phonological units and decrease the possibility of inhibition from letter units to orthographic units. This change in parameter values enabled the phonology to play a much more significant role in the activation of target words and yielded results that corroborate their data from the primary experiments. Nevertheless, the parameter alterations, specifically the decrease in value for the inhibition from letter units to orthographic units, created an unwanted effect that caused total orthographic activation to be achieved more precisely with the graphemic controls than with the phonological primes. So, a fifth simulation was designed to tackle that problem.

In the fifth simulation, the experimenters wanted to see if minor changes in the previous set of parameters, that is, raising the value of the parameter that controls the grapheme-to-phoneme route, would yield total orthographic activation from phonological primes to a greater extent and produce accurate results in early stages of processing. As predicted, the adjustment generated the results expected, however, this improvement came with a cost. With the last few alterations made, the model became unable to read exception words aloud due to the greater importance given to phonology assembly. The authors conjectured that it would be reasonable to assume one set of parameters for lexical decision tasks and another for reading aloud.

Finally, the researchers designed simulation 6 in an attempt to offer a justification for using the set of parameters in simulation 5 for lexical decision and the standard set of parameters used in simulation 1 for reading aloud. They departed from the understanding that, in lexical decision tasks, readers have to discern between word and nonword stimuli, and any strategic adjustments in the parameters meant to fit the specificities of this kind of task would have to improve the model's ability to make that discrimination. The results showed that, under the parameters used in simulation 5, the model's performance concerning the distinction was highly deficient. Consequently, Rastle and Brysbaert concluded that the use of the parameters from simulation 5, which yielded the most accurate results for lexical decision, was not justified by the specificities of the task itself. Finally, the researchers suggested that more research should be done on the relevance of phonological assembly in word recognition and on its role in the DRC model.

Souza and Dias (2018) replicated the lexical decision experiment done by Rastle and Brysbaert (2006) with native speakers of Brazilian Portuguese and Portuguese-English Bilinguals. Initially, they adapted the experiment to Brazilian Portuguese in order to see if the same effect would be found in the subjects' L1. So the first experiment compared the three following conditions: 1. the subliminal presentation of pseudohomophone primes whose first graphemes (<x>, <ch>, <s>, <c> and <k>) corresponded to the consonantal onsets (/ʃ/, /s/ and /k/) of the first syllable in the target words (eg.: koifa – COIFA); 2. the presentation of identical graphic representations (eg.: chacal – CHACAL); 3. the presentation of prime and target pairs that did not bare any phonological, graphemic or semantic relation with each other (eg.: tundra – ELFO). Surprisingly, no facilitation effect was observed in the first condition of this experiment. The researchers hypothesized that this happened due to a frequency effect, given that the words selected were highly frequent in the language. Thus, another experiment was designed, only this time the words selected were under the 40.000 most frequent words of the language. Under these experimental conditions, a statistically significant facilitation effect was observed.

Having found a facilitation effect due to phonological priming in Brazilian Portuguese, the researchers moved to a second stage. In this phase of the study, they asked whether the same effect would be observed among Brazilian Portuguese-English bilinguals, when performing in their L2. To investigate that, they employed the same stimuli used with monolinguals of English by Rastle and Brysbaert (2006). The analysis of the data showed a facilitation effect that happened only in very specific contexts. Souza and Dias (2018) reported that the effect only emerges in the access of target words that bear phonographemic resemblance with words of Brazilian Portuguese. That finding, by itself, indicates a level of interdependence among a bilingual's languages and their formal representations.

This data opens new doors for further investigation on what exactly the role of phonological and graphemic representations in word recognition is. Moreover, these findings reinforce the need for additional research on the interactions of formal representations in a bilingual's lexicon, which might foster new insights and reinterpretations of the architecture of the DRC model.

METHODOLOGICAL ISSUES

As stated before, analysing each of the variables and effects that have been investigated in the literature on reading would far surpass the aims of the current study. Instead, in this chapter, I will consider some of the main issues that have been examined by other researchers with regard to VWR, which will inform my discussion of the findings reported by Souza and Dias (2018). The fundamental questions I try to elaborate upon here is: What variables are important in the visual recognition of individually presented words?

3.1 Length

"There is clear evidence that longer words take more time in perceptual identification […] and produce longer fixation durations in reading […], but the effect of length in lexical decision and naming performance has been a bit more inconsistent[…]" (Balota et. al., 2006)

This discussion is expanded and other issues are brought to light by Rastle and Coltheart (1998), Yap and Balota (2015); Balota et al. (2006); Randall (2007).

3.2 Word frequency

As pointed out by Yap and Balota (2015, p. 32), "In order to understand the processes underlying visual word recognition, researchers have identified the many statistical properties associated with words […] influence performance on different word recognition tasks.". With respect to word frequency, Balota et al. (2006, p.312) have noted that "the frequency with which a word appears in a language has an influence on virtually all word recognition tasks." In general, high frequency words are recognized faster than low frequency words (Norris, 2013) However, Balota et al. (2006) have also observed that "Although it would appear to be obvious why word-frequency modulates performance in word recognition tasks" Indeed, word frequency has been a central issue for models of reading. (Randall, 2007)

An evaluation of different explanations for the frequency effects present in the literature, as discussed by Randall, (2007): Foster’s autonomous serial search model > Logogen Model > IAC model > DRC model.

3.3 Digraphs/Bigrams

“Although there is clear evidence that single letters may be units of orthographic representation, there is also evidence that they are not the only orthographic units.” (Rapp & Fischer-Baum, 2014, p. 344)

“Houghton and Zorzi (2003) proposed that the single or multiple letter sequences that correspond to single phonemes are represented as single orthographic units.” (Rapp & Fischer-Baum, 2014, p. 344)

Evidence from differences in handwriting times of French words related to the presence or absence of digraphs. (Rapp & Fischer-Baum, 2014, p. 344)

“In addition, Fischer-Baum and Rapp (in preparation) specifically presented evidence that the constituents of digraphs ‘travel’ together” (Rapp & Fischer-Baum, 2014, p. 344)

Justi and Pinheiro (2006) for bigram frequency as a possible confounding variable in studies of neighborhood effects.

Whammy effect (Rastle & Coltheart, 1998, p. 280)

“Not all multiletter graphemes are harmful to processing, however” (FF > /f/)

Other multiletter graphemes produce extremely destructive whammies” (EIGH > /l/)

3.4 Words vs Nonwords

As previously noted, according to a dual-route perspective on VWR, readers have at their disposal two different routes for converting print to speech.(Coltheart et al., 1993)

> By this view, any word the reader has learned is represented as an entry in a mental dictionary or internal lexicon, and such words can be read aloud by accessing the word’s lexical entry from its printed form and retrieving from that entry the word’s pronunciation. (Coltheart et al., 1993, p. 589)

> Readers can, of course, read aloud pronounceable letter strings that they have never seen before: nonwords, for example. Nonwords do not possess lexical entries. Therefore, dual-route theorists claim, the reader must also have available a nonlexical route for reading aloud: a system

> of rules specifying the relationship between letters and sounds in English. (Coltheart et al., 1993, p. 589)

> This nonlexical route allows the correct reading aloud of pronounceable nonwords and of words that obey the spelling-sound rules of English, but it delivers incorrect translations of the “exception” or “irregular” words of English, words like *pint* or *colonel*, that disobey the rules. (Coltheart et al., 1993, p. 589)

> In summary, then, the lexical route will succeed when the input string is a word but will deliver no output when it’s a nonword, whereas the nonlexical route will deliver correct output when the input string is a nonword or a regular word and will deliver incorrect output (a “regularization error”) when the input string is an exception word. (Coltheart et al., 1993, p. 589)

However, as pointed out by (Coltheart & Rastle, 1994, p. 484), “Nonwords are not entirely processed by the nonlexical route[…]. They activate word neighbors in the orthographic lexicon, which then activate phonological representations of words and their phonemes.”

3.5 Regularity vs Consistency

“The regularity of a word is defined by whether it conforms to the most statistically reliable spelling-to-sound correspondence rules in the language.” (Yap and Balota, 2015, p. 34)

Consistency reflects the extent to which a word is pronounced like similarly spelled words. Yap and Balota. (2015)

“Regular words are those that obey the grapheme–phoneme correspondence rules of English: words like maid or cave. Irregular words are those words which violate such rules: words like said or have. Regular words can be correctly read by the lexical and the non-lexical reading routes, but irregular words can be read correctly only by the lexical reading route: the non-lexical route will get them wrong (it will read said to rhyme with ‘maid’, have to rhyme with ‘cave’—and yacht to rhyme with ‘matched’).” (Coltheart, 2006, p. 9)

“A word is regular if its pronunciation is correctly generated by a set of grapheme-phoneme correspondence rules. Hence for some words there is room for debate about whether the word is regular but this will always be a debate about whether a certain GPC rule is appropriate.” (Coltheart et al., 2001, p 231)

In general, studies have shown that rime consistency has a larger influence than regularity on latencies and errors. Balota et al. (2006, p. 301)

"Because many irregular words (i.e., words whose pronunciation violates grapheme-phoneme correspondence (GPC) rules) are also inconsistent at the rime level, regularity and consistency have typically been confounded." Balota et. al. (2006)

Regular Consistent words and Regular Inconsistent words: (Coltheart et al., 1993, p. 602)

Different definitions for consistency in the literature: (Rastle & Coltheart, 1999, p. 485); (Coltheart et al., 2001, p. 232)

Position of irregularity modulates the regularity effect in naming: (Rastle & Coltheart, 1999)

3.6 Graphemes vs Bodies

"Almost all of the empirical work on the effects of consistency on reading aloud has used the same definition of consistency: A word is consistent if the pronunciation of its orthographic body (the phonological rime) is the same in all words that share it's orthographic body." (Rastle & Coltheart, 1999, p. 485)

"[…] the pronunciation that skilled readers choose are generally those that the GPC procedure chooses." (Coltheart et al., 1993, p. 603);

3.7 Neighborhood Effects

"Almost all studies of neighborhood effects have use Coltheart's N as a measure of neighborhood density."(Norris, 2013, p. 520)

A better measure of density that accounts for more unique variance in lexical decision times is provided by the orthographic Levenshtein distance (OLD20)." (Norris, 2013, p. 520)

Orthographic and Phonological neighborhood effects: Frisson et al. (2014) Balota et al. (2006), Yap and Balota (2015), Randall (2007), Souza and Dias (2018), Justi et al. (2013), Justi and Pinheiro (2006)

Neighborhood size and Neighborhood frequency effects on Lexical Decision (Coltheart et al., 2001, pp. 229-230); (Justi et al., 2013)

3.8 The role of sound in reading

“One of the most significant controversies in the theory of reading concerns the role of phonology in visual word recognition.”(Rastle and Brysbaert, 2006, p. 98)

“There is broad consensus the recognition of a visually presented word can be influenced by the computation of its phonology. Perspectives differ, however, with regard to the extent to which phonology influences the recognition of printed words.” (Rastle & Brysbaert, 2006)

The large majority of studies on phonological coding in word identification comes from single-word identification tasks. Pollatsek (2015, p. 186)

“Most of the literature on the role of phonological coding in lexical access has been on the coding of phonemes.” Pollatsek et al. (2015, p. 186)

Masked phonological priming: Rastle and Brysbaert (2006); Souza and Dias (2018);

Can phonetics affect VWR? Norris (2013)Pollatsek (2015); Wheat et al. (2010)

CONCLUSIONS

In the present study, I have tried to review the literature on visual word recognition, with particular focus on the role of lexemic-level representations in such process. Moreover, by means of a discussion of the results reported by Souza and Dias (2018), I intended to raise some issues that may be important for future empirical research on the topic. Unfortunately, due to adverse circumstances, I have not yet been able to develop that discussion (in written form) to the level that I had intended when I first outlined this project. However, the literature review has brought to my attention conflicting perspectives on these issues and different methodological problems that have allowed me to envision some of the next steps we should take to advance our knowledge in this area.

Baring in mind that the discussion in this manuscript, in its present condition, is not fully refined, I will conclude by suggesting possible issues that future research on VWR with bilinguals may need to consider. Firstly, although Rastle & Brysbaert (2006) have concluded, based on an exhaustive literature review, that effects of masked phonological priming in English have been found and may be explained by the DRC model, many new methodological problems emerge when these effects are investigated in a bilingual context. After closer analysis of the experimental design proposed by Souza and Dias (2018), I believe, in line with what we had concluded previously, that a phonological priming effect has indeed been found for skilled readers of Brazilian Portuguese when reading in their L1, and that this effect is modulated by the frequency of target items. Furthermore, and also in agreement with our earlier interpretation of the results from experiment 2, I consider our findings to be evidence that the mechanism involved in the VWR of words in a second language, for highly educated bilinguals of the pair Brazilian Portuguese - English performing a lexical decision task, is similar to the one used in the recognition of low frequency words in their native language, being supported, however, by grapheme-phoneme associations available in the L1.

However, based on the remarks made by Frisson et al. (2014) on the overlap between orthographic and phonological representations in fast and masked priming experiments and on the considerations made by (Wheat et al., 2010) on the spatiotemporal pattern of brain responses induced by a masked pseudohomophone priming tasks, I have come to the conclusion that we have a long way to go before we can say that we fully understand the basic processes involved in visual word recognition. Once we consider the implications of these observations for future experimental research with bilinguals, this perception, which is, at the moment, very rudimentary and personal, becomes even more clear.

On that note, I feel that it is important for me to say that I have only been acquainted with the specific literature examined by Wheat et al. (2010) for a very brief period of time. Nevertheless, the initial impressions these findings have generated on me have led me to believe that a combination of lexical decision tasks and neuroimaging techniques might be precisely what we need to investigate in more detail some of the fundamental issues raised by the present study. Moreover, in line with Norris's (2013) evaluation of the current models of VWR, I also believe that “There is a need for more integrated theories of word recognition.” (Norris, 2013, p. 523).

In addition, my review of the literature has indicated that it is highly important that we take into consideration, and actively control for, possible orthographic neighborhood effects that might arise in lexical decision tasks, especially when the visual recognition of nonwords is involved. This is suggested because, as acknowledged by the proponents of the DRC model, although the lexical route of the model cannot read nonwords, these items can still activate orthographic neighbors in the orthographic lexicon, leading to the activation of their respective phonological representations, which would conflict with the output given by the GPC route.

This has been shown to affect naming latencies, but it may very well have impacts on lexical decision. Importantly, some work has been done with natives of Brazilian Portuguese concerning specifically orthographic neighborhood effects in lexical decision tasks of the Go/No-go type (e.g.: Justi and Pinheiro, 2006) and in reading aloud tasks (e.g.: Justi et al., 2013). However, very little work has been done with respect to masked phonological priming effects in this language. As far as I have been able to research, it seems that Souza and Dias (2018) have indeed pioneered this kind of research with Brazilian Portuguese Speakers. Thus, in line with Randall's (2007) remarks on how important it is for one to consider data from different languages other than English when developing mental models of reading, I believe it is vital for the expansion of our understanding of VWR and reading in general that we explore further explore these issues in Brazilian Portuguese, by employing different tasks (and paradigms) with the aid of neuroimaging techniques. This would allow us to not only observe the effects through behavioral measurements, but it would also give us a better understanding of which areas of the brain are activated during these processes. Moreover, since different patterns of activation and distinct areas of the brain have been shown to be linked to different components of these processes (see Wheat et al., 2010, for further discussion), by using these techniques in conjunction with lexical decision tasks, for instance, we would be able to make more precise suggestions as to how current models of reading should be adapted in order to account for the plethora of conflicting effects found in the literature. Furthermore, as pointed out by Souza and Dias (2018), it is highly desirable that we confirm our interpretations of the effects reported by employing tasks which involve the production of the items utilized in this study. That would give us a better understanding of how the items are being processed by our subjects, which, in turn, would allow us to interpret the lexical decision data in more detail.

Concerning the orthographic neighborhood effects that have found in Brazilian Portuguese (see Justi and Vieira Pinheiro, 2006; and Justi et al., 2013 for a discussion.), and their possible interactions with phonological priming effects, I believe, that further and more careful investigation of this interaction should be the next step in broadening our understanding of the processes involved in VWR. Importantly, these orthographic neighborhood effects actively controlled by Souza and Dias, (2018), and the overlap between orthography and phonology in the first experiment was partially overlooked. For instance, if we take a closer look at the items used in the first experiment reported in this study, which was done with monolinguals of Brazilian Portuguese, we will find a discrepancy in the orthographic overlap between primes and targets when we compare the lists of high and low frequency items. This is important because the difference between lists concerning orthographic overlap could have influenced our results.

Furthermore, and crucial to the analysis of these effects, is the fact that, in their experiment, Souza and Dias (2018) employed a different experimental design than what had been done by Rastle & Brysbaert (2006). Specifically, while the latter emphasized the importance of comparing a pseudohomophone condition with a graphemic control condition, the former designed an experiment in which the pseudohomophone condition was compared with a full identity condition and with unrelated word primes. Critically, Rastle and Brysbaert (2006, p. 115) argued that "An unrelated control condition (present in many of the studies in Table 4) does not reveal information with respect to the issue of phonological priming […]" This idea is more clearly stated in the section dedicated to their discussion of what constitutes an adequate graphemic control:

> Phonological primes typically overlap their targets on both phonological and orthographic dimensions (e.g., kake–CAKE). The influence of phonological overlap alone is therefore obtained by comparing the phonological priming condition to a graphemic control priming condition (e.g., pake–CAKE), the logic being that any additional priming observed in the phonological priming condition must be due to phonological overlap alone. This logic hinges on the requirement that phonological primes and graphemic control primes share equivalent orthographic similarity with their targets. If targets are more orthographically similar to their phonological primes than to their graphemic control primes, then any benefit yielded by the phonological primes can be ascribed to the ortho- graphic similarity between primes and targets instead of their phonological similarity. Conversely, if targets are more orthographically similar to their graphemic control primes than to their phonological primes, then any additional benefit yielded by phonological overlap may be hidden. Rastle & Brysbaert, (2006, p. 111)

Therefore, although I believe that the results reported by Souza and Dias (2018) suggest an effect of phonological priming for monolinguals of Brazilian Portuguese, it is also my understanding that more research, which carefully attends to the interactions between orthographic and phonological representations in during the process of VWR, must be done.

Also, based on the observations made by Frisson et al. (2014) on the different effects found in tasks that use masked priming and fast priming paradigms, I think that further exploration of the findings reported by Souza and Dias (2018) by means of the latter paradigm could be informative as to how generalizable these findings can be. Specifically, Frisson et al.

(2014) investigated to what extent activation of orthographic and phonological information, either combined or in isolation, would effect visual word recognition. The focus of their study was to evaluate these interactions when words were read in context. For that, they developed a reading task in the fast priming paradigm. They also investigated these interactions during single word recognition, by means of a lexical decision task in the paradigm of masked phonological priming. By contrasting different types of overlap between primes and targets and different prime durations in both paradigms, the authors found conflicting results. In the fast priming paradigm, they found facilitatory priming effects when phonology and orthography overlapped, and when primes and targets only overlapped orthographically. In the masked priming paradigm, however, they found inhibitory effects for end overlap between primes and targets, irrespective of phonological overlap. No difference was found for beginning overlap, which presents a challenge for a dual-route perspective in which the GPC route operates sequentially in VWR, processing words from left to right, letter by letter. Moreover, the authors reported that when the overlap between primes and targets was mainly of phonological nature, facilitation was only found in the fast priming paradigm with longer prime durations, whereas, in the masked priming paradigm, no differences were found. Frisson et al. (2014) interpreted these conflicting effects as suggestive that fast priming and masked priming paradigms may tap into different types of processing, with fast priming results reflecting an earlier stage of processing than masked priming results. Therefore, I believe that attempting to replicate the results reported by these authors with monolinguals of Brazilian Portuguese and Brazilian Portuguese – English bilinguals, in both fast priming and masked priming paradigms, would be highly informative in as much as the interactions between orthographic and phonological representations during VWR are concerned.

As previously noted, one of the final remarks made by Norris (2013) was that current models of reading have focused on specific subcomponents of the reading process. (see pages 522, 523 and box 4 of that study for further discussion). In this regard, during his discussion of such models, he goes even further, by saying that "Whereas models of eye-movement control during reading tend to make simplifying assumptions about how individual words are identified [17–19], models of word recognition rarely consider how they might be integrated with models of reading." (Norris, 2013, p. 520). Baring in mind that much more empirical research needs to be done in order for us to have a more refined comprehension of these initial processes involved in VWR, I find that the results reported by Frisson et al. (2014) and the discussion on mental models of reading made by Norris (2013) at least point to the fact that, in advancing our efforts to understand such processes, we need to employ and carefully consider data coming from different task types and paradigms. This is further corroborated by (Balota et al., 2006), who repeatedly stated, in their chapter on VWR, based on their review of this literature, that task constraints strongly modulate the influence of a variable. Finally, it is my understanding that this is an enterprise that should easily provide new empirical questions for a decade’s worth experimental research.

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