ESTUDIOS

Revista de Investigación en **Logopedia**
ISSN-e: 2174-5218

EDICIONES COMPLUTENSE

https://dx.doi.org/10.5209/rlog.81781

Propagación de la activación fonológica en la dislexia a lo largo de la vida

Lucía Buil-Legaz[1], Javier Rodríguez-Ferreiro[2], Fernando Cuetos[3], Paz Suárez-Coalla[3]

Received 2nd May 2022 / First revision 11th July 2022 / Accepted 10th November 2022

Resumen. En este trabajo estudiamos el curso evolutivo de la propagación de la activación fonológica en personas con y sin dislexia mediante una versión de la tarea de falsa memoria de Deese/Roediger-McDermott. Se entiende que el efecto de falsa memoria refleja la propagación de la activación desde los estímulos presentados a las palabras similares en el léxico. Evaluamos a 35 voluntarios con dislexia y a un grupo control emparejados por edad (entre los 6 y los 58 años). Primero se les presentaron seis listas de diez palabras de dos sílabas cada una, todas las cuales compartían una sílaba con una palabra de referencia no presentada. A continuación, respondieron a un cuestionario de reconocimiento que incluía 24 palabras presentadas, 18 palabras no presentadas relacionadas fonológicamente y 12 palabras no presentadas no relacionadas. El reconocimiento falso de palabras relacionadas fonológicamente aumentó con la edad en el grupo de control, pero se mantuvo en niveles muy bajos en el grupo con dislexia. El presente estudio indica la existencia de un déficit en la propagación de la activación fonológica en personas con dislexia a lo largo de la vida.
Palabras clave: Deese/Roediger-McDermott; Dislexia; Falsos recuerdos fonológicos; Tendencia evolutiva.

[en] Spreading of phonological activation in dyslexia throughout life

Abstract. We studied the developmental course of the spreading of phonological activation in individuals with and without dyslexia by means of a phonological version of the Deese/Roediger-McDermott false memory task. The false memory effect is assumed to reflect the spreading of activation from the presented stimuli to similar words in the lexicon. We assessed 35 volunteers with dyslexia and a group of matched controls with ages ranging from 6 to 58 years. They were first presented with six lists of ten two-syllable words each, all of which shared one syllable with a reference unpresented word. Then, they answered a recognition questionnaire including 24 presented words, 18 phonologically related unpresented words, and 12 unrelated unpresented words. False recognition of phonologically related words increased with age in the control group but stayed at very low levels in the dyslexia group. Our study indicates the existence of a deficit in the spreading of phonological activation in individuals with dyslexia throughout life.
Keywords: Deese/Roediger-McDermott; developmental trend; Dyslexia; Phonological false memories.

Cómo citar: Buil-Legaz, L., Rodríguez-Ferreiro, J., Cuetos, F. y Suárez-Coalla, P. (2023). Propagación de la activación fonológica en la dislexia a lo largo de la vida. *Revista de Investigación en Logopedia* 13(1), e81781. https://dx.doi.org/10.5209/rlog.81781

Introduction

Individuals with dyslexia present difficulties in accurately and/or fluently recognizing words in print, as well as poor decoding and spelling abilities (Lyon, Shaywitz, & Shaywitz, 2003). These reading difficulties appear during reading acquisition in childhood and persist into adulthood despite compensation efforts (Bruck, 1990; Snowling, Muter, & Carroll, 2007; Suárez-Coalla & Cuetos, 2015a; Undheim, 2009).

Although theories based on visual processing impairments have been proposed (Demb, Boynton, & Heeger, 1997; Stein & Walsh, 1997; Vidyasagar & Pammer, 2010), most authors agree that a phonological deficit underlies the reading deficits associated with dyslexia (Lyon et al., 2003; Peterson & Pennington, 2015; Ramus & Szenkovits, 2008; Snowling, 1998). Evidence supporting the phonological deficit theory comes mainly from

[1] Investigació en Desenvolupament, Educació i Llenguatge (I+DEL), Institut de Recerca i Innovació Educativa (IRIE). Departament de Pedagogia Aplicada i Psicologia de l'Educació, Universitat de les Illes Balears, Spain
[2] Grup de Recerca en Cognició i Llenguatge, Departament de Cognició, Desenvolupament i Psicologia de la Educació, Institut de Neurociències, Universitat de Barcelona, Barcelona, Spain
rodriguezferreiro@ub.edu
[3] Departamento de Psicología, Universidad de Oviedo, Oviedo, Spain

studies reporting specific impairments in people with dyslexia within three domains: phonological awareness, as measured by tasks like phoneme depletion; verbal short-term memory, as measured by tasks like digit span or nonword repetition; and lexical retrieval, as measured by rapid automatic naming tasks (Cuetos, Martínez-García, & Suárez-Coalla, 2018; Ramus & Szenkovits, 2008; Wagner & Torgesen, 1987). Like in the case of specific reading difficulties, deficits in these domains of phonological processing have been shown to persist even in higher education students with a diagnosis of dyslexia (Bogdanowicz, Łockiewicz, Bogdanowicz, & Pąchalska, 2014; Suárez-Coalla & Cuetos, 2015b).

In the present study, we assess the phonological processing abilities of individuals with dyslexia from a different perspective: we study the spreading of phonological activation by means of a false memory task. The Deese/Roediger-McDermott paradigm (DRM; Deese, 1959; Roediger & McDermott, 1995) has usually been applied to the study of semantic processing. In this paradigm, the volunteers are presented with lists of words (e.g., “bed”, “rest”, “awake”, “tired”, “dream”, “wake”, “night”, “blanket”, “doze”, “slumber”, “snore”, “pillow”, “peace”, “yawn”, “drowsy”) semantically related to an unpresented reference word (e.g., “sleep”). Then, they are asked to recall the words presented or fill in a recognition questionnaire including some of the presented words as well as the reference word and other unpresented words. Participants in these experiments tend to falsely remember the critical lures almost as highly as presented targets (Reyna, Corbin, Weldon, & Brainerd, 2016).

The false memory effect has been interpreted in terms of associative activation of the word representations which are semantically related to the words presented during the study phase. For instance, the associative activation theory (Howe, Wimmer, & Blease, 2009) proposes that list items activate the critical lure through the process of automatic spreading of activation in the semantic network. Another influential account of false memory, the fuzzy trace theory (Reyna & Brainerd, 1995; Reyna et al., 2016), assumes that presented items generate both literal or verbatim traces as well as meaning or gist traces. Whereas both kinds of traces support true memories of presented words, gist traces can lead to falsely remembering critical lures, due to their semantic relation to the lists.

The most influential models of word recognition (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Plaut, 1997) postulate that when a word is presented, activation in the lexical system spreads to the representation of words similar to the given stimuli. Specifically, according to the Neighborhood Activation Model of word identification (NAM) by Luce and Pisoni (1998), phonological similarity among words is one of the principles that structure the mental lexicon. That is, phonologically similar words are closer to each other in the lexicon, forming phonological neighborhoods. The identification of a word depends on the successful discrimination of specific entries in the lexicon based on activation coming from the stimulus input. Importantly, activation levels received by the lexical entries are assumed to be a direct function of the similarity between the stimulus input and their corresponding phonological structure. In sum, a given auditory input activates a neighborhood of phonologically similar words, with higher activation levels for more phonologically similar items, and lower activation levels for less similar ones. This process is analogous to that thought to underlie semantic false memories, in which words semantically similar to a given one are activated. Hence, phonological false memories can be considered a measure of phonological processing in terms of spreading of phonological activation in the mental lexicon. Going back to the main focus of our study, if we assume that dyslexia is caused by a phonological processing deficit, we could expect phonological false memories to be affected in dyslexic volunteers.

Phonological false memories have already been observed in previous studies (Ballardini, Yamashita, & Wallace, 2008; McDermott & Watson, 2001; Sommers & Lewis, 1999; Westbury, Buchanan, & Brown, 2002). However, despite general similarities between the results observed in semantic and phonological false memory experiments some studies have pointed out that activation processes supporting phonological and semantic false memories might not be completely analogous (Finley, Sungkhasettee, Roediger, & Balota, 2017; Watson, Balota, & Roediger, 2003). Moreover, results seem to depend on the presentation modality (visual *vs* oral), population under study, test delay, or test type (recall *vs*. recognition) (Chang & Brainerd, 2021- for a review).

Of special interest to the present study are the results of previous research comparing the developmental trends of semantic and phonological false memories because they investigate how the maturity of the lexical network influences performance in false memory tasks. On the one hand, semantic false memories have consistently been shown to increase with age (Brainerd, Reyna, & Forrest, 2002; Howe et al., 2009). This increased rate of false memories can be interpreted as a side effect of more automatic or stronger activation spreading mechanisms in the mental lexicon. From the associative perspective, the developmental reversal (i.e. worse performance due to more semantically related false memories for older individuals) observed in semantic memories reveals an increase in the direct activation of the associative links between the concepts (Howe et al., 2009). Similarly, from the fuzzy trace theory point of view, this trend reflects the development of stronger connections between concepts (Brainerd, Reyna, & Ceci, 2008).

The results of studies assessing the developmental trend of phonological false memories, on the other hand, are not as consistent. Whereas some researchers have shown that phonological false memories decrease with age (Brainerd & Reyna, 2007; Dewhurst & Robinson, 2004; Holliday & Weekes, 2006) a more recent study (Swannell & Dewhurst, 2012) has replicated the developmental reversal observed in semantic false memory research. Swannell and Dewhurst (2012) argue that the differences between their results and those of previous research stem from methodological reasons, such as the length of study lists or whether they converge into a single critical word or they activate multiple ones (i.e. if they include words not related to the critical lure). Only longer lists with words converging into a single critical word allow for the developmental reversal to be observed, as they lead to greater dependence on gist traces or associative activation compared to shorter or divergent lists. In the context of the NAM (Luce & Pisoni, 1998), the mental lexicon of children is assumed to have more sparse or immature phonological neighborhoods than that of adults (Charles-Luce & Luce, 1995; Swannell & Dewhurst, 2012), which would explain the diminished rate of false memories in the former. In addition, regarding children with reading comprehension disabilities, Weekes and colleagues (2008) did not find differences when compared to a control group in phonological false recall nor false recognition, meanwhile, McGeown and colleagues (2014) found a negative relationship between false recall and phonological awareness in 8- and 11-years-old children.

Considering the disparity of previous results, the aim of this study is twofold. On the one hand, we will compare the spreading of phonological activation of volunteers with and without dyslexia. Following the phonological deficit hypothesis (Lyon et al., 2003; Peterson & Pennington, 2015; Ramus & Szenkovits, 2008; Snowling, 1998), we expect to find reduced phonological false memories in a group of dyslexic participants compared to their matched controls. On the other hand, we will study the presence of a developmental reversal in phonological false memory analogous to that observed with the semantic version of the paradigm. Following Swannell and Dewhurst (2012), given that we will use stimuli lists converging into a single reference word, we expect older participants to present higher false memory rates than younger ones. Given that a phonological impairment has been observed also in adults (Bogdanowicz et al., 2014; Hatcher, Snowling, & Griffiths, 2002), we could expect false memories to be reduced even in older volunteers in the dyslexia group.

Methods

Participants

We tested a group of 35 Spanish volunteers (16 females) with a prior diagnosis of dyslexia ranging from 6 to 58 years of age, mean = 21.98, *SD* = 14.64. We also recruited 33 (15 females) non-dyslexic volunteers matching the age and sex distribution of the dyslexia group to serve as control group, mean age = 22.26, *SD* = 15.12. The distribution of the participants' ages can be observed in Figure 1 in the results section.

All the participants with dyslexia completed a detailed questionnaire to obtain information about their reading and writing difficulties, family history of literacy problems, and history of language therapy. Children and adults with dyslexia reported spelling mistakes, as well as persistent difficulty finishing exams and homework, and extra homework practice intended to improve their reading and writing performance during schooling. In addition, we confirmed the diagnosis of dyslexia based on a test of general ability (Wechsler, 1981 for adults, 2001 for children), and a test of reading processes (for younger children: Cuetos, Rodríguez, Ruano, & Arribas, 2014; for older children and adults: Ramos-Sánchez & Cuetos, 2003). The reading battery includes tasks designed to evaluate all the processes involved in reading: letter identification; lexical and sub-lexical processing; syntactic processing; and reading comprehension. We inferred decoding ability and word recognition ability from speed and accuracy in the reading of words and pseudowords. All the participants from the dyslexic group showed levels of reading accuracy and speed at least 1.5 SD below the mean for their age, thus confirming their reading deficit. Moreover, they were significantly slower than those in the control group, who also completed word and pseudoword reading tasks (*p*s < .001). We gathered informed consent from the participants or their parents/tutors in the case of minors. The volunteers were treated following the Declaration of Helsinki for studies involving humans.

Materials

We selected six two-syllable Spanish words to be used as reference for the generation of the DRM lists (e.g., "cebo"). For each of them, we prepared one list of ten words, so we had six different lists of words. In each list, one-half of the words shared the first syllable or head of the reference word (e.g., "ceja", "celo", "cepo", "cera", "ceño"), whereas the other half shared its last syllable or tail (e.g., "lobo", "nabo", "robo", "sebo", "tubo"). The full list of stimuli is presented as Supplementary Material.

For the recognition test, we selected four of the presented words from each of the six lists (one list per reference word), two head-related and two tail-related to the critical item. We also included the reference words, along with two other unpresented but phonologically related words for each of them (e.g., "cena" and "rabo"). We will call all these unpresented related items critical lures. Finally, we also incorporated twelve new unpresented words not phonologically related to any of the critical items. All in all, the recognition questionnaire comprised 24 presented words (four words per list), 18 critical lures (the reference word plus two related but unpresented words per list), and 12 unpresented unrelated words. The presented, critical, and unrelated word categories were matched in lexical frequency, phonological neighborhood and biphoneme frequency (*ps* > .146) gathered from the EsPal lexical database (Duchon, Perea, Sebastián-Gallés, Martí, & Carreiras, 2013).

Procedure

The participants were tested individually. They were instructed that they were taking part in a memory experiment in which they would be presented with lists of words to be remembered. The stimuli were presented and responses were recorded by means of the DMDX software (Forster & Forster, 2003). The task, adapted by one of the authors from the one used by Weekes et al. (2008), consisted of two parts: the study phase (including presentation + recall) and the recognition phase. In the study phase, the volunteers were presented with six ten-word lists and after each list, they had to recall the stimuli. The words were recorded by one of the researchers and presented through headphones. The order of the lists and the words within the lists were randomly established for each participant. Auditory presentation of each word was preceded by an asterisk presented for 500ms on the computer screen as a fixation mark. The next fixation mark appeared 2.5 seconds after the word onset. After all the items in each list had been presented, the participant had 30s to orally recall all the words they could. Then, the next list started. The study phase was followed by the recognition phase, in which the participants listened to the 54 words selected for the recognition questionnaire in random order. Each word was preceded by an asterisk presented as a fixation point for 500ms. The volunteers were given up to four seconds to press one key if they thought the word had appeared in the previous phase, and a different one if they thought it was new.

Results

The full results are accessible at OSF. We present a summary of the raw recall and recognition proportions produced by each group in response to each word type in table 1. We conducted separate sets of linear regression analyses for recall and recognition scores. The regression models included group (control vs. dyslexia) and age, as well as the interaction between these two variables, as predictors for true and false memory measures. To avoid collinearity between the factors representing age and the interaction between age and group, we centered the continuous variable age on its mean before the calculation of the interaction term. We observed no cases with Cook's D values higher than 1, which indicates an absence of influential outliers in the dataset.

Table 1. Proportions of recalled and recognized items for each word type by the dyslexia and control groups

	Recall		**Recognition**	
	Dyslexia	**Control**	**Dyslexia**	**Control**
	M (SD)	***M (SD)***	***M (SD)***	***M (SD)***
Critical	0.02 (0.03)	0.04 (0.05)	0.22 (0.11)	0.27 (0.15)
Presented	0.41 (0.12)	0.44 (0.12)	0.57 (0.19)	0.7 (0.12)
Unrelated	–	–	0.22 (0.18)	0.18 (0.13)

True recall of the participants, $F(3, 67) = 10.429$, $p < .001$, $R^2 = .328$, adj$R^2 = .297$, was not influenced by group, as participants in the control and dyslexia groups accurately recalled a similar proportion of presented words, $\beta = -.177$, $p = .089$. Nevertheless, our analysis indicated that older participants correctly recalled significantly more presented words than younger ones, $\beta = .603$, $p < .001$. This effect was not modulated by group, $\beta = -.09$, $p = .537$.

In contrast, false recall of the participants, $F(3, 67) = 2.797$, $p = .047$, $R^2 = .116$, adj$R^2 = .074$, was affected by group, $\beta = -.304$, $p = .012$, so that control participants falsely recalled more unpresented critical words than volunteers in the dyslexia group. In this case, neither age, $\beta = .208$, $p = .215$, nor the interaction between age and group, $\beta = -.126$, $p = .452$, significantly influenced the volunteers' false recall rates.

Given that results in recognition tests depend on the degree of the participants' conservatism when responding, we applied the signal detection theory approach (Stanislaw & Todorov, 1999) and calculated two sensitivity scores for each participant (see Figure 1). Thus, we calculated d'_{true} values comparing hits to presented items with false alarms to unrelated unpresented items, as well as d'_{false} comparing the false recognition of critical items with false alarms to unrelated unpresented items. We followed the procedure recommended by Snodgrass and Corwin (1988) to correct our data when any of our participants presented zero hits or zero false alarms, which prevents the calculation of *d'* scores. Hence, we calculated the hit rate as (number of hits + 0.5)/(number presented items + 1), and the false-alarm rate as (number of false alarms + 0.5)/(number of new items + 1). The participants who are unable to discriminate between the respective item categories obtain *d*' values close to zero, whereas those who tend to accept target words (or critical words in the case of d'_{false}) and reject unpresented lures obtain higher *d'* values. Thus, higher d'_{true} and d'_{false} values respectively indicate higher corrected true and false memory rates.

Again, we conducted separate regression analyses including group (control vs. dyslexia) and age, as well as the interaction between these two variables, as predictors for each dependent measure, d'_{true} and d'_{false}. Regarding true recognition, $F(3, 67) = 9.063$, $p < .001$, $R^2 = .298$, adj$R^2 = .265$, both group, $\beta = -.292$, $p = .007$, and age, $\beta = .533$, $p < .001$, appeared to significantly influence the participants' d'_{true} scores. The analysis showed no significant interaction between these two variables, $\beta = -.116$, $p = .435$. Although control participants showed higher discriminability between presented and unrelated items than participants in the dyslexia group did, true recognition values increased with age in both groups.

As for false recognition, $F(3, 67) = 3.764$, $p = .015$, $R^2 = .151$, adj$R^2 = .111$, whereas group did not reach significance in this analysis, $\beta = -.206$, $p = .078$, the age of the volunteers significantly influenced their d'_{false} scores, $\beta = .462$, $p = .006$. Crucially, the interaction between age and group was also significant, $\beta = -.329$, $p = .048$, as false recognition of critical lures increased with age in the control group, while it remained low in the dyslexia group.

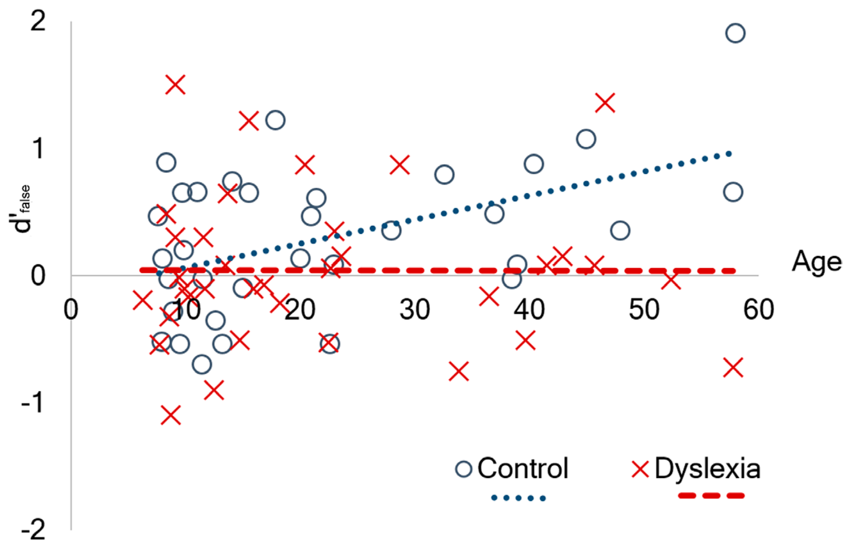

Figure 1. Sensitivity scores for false recognition in the dyslexia and control groups

Discussion

This research aimed to study the developmental trend of the spreading of phonological activation and compare that of people with and without dyslexia. We presented our participants with a phonological version of the DRM task, which is usually applied to the study of automatic spreading of activation during auditory word recognition. The task included two phases: the study phase (including presentation + recall) and the recognition phase.

Regarding the comparison between volunteers with or without specific reading disorders, our study provides further evidence in support of the phonological deficit hypothesis of dyslexia (Lyon et al., 2003; Peterson & Pennington, 2015; Ramus & Szenkovits, 2008; Snowling, 1998), coming from a new task previously applied to the study of semantic processing. In short, the phonological deficit in the dyslexia group was evidenced by false memory rates that remained lower through age, as well as by lower percentages of falsely recalled critical words as compared with those of the control group.

In more detail, the differences in phonological false recognition between the two groups of participants were mediated by age. Whereas younger volunteers in the dyslexia and control groups showed similar phonological false recognition rates, differences between the two groups increased the older they were. In other words, whereas false recognition increased with age in the control group, thus paralleling the effects observed in semantic false memory studies, it remained at very low levels in the dyslexia group. The developmental reversal of false memories is usually interpreted as evidence of a more mature activation-spreading system for older participants (Howe et al., 2009). With this in mind, our results could be taken as proof of the existence of a specific deficit in the automatic distribution of phonological activation during word recognition in people with dyslexia that persists throughout life. Although results regarding recall are known to be less sensitive to false memory effects (Roediger & McDermott, 1995), it is also worth noting that the proportions of false recall for the control participants were significantly higher than those for the volunteers in the dyslexia group. Following the fuzzy-trace theory, this suggests stronger reliance of control participants on phonological gist (Reyna & Brainerd, 1995), which could also be interpreted as an indicator of enhanced associative activation processes (Howe et al., 2009).

Besides comparing the spreading of phonological activation of individuals with and without dyslexia, with this research, we also aimed to more generally study the developmental trend of phonological false memories. Previous studies had observed a decrease in this effect with age (Brainerd & Reyna, 2007; Dewhurst & Robinson, 2004; Holliday & Weekes, 2006), contrasting with the developmental reversal of false memories consistently observed with the semantic variant of the DRM paradigm (Brainerd et al., 2002; Howe et al., 2009). Nevertheless, our results replicated those obtained by Swannell and Dewhurst (2012), whose data reflected an increase in false memory generation in older participants similar to that observed with the semantic version of the procedure.

The developmental reversal of semantic false memories is usually interpreted as a result of stronger connections (Brainerd et al., 2008) or enhanced associative activation mechanisms (Howe et al., 2009) in more mature semantic systems. Holliday and Weekes (2006) attributed the lack of developmental reversal of phonological false memories in their study to differences between the nature of the phonological and semantic networks. According to their interpretation, based on the assumptions of the fuzzy trace theory, the infinite amount of semantic interconnections between concepts allows for sustained growth of semantic gist throughout life. In contrast, the phonological gist would reach its maximum at relatively early ages due to the finite amount of phonological relations in a given language. Hence, whereas verbatim-based rejection abilities are not able to counteract the effects of increasingly stronger semantic gist, thus allowing for a rise of semantic false memories, they soon outgrow phonological gist, reducing false memories in the phonological domain.

Our findings, however, suggest that the developmental course of phonological false memories mirrors that of semantic ones. In the context of the NAM (Luce & Pisoni, 1998), this could be interpreted as evidence that the complexity of phonological neighborhoods increases with age (Charles-Luce & Luce, 1995; Swannell & Dewhurst, 2012). From a different point of view, it could reflect an increase in the direct activation of the associative links between nodes in the phonological lexicon as proposed by Howe et al. (2009) concerning semantic false memories.

Swannell and Dewhurst (2012) attributed the discrepancies between their results and those of previous studies to methodological reasons, such as differences in list length and the degree of convergence of the words in each list. On the one hand, they argued that longer lists, like those of 14 associates included in their study, impose greater memory demands, leading to increased reliance on associative activation compared to the shorter lists used in other studies: eight words per list in the case of Brainerd and Reyna (2007) and Dewhurst and Robinson (2004). In both Holliday and Weekes' (2006) and our experiment, the volunteers were presented with ten-word lists so the discrepancies regarding the false memory rates between the two studies cannot be attributed to list length differences in this case.

From our point of view, also following Swannell and Dewhurst (2012), the crucial difference between these two studies relies on the degree of convergence of the lists used in each of them. Thus, Holliday and Weekes used the lists constructed by Westbury et al. (2002), in which only some of the stimuli (six out of ten in the lists provided as examples by the authors) were phonologically related to the critical words. In our experiment, in contrast, all the words in each list shared one syllable with the reference word, which might have increased the degree of activation of critical lures, especially in the case of older volunteers with more mature phonological lexicons.

It should be noted that, in our study, the developmental reversal was only apparent in the false recognition proportions, and not in the false recall data, in which we observed no significant influence of the age of the participants. We believe this is due to a lack of enough variability in the results of the recall phase of the study, with most of the control volunteers recalling no phonologically related unpresented words at all, and the maximum amount of critical words reached being three. It could be considered that our false recall scores were very low, but, in general, recall tasks are known to be less sensitive to false memory formation than recognition tasks (Roediger & McDermott, 1995), so stronger effects can be expected to appear in the latter compared to the former.

In sum, our results show that phonological false memories follow the same developmental reversal previously observed with semantic false memories, as older participants falsely recognize more words than younger ones. Furthermore, the increase in phonological false memories is observed in control volunteers but not in participants with dyslexia, indicating the existence of a more immature phonological activation-spreading system in these individuals.

Assuming that phonological false memories can be considered a measure of phonological processing in terms of propagation of phonological activation in the mental lexicon, our study implies a relevant contribution to the literature about a phonological deficit in dyslexia, with special relevance to a transparent language.

Nevertheless, one limitation is that the number of volunteers we have tested is small. Although previous studies have included similar sample sizes (Brainerd et al., 2002; Brainerd et al., 2007), the heterogeneity of our participants makes this issue more concerning, especially in the case of dyslexic adults, who have been shown to present very distinctive profiles (Eden, et al., 2004; Soriano-Ferrer & Martínez, 2017; Swanson, 2012). In this sense, a useful direction for future research might be to include more participants, considering age subgroups, as well as individual differences.

References

Ballardini, N., Yamashita, J. A., & Wallace, W. P. (2008). Presentation duration and false recall for semantic and phonological associates. *Consciousness and Cognition*, *17*(1), 64–71. https://doi.org/10.1016/J.CONCOG.2007.01.008

Bogdanowicz, K. M., Łockiewicz, M., Bogdanowicz, M., & Pąchalska, M. (2014). Characteristics of cognitive deficits and writing skills of Polish adults with developmental dyslexia. *International Journal of Psychophysiology*, *93*(1), 78–83. https://doi.org/10.1016/J.IJPSYCHO.2013.03.005

Brainerd, C. J., & Reyna, V. F. (2007). Explaining Developmental Reversals in False Memory. *Psychological Science*, *18*(5), 442–448. https://doi.org/10.1111/j.1467-9280.2007.01919.x

Brainerd, C. J., Reyna, V. F., & Ceci, S. J. (2008). Developmental reversals in false memory: A review of data and theory. *Psychological Bulletin*, *134*(3), 343–382. https://doi.org/10.1037/0033-2909.134.3.343

Brainerd, C. J., Reyna, V. F., & Forrest, T. J. (2002). Are young children susceptible to the false-memory illusion? *Child Development*, *73*(5), 1363–1377. https://doi.org/10.1111/1467-8624.00477

Bruck, M. (1990). Word-recognition skills of adults with childhood diagnoses of dyslexia. *Developmental Psychology*, *26*(3), 439–454. https://doi.org/10.1037/0012-1649.26.3.439

Charles-Luce, J., & Luce, P. A. (1995). An examination of similarity neighbourhoods in young children's receptive vocabularies. *Journal of Child Language*, *22*(3), 727–735. doi:10.1017/S0305000900010023

Chang, M., & Brainerd, C. J. (2021). Semantic and phonological false memory: A review of theory and data. *Journal of Memory and Language*, 119, 104210. https://doi.org/10.1016/j.jml.2020.104210

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review*, *108*, 204–256. https://doi.org/10.1037/0033-295X.108.1.204

Cuetos, F., Martínez-García, C., & Suárez-Coalla, P. (2018). Prosodic Perception Problems in Spanish Dyslexia. *Scientific Studies of Reading*, *22*(1), 41–54. https://doi.org/10.1080/10888438.2017.1359273

Cuetos, F., Rodríguez, B., Ruano, E., & Arribas, D. (2014). PROLEC-R. Batería de Evaluación de los Procesos Lectores. *Batería de Evaluación de Los Procesos Lectores*.

Deese, J. (1959). On the prediction of occurrence of particular verbal intrusions in immediate recall. *Journal of Experimental Psychology*, *58*, 17–22. https://doi.org/10.1037/h0046671

Demb, J., Boynton, G., & Heeger, D. (1997). Brain activity in visual cortex predicts individual differences in reading performance. *Proceedings of National Academy of Sciences*, *94*(24), 13363–13366. https://doi.org/10.1073/pnas.94.24.13363

Dewhurst, S. A., & Robinson, C. A. (2004). False Memories in Children: Evidence for a Shift from Phonological to Semantic Associations. *Psychological Science*, *15*(11), 782–786. https://doi.org/10.1111/j.0956-7976.2004.00756.x

Duchon, A., Perea, M., Sebastián-Gallés, N., Martí, A., & Carreiras, M. (2013). EsPal: One-stop Shopping for Spanish Word Properties. *Behavior Research Methods.*, *45*, 1246–1258. https://doi.org/10.3758/s13428-013-0326-1

Eden, G. F., Jones, K. M., Cappell, K., Gareau, L., Wood, F. B., Zeffiro, T. A., ... & Flowers, D. L. (2004). Neural changes following remediation in adult developmental dyslexia. Neuron, 44(3), 411-422. DOI: 10.1016/j.neuron.2004.10.019

Finley, J. R., Sungkhasettee, V. W., Roediger, H. L., & Balota, D. A. (2017). Relative contributions of semantic and phonological associates to over-additive false recall in hybrid DRM lists. *Journal of Memory and Language*, *93*, 154–168. https://doi.org/10.1016/J.JML.2016.07.006

Forster, K. I., & Forster, J. C. (2003). DMDX: A Windows display program with millisecond accuracy. *Behavior Research Methods, Instruments and Computers*, *35*, 116–124. https://doi.org/10.3758/BF03195503

Hatcher, J., Snowling, M. J., & Griffiths, Y. M. (2002). Cognitive assessment of dyslexic students in higher education. *The British Journal of Educational Psychology*, *72*(Pt 1), 119–133. DOI: 10.1348/000709902158801

Holliday, R. E., & Weekes, B. S. (2006). Dissociated developmental trajectories for semantic and phonological false memories. *Memory*, *14*(5), 624–636. https://doi.org/10.1080/09658210600736525

Howe, M. L., Wimmer, M. C., & Blease, K. (2009). The role of associative strength in children's false memory illusions. *Memory*, *17*(1), 8–16. https://doi.org/10.1080/09658210802438474

Luce, P. A., & Pisoni, D. B. (1998). Recognizing spoken words: the neighborhood activation model. *Ear and Hearing*, *19*(1), 1–36. doi: 10.1097/00003446-199802000-00001

Lyon, G. R., Shaywitz, S. E., & Shaywitz, B. A. (2003). A definition of dyslexia. *Annals of Dyslexia*, *53*(1), 1–14. https://doi.org/10.1007/s11881-003-0001-9

McBride, D. M., Coane, J. H., Xu, S., Feng, Y., & Yu, Z. (2019). Short-term false memories vary as a function of list type. *Quarterly Journal of Experimental Psychology*, 72(12), 2726-2741. https://doi.org/10.1177/1747021819859880

McDermott, K. B., & Watson, J. M. (2001). The Rise and Fall of False Recall: The Impact of Presentation Duration. *Journal of Memory and Language*, *45*(1), 160–176. https://doi.org/10.1006/JMLA.2000.2771

McGeown, S. P., Gray, E. A., Robinson, J. L., & Dewhurst, S. A. (2014). What factors underlie children's susceptibility to semantic and phonological false memories? Investigating the roles of language skills and auditory short-term memory. *Cognition*, 131(3), 323–329. https://doi.org/10.1016/j.cognition.2014.02.005

Peterson, R. L., & Pennington, B. F. (2015). Developmental Dyslexia. *Annual Review of Clinical Psychology*, *11*(1), 283–307. https://doi.org/10.1146/annurev-clinpsy-032814-112842

Plaut, D. C. (1997). Structure and function in the lexical system: Insights from distributed models of word reading and lexical decision. *Language and Cognitive Processes*, *12*, 765–805. https://doi.org/10.1080/016909697386682

Ramos-Sánchez, J. L., & Cuetos, F. (2003). *PROLEC-SE : evaluación de los procesos lectores en alumnos del tercer ciclo de educación primaria y educación secundaria obligatoria*. Madrid: TEA Ediciones.

Ramus, F., & Szenkovits, G. (2008). What Phonological Deficit? *Quarterly Journal of Experimental Psychology*, *61*(1), 129–141. https://doi.org/10.1080/17470210701508822

Reyna, V. F., & Brainerd, C. J. (1995). Fuzzy-trace theory: an interim synthesis. *Learning and Individual Differences*, *7*, 1–75. https://doi.org/10.1016/1041-6080(95)90031-4

Reyna, V. F., Corbin, J. C., Weldon, R. B., & Brainerd, C. J. (2016). How fuzzy-trace theory predicts true and false memories for words, sentences, and narratives. *Journal of Applied Research in Memory and Cognition*, *5*(1), 1–9. https://doi.org/10.1016/J.JARMAC.2015.12.003

Roediger, H. L., & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *21*(4), 803–814. https://doi.org/10.1037/0278-7393.21.4.803

Snowling, M. (1998). Dyslexia as a Phonological Deficit: Evidence and Implications. *Child Psychology and Psychiatry Review*, *3*, 4–11. https://doi.org/10.1111/1475-3588.00201

Snowling, M., Muter, V., & Carroll, J. (2007). Children at family risk of dyslexia: a follow-up in early adolescence. *Journal of Child Psychology and Psychiatry*, *48*(6), 609–618. DOI: 10.1111/j.1469-7610.2006.01725.x

Sommers, M. S., & Lewis, B. P. (1999). Who Really Lives Next Door: Creating False Memories with Phonological Neighbors. *Journal of Memory and Language*, *40*(1), 83–108. https://doi.org/10.1006/JMLA.1998.2614

Soriano-Ferrer, M., & Martínez, E. P. (2017). A review of the neurobiological basis of dyslexia in the adult population. *Neurología* (English Edition), 32(1), 50-57. DOI: 10.1016/j.nrl.2014.08.003

Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods, Instruments, & Computers*, *31*(1), 137–149. https://doi.org/10.3758/BF03207704

Stein, J., & Walsh, V. (1997). To see but not to read; the magnocellular theory of dyslexia. *Trends in Neurosciences*, *20*(4), 147–152. DOI: 10.1016/s0166-2236(96)01005-3

Suárez-Coalla, P., & Cuetos, F. (2015a). Reading difficulties in Spanish adults with dyslexia. *Annals of Dyslexia*, *65*(1), 33–51. https://doi.org/10.1007/s11881-015-0101-3

Suárez-Coalla, P., & Cuetos, F. (2015b). Reading difficulties in Spanish adults with dyslexia. *Annals of Dyslexia*. https://doi.org/10.1007/s11881-015-0101-3

Swannell, E. R., & Dewhurst, S. A. (2012). Phonological false memories in children and adults: Evidence for a developmental reversal. *Journal of Memory and Language*, *66*(2), 376–383. https://doi.org/10.1016/j.jml.2011.11.003

Swanson, H. L. (2012). Adults with reading disabilities: Converting a meta-analysis to practice. *Journal of Learning disabilities*, 45(1), 17-30. DOI: 10.1177/0022219411426856

Undheim, A. M. (2009). A thirteen-year follow-up study of young Norwegian adults with dyslexia in childhood: reading development and educational levels. *Dyslexia*, *15*(4), 291–303. DOI: 10.1002/dys.384

Vidyasagar, T. R., & Pammer, K. (2010). Dyslexia: a deficit in visuo-spatial attention, not in phonological processing. *Trends in Cognitive Sciences*, *14*(2), 57–63. https://doi.org/10.1016/J.TICS.2009.12.003

Wagner, R. K., & Torgesen, J. K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin*, *101*(2), 192–212. https://doi.org/10.1037/0033-2909.101.2.192

Watson, J. M., Balota, D. A., & Roediger, H. L. (2003). Creating false memories with hybrid lists of semantic and phonological associates: Over-additive false memories produced by converging associative networks. *Journal of Memory and Language*, *49*(1), 95–118. https://doi.org/10.1016/S0749-596X(03)00019-6

Wechsler, D. (1981). *Wechsler adult intelligence scale-revised*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (2001). *Escala de Inteligencia para Niños-Revisión*. New York, NY: Psychological Corporation.

Weekes, B. S., Hamilton, S., Oakhill, J. V., & Holliday, R. E. (2008). False recollection in children with reading comprehension difficulties. *Cognition*, 106(1), 222-233. https://doi.org/10.1016/j.cognition.2007.01.005

Westbury, C., Buchanan, L., & Brown, N. R. (2002). Sounds of the Neighborhood: False Memories and the Structure of the Phonological Lexicon. *Journal of Memory and Language*, *46*(3), 622–651. https://doi.org/10.1006/JMLA.2001.2821