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Strategic effects on pseudohomophone reading in phonological dyslexics with and without phonological impairment.

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Short title: Pseudohomophone reading in phonological dyslexia

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Abstract

The literature concerning reading in acquired phonological dyslexia is conflicted with regard to performance with pseudohomophones (e.g SKOOL). While some cases are more accurate in pronouncing non-words that sound like known words than those that do not, other cases show no pseudohomophone advantage. Some cases are more successful when pseudohomophones are orthographically similar to their base words (SKOOL versus KLOO); other cases show no visual similarity effects. We collected data from two phonological dyslexics in order to examine whether pseudohomophone reading was influenced by a) the presence of a generalised phonological impairment b) whether pseudohomophones appeared alone or intermixed with non-words and c) whether the phonological dyslexic was told that pseudohomophones were included among the stimuli. Results showed that patterns of reading accuracy were different in cases with and without phonological impairment, and that altering the presentation context or providing explicit instruction affected the responses. The findings are discussed in relation to models of word reading.

1. Introduction

The normal reading system not only allows for the pronunciation of known familiar words, but also enables the reader to generate pronunciations for unfamiliar and for non-words. However, in some patients with brain damage and acquired dyslexia the reading system has been compromised such that the processing of the latter types of written stimuli becomes inaccurate referred to as "acquired phonological dyslexia (PD)". For example, Beauvois & Derouesne (1979) reported the case of RG, who was able to read aloud nouns without error, but only generated appropriate pronunciations for non-words in 10% of trials. Since this first published report, the neuropsychological literature has documented a number of other PD cases (see Tree, 2008 for a review) sometimes with co-occurring deficits of function word reading (e.g. KT, Patterson, Suzuki & Wydell, 1996 versus WE, Berndt, Haendiges, Mitchum & Wayland, 1996) and poor non-word repetition (e.g., (Friedman, 1995) with this latter pattern being argued to reflect the possibility that PD is in fact a symptom of a more 'generalised' phonological deficit (Harm & Seidenberg, 2001). However, despite many reports of PD cases – few have taken into account the fact that non-words can vary in their similarity to actual words. The nature of the English language is such that the same phoneme can often be represented by different letter combinations. It is therefore possible to create stimuli that may be pronounced in the same way as existing words (e.g. BRANE sounds like BRAIN) but do not have any meaning in and of themselves. These are referred to as *pseudohomophones.*

Pseudohomophones are particularly interesting in the context of acquired phonological dyslexia as they combine characteristics of stimuli that patients fail to read (their non-word orthography) with characteristics of stimuli that are preserved (their word-like phonology). As a consequence, it might be expected that the familiar phonology linked to pseudohomophone items might 'boost' performance with these items as compared to other nonwords with no such familiarity, and indeed some early reports of PD cases indicated that this was the case (see Patterson, 1982, Derouesne & Beauvois, 1985), but not always (see Funnell, 1983). We conducted a literature review and identified 24 cases of acquired phonological dyslexia in which pseudohomophone reading was explicitly assessed. The findings are summarised in Table 1 below. Fifteen (62.5%) of the patients were significantly more accurate in pronouncing pseudohomophones than non-words – suggesting that two thirds of this population show a pseudohomophone advantage in reading, but interestingly the presence of this advantage was not obviously linked to degree of overall nonword (or word) reading impairment.

[Table 1 about here]

A further issue to consider is the relationship between the pseudohomophone and the base word in terms of orthography, that is to say a pseudohomophone can vary in the degree to which it looks similar to the real word it sounds like (e.g, - SKOOL-School vs. KLOO-Clue) – and evidence suggest that this *visual similarity* manipulation can have consequences on both pseudohomophone reading accuracy (McCann & Besner, 1987) and recall (Tree, Longmore, Majerus and Evans, 2011) in normal participants. In the case of PD cases, our review determined that only five studies have examined this issue – three patients showed an advantage for pseudohomophones that were visually similar to their base word (AM (Patterson, 1982), LB (Derouesne & Beauvois, 1985) and NJ (Nickels, Biederman, Coltheart, Saunders & Tree, 2008) whilst two did not (GSW, Nickels et al., 2008) and RG (Derouesne & Beauvois, 1979).

The question arises as to which factors influence whether pseudohomophone effects manifest. The majority of phonological dyslexics show non-word reading impairments coupled with a deficit in other phonological tasks such as phoneme manipulation, segmentation or phoneme blending (e.g. Patterson & Marcel, 1992) or impairments in phonological short term memory (e.g. RR, Bisiachi, Cipolotti & Denes, 1989). As a consequence, some researchers have argued that PD as a pattern of impairment reflects not a *reading specific* deficit – but rather a symptom of a more generalised deficit linked to phonological processing (Plaut et al. 1996). Harm and Seidenberg (2001) discussed this potential account for the PD pattern of impairment within the framework of a connectionist "triangle" model (see Figure 1). Triangle models posit that a single mechanism underpins reading for all stimuli irrespective of their lexicality. When presented with a letter string a pronunciation is generated using direct mappings between orthography and phonology based on the spelling-sound patterns that have been learned through experience with the language. It should be noted that the concept of generalised phonological deficits in reading difficulty has been the subject of some debate in the developmental dyslexia literature, though a full consideration of this issue is beyond the scope of the current paper. Proponents of this phonological core deficit position (e.g. Manis, Seidenberg, Doi, McBride-Chang & Peterson, 1996) suggest that dyslexia is commonly associated with difficulties in storing and representing phonological information, particularly affecting non-word reading. They suggest, however, that developmental surface dyslexia (accurate non-word reading accompanied by a particular difficulty in pronouncing words with unusual spelling to sound correspondences such as *colonel*) is simply "normal" reading that has been delayed - such a pattern can be accommodated by the triangle framework. The existence of "pure" developmental surface dyslexic cases (e.g. Castles & Coltheart, 1993; McDougall, Borowsky, McKinnon & Hymel, 2005) is a problem for these kinds of models.

Returning to the current study, according to the triangle framework, word reading can be complemented by activation from the semantic system or the phonological system – given nonwords have no meaning their fate is intrinsically linked to the preservation (or otherwise) of the phonological system. Patterson et al (1996) suggested that the pseudohomophone advantage is attributable to partial phonological activation from the stimulus (BRANE) causing activation in the semantic system of the base word (BRAIN), which in turn bolsters the activation of the phonological output. In triangle models with the architecture shown in Figure 1 the semantic system may be accessed in two ways. One method is to first compute phonology (O -> P -> S). The second is via direct connection between orthography and semantics. The general assumption has been that non-words (and pseudohomophones) will not activate the semantic system in this way as they do not have any meaning in and of themselves. Thus the only way for non-word reading to receive support from the semantic system is via phonology. Harm and Seidenberg's (2001) simulations demonstrated that by damaging the phonological attractor network in their model it was possible to produce pseudohomophone and nonword performance that was qualitatively similar to that observed in phonological dyslexia (specifically in MJ, a developmental phonological dyslexic described by Howard & Best, 1996). They argued that degrading the phonological representations made the conversion from print to pronunciation more difficult, and that this was particularly detrimental when the phonological representation was unstable to begin with (as it is for non-words).

[FIGURE 1 HERE]

Although PD cases have been reported with a generalised phonological impairment, and are therefore consistent with the above theoretical account, these concurrent deficits in phonological processing are by no means universal, and an increasing number of reports of phonological dyslexics without phonological impairment are emerging (e.g. MO and IB, Caccappolo-van Vliet, Miozzo & Stern, 2004a; RG, Caccappolo-van Vliet, Miozzo & Stern, 2004b; LB, Derouesne & Beauvois, 1985; FG, Macoir, Fossard, Saint-Pierre & Auclair-Ouellet, 2012; JH, Tree & Kay, 2006). The evidence from these reports suggests that PD as a pattern of impairment is likely, at least in some cases, to reflect a *reading specific* deficit and is therefore suited to a theoretical account that couches their impairment in such a way. Such an alternative explanation of phonological dyslexia is offered by dual route models of reading (e.g. Coltheart, Curtis, Atkins & Haller, 1993; Coltheart, Rastle, Perry, Langdon & Ziegler, 2001). Dual route models propose that there are two methods for generating pronunciations for written letter strings (see Figure 2). The first route, the *non-lexical* route, uses a set of rules that pairs letter patterns (graphemes) with commonly associated sounds (phonemes) and assembles them serially to pronounce the stimulus. However, there are a number of words in English that have pronunciations which deviate from these grapheme-phoneme conversion rules. These irregular words (e.g. YACHT or PINT) cannot be pronounced correctly using the non-lexical route. For these words the *lexical* route is required. Reading by this route accesses a store of whole word representations containing all known words and retrieves the appropriate pronunciation. In circumstances where the letter string does not match a representation in the lexicon, either because it is a new word that the reader has not encountered previously or because it is a non-word, lexical reading is not possible.

[FIGURE 2 HERE]

Acquired phonological dyslexia has been argued to be the result of selective damage to the non-lexical reading route (Coltheart, 1996). The lexical route, however, remains largely undamaged. This allows for the phonological representation of the base word to be activated by the pseudohomophone, such that reading accuracy improves. Nickels et al. (2008) performed systematic lesions of a computationally implemented version of Coltheart et al.'s (2001) dual route cascaded model (DRC) in order to examine the impact of a) impairment of the grapheme-phoneme correspondence system and b) damage to phonological representations and the phoneme system on reading accuracy for words, pseudohomophones and non-words. They reported that increasing the time taken by the model to move from one letter in a sequence to the next (a parameter called *inter-letter interval*) could significantly decrease the accuracy of non-word reading without creating a word reading deficit. This parameter has the effect of weakening the activation in the grapheme-phoneme correspondence system. If random noise was added into the phoneme system before the output was generated, non-word reading was adversely affected. Greater levels of noise also reduced the model's reading accuracy for words. Nickels et al (2008) went on to simulate the pattern of performance that was shown by three phonological dyslexics by damaging the grapheme-phoneme correspondence system and adding noise in the phoneme system to different degrees. Damaging the grapheme-phoneme correspondence system in the DRC simulation created a deficit in non-word reading, but no pseudohomophone advantage. This replicated the performance of JH (Tree & Kay, 2006), a case of acquired phonological dyslexia without generalised phonological impairment. The performance of the other two cases was approximated by damaging the grapheme-phoneme correspondence system in the DRC *and* increasing the phoneme noise parameter. This created a non-word reading deficit and a pseudohomophone advantage.

At the time that Harm and Seidenberg (2001) performed their simulations, only one case of PD without phonological impairment had been reported (LB, Derouesne & Beauvois, 1985). Harm and Seidenberg argued that the evidence for LB's preserved phonological ability was not convincing, and neither was the conclusion that he had a selective impairment of non-word reading. Consequently they did not attempt to model pseudohomohone reading in PD without a general impairment to the phonological system. Since then a number of cases of selective non-word reading impairment have been observed in patients that have had their phonological ability carefully assessed, and clearly show that these skills are preserved (most notably JH, Tree & Kay, 2006). The question arises as to how these cases might be handled by triangle models. In such models the pseudohomophone advantage is a consequence of support from the semantic system which assists in activating the phonological representation - support which is particularly useful if the phonological representations themselves are damaged. If the phonological representations are *not* damaged then the pseudohomophone advantage is dramatically reduced and all non-word reading is highly accurate, as it is in normal readers (Harm & Seidenberg, 2001). Thus the existence of a non-word reading deficit without general phonological impairment is potentially problematic for the triangle account.

One explanation that could be offered for PD without phonological impairment within a triangle framework is to suggest that in such cases the phonological representations are intact, but that the connections in the orthography - phonology pathway are in some way damaged. This would increase reliance on the orthography - semantics - phonology pathway. As non-words do not activate the semantic system strongly (see Plaut et al., 1996) accuracy with these items would decrease considerably. Word reading would be largely unaffected. When using the orthography - semantic - phonology pathway accuracy in pseudohomophone reading would become strongly dependent on the visual similarity between the pseudohomophone and its base word. Indeed, in their discussion, Harm and Seidenberg (2001) noted that severing the direct orthography - phonology pathway resulted in the model reading only 12 of 120 pseudohomophones correctly, all of which were orthographically similar to the base words. Simply put, triangle models would predict large visual similarity effects in pseudohomophone reading in cases of PD without pervasive phonological deficits[1].

As we have outlined, the issue of reading non-words and pseudohomophones in phonological dyslexia is complex and performance is highly variable. It has also been recognised that there may be different types of PD which may reflect damage to different reading processes. In this paper, we aimed to undertake a systematic examination of pseudohomophone effects (and the visual similarity effect) in phonological dyslexia with and without a generalised phonological impairment. At the same time, our review of the literature suggests that pseudohomophone effects may be influenced by the *context* in which they are presented (e.g. pseudohomophones presented either as a single block or mixed with other nonwords), or by *explicit instruction*, neither of which have so far been considered systematically in cases of PD – each of these issues will be discussed below.

[1] This is the most extreme circumstance in which the O - P pathway is not available at all. Less severe damage may allow for some non-words to be pronounced correctly without requiring prior semantic access.

On the issue of explicit instruction a key study is relevant - Patterson et al (1996) described a Japanese phonological dyslexic named KT. KT's non-word reading was completely abolished, but she was able to read pseudohomophones correctly. The percentage of trials in which KT provided the correct pronunciation of a pseudohomophone was increased by telling her explicitly that the list contained non-words that sounded the same as words (43% versus 10%). KT's success in reading pseudohomophones was also influenced by the way that the list of stimuli was constructed (what we are referring to as presentation context). When pseudohomophones and non-words were presented intermixed within a single list, KT read 20% of pseudohomophones correctly. If the items were presented in two separate lists, one comprising non-words, the other pseudohomophones, then her pseudohomophone accuracy increased to 73% (non-words remained incorrect in all trials). It appears that KT's success was influenced by strategic reading processes, whether implicitly or explicitly encouraged to use them. Influences of presentation context have also been reported in studies of pseudohomophone reading in non-impaired readers, though in these studies the effects are visible in reaction time measures rather than accuracy. It has been shown that variability in the patterns of pseudohomophone reading seems to related to the characteristics of the stimuli that the participants have already been exposed to during the experiment. For example, participants are generally faster to read pseudohomophones than they are to read non-words when presented in mixed lists (McCann & Besner, 1987). When pseudohomophones and non-words are presented in separate blocks, however, the pattern changes contingent on the overall order of presentation (Borowsky, Owen, & Masson, 2002). Borowsky et al. indicated that when a block of pseudohomophone trials is presented first, participants are likely to respond less accurately to pseudohomophones than to non-words. On the other hand, if non-words are presented first, this effect is eradicated. According to Reynolds and Besner (2005) this context effect is due to the breadth of lexical knowledge that is recruited to help to generate a pronunciation. Reading a mixed list uses a broad lexical scope to try and gather as much helpful information as possible about the item to be read. This benefits pseudohomophones more than it does non-words because there is an exact overlap with the phonological lexicon entry for the base word. In pure blocks, however, pseudohomophone reading uses a narrow lexical scope, searching only for the overlapping phonological representation. This is successful in generating a pronunciation, but the response takes longer to reach criterion levels for output. Non-word reading always uses broad lexical activation, as there is no corresponding lexical entry to be found, and hence the necessary activation of the pattern in the phoneme system is accrued more quickly. Reynolds, Besner and Coltheart (2011) have successfully simulated this pattern of responses by varying several parameters of the DRC model to broaden the scope of the lexical activation (the DRC's default parameters determine that the lexical activation is narrow in any case). Under this assumption, the way in which lists of stimuli are presented implicitly cues the use of a particular strategy. The mixed list context encourages participants to employ every available source of lexical information to complete the reading task. Pure blocks encourage participants to focus on one particular aspect of lexical knowledge, namely phonology. Some of these strategic processes carry over from one list to the next (hence the influence of presentation order reported by Borowsky et al., 2002). Given the damage to non-lexical reading processes and/or phonological representations in PD, we predict that such a change in strategy is likely to have an even larger effect. In a similar way, it is likely that informing the participant that there are pseudohomophones present in the stimulus list will also result in a focus on phonological information - this time via an explicit cue. We know of no discussion of the precise mechanisms in the triangle framework that underpin differences between reading responses as a consequence of manipulations of presentation context or task instructions. However, Patterson et al (1996) argued that pseudohomophone effects in PD would be modulated by any manipulation that might increase the degree of semantic influence on the generation of a phonological output. It seems likely that telling the patient that there were to be pseudohomophones presented would increase the probability that activation of the semantic system was deemed important for the task.

Likewise, an implicit realisation that semantic activation was useful in the generation of the phonological code ought to increase the level of semantic influence for the task. In this paper, the precise mechanism by which presentation context or explicit instruction influences the performance of our cases is of lesser importance than determining whether strategic effects might have been implicated in the variability of pseudohomophone effects in the PD literature.

We consider that whether a similar (possibly exaggerated) pattern of responding might be seen in cases of PD remains an open question – and moreover, argue that such results might shed light on why some PD cases show pseudohomophone advantages in reading while others do not. It is for these reasons we undertook the current study with two PD cases presented below and will evaluate our findings with reference to theoretical accounts provided by the aforementioned work with normal participants and the models of reading discussed earlier.

2. Method

2.1 Case descriptions

In this study we investigated the impaired nonword and pseudohomophone reading pattern seen in two phonological dyslexic cases, JH and CL. Basic neuropsychological data is presented in Table 2.

[Table 2 about here]

JH is male and was 62 years old at the time of testing. He had a stroke in December 2002 which affected his speech and language and caused some limited mobility on his right side. A CT scan conducted in July 2005 determined the presence of a mature left anterior circulation infarct. He received speech and language therapy early in 2003. At the time of our testing, there was no evidence of hearing loss, visual impairment or apraxia. JH's speech is generally fluent, but he occasionally had word finding difficulties. A full description of his performance on a number of standardised tests and medical history has been described elsewhere (Tree & Kay, 2006), so only a summary of the important points is included here. The key features of JH's profile are that he was unimpaired at semantic testing, word reading (varying regularity, morphology and grammatical class), lexical decision and spelling (see Table 3). Unlike many phonological dyslexic cases (see Tree, 2008) JH has normal phonological processing, being normal on word and nonword repetition, auditory lexical decision and testing of segmentation and blending (see Table 3).

CL is female and was tested at the age of 48. She suffered a left middle cerebral artery CVA in Jan 2001. CT scan in 2003 confirmed left CVA, showing hypodensity in the left fronto-parietal region, including Broca's area. She received speech and language therapy in 2002 and physiotherapy in the same year. Upon presentation for our research, CL had moderate right hemiplegia, but no other physical abnormalities or apraxia, and normal vision. Her speech was mildly non-fluent. Like JH, she showed no impairment at semantic testing, word reading, word spelling and lexical decision. However CL was impaired at nonword spelling and had a mild impairment of auditory verbal short-term memory. A main difference between these cases is that CL showed a generalised impairment of phonological processing – with impairments of nonword repetition, auditory lexical decision (many false positives to nonword items) and a complete inability to do segmentation and blending tasks (consistent with other phonological impaired PD cases – see Patterson & Marcel, 1992).

[Table 3 about here]

2.2 Materials & Procedure

The study examined the reading of a large set of 120 pseudohomophones and 120 non-wordss generated by the work of Howard & Best (1996; see Supplementary Material Online: Appendix A). Items were tested across four sessions (3 weeks apart) in the following order (1) a mixed presentation – all pseudohomophones and non-words presented together, (2) two separate blocks of pseudohomophones and nonwords with the pseudohomophones presented as the first block, (3) two separate blocks of pseudohomophones and nonwords with the nonwords presented as the first block – all three of these sessions included the instruction that the participant was going to see a set of items that were not real words and to produce the response they felt was appropriate, (4) a final session involved blocked presentation of the pseudohomophone and non-word items, but this time the participants were instructed before each block that they were to see a block of nonword items that either (a) sound like real words when you say them (pseudohomophones) or (b) do not sound like real words when you say them (nonwords).

3. Results

3.1 Presentation context

The first analysis examined whether the presence or absence of a pseudohomophone naming advantage was contingent on the stimuli presented for reading. The percentage accuracy for each case and in each presentation context is shown in Figure 3.

[Figure 3 about here]

There was little numerical difference in accuracy for JH in any presentation context, while CL showed substantially greater accuracy for pseudohomophones than for non-words. To examine this pattern further, chi square analyses were carried out for both cases. As predicted, JH did not show a significant pseudohomophone advantage in any presentation context [mixed presentation χ^2 (1) < 1; pseudohomophones first χ^2 (1) < 1; non-words first χ^2 (1) = 2.200, $p > .1$]. In contrast, CL showed significantly better reading accuracy for pseudohomophones than for non-words in all contexts [mixed presentation χ^2 (1) = 7.602, $p < .01$; pseudohomophones first χ^2 (1) = 25.104, $p < .001$; non-words first χ^2 (1) = 9.152, $p < .005$].Overall JH is clearly an example of a PD case who shows no pseudohomophone effect in reading (like case WB (Funnell, 1983)) whereas CL is an example of a case who shows a pseudohomophone advantage (like case AM – Patterson, 1982). Importantly, our investigations indicate this general pattern is *not* sensitive to the manner of presentation.

3.2 Visual similarity

The second analysis examined whether the two phonological dyslexics were better able to pronounce pseudohomophones that were orthographically similar to their base words. Further, we examined whether any visual similarity effects were contingent on the context in which the pseudohomophones were presented. The accuracy rates for each patient in each condition are presented in Figure 4.

[Figure 4 about here]

JH showed no significant visual similarity effects in any context [mixed presentation χ^2 (1) < 1; pseudohomophones first χ^2 (1) = 1.805, p > .1; non-words first χ^2 (1) < 1]. CL showed a marked advantage for naming pseudohomophones that were orthographically similar to their base words in mixed list presentations [χ^2 (1) = 12.255, p < .001] but there was no significant visual similarity effect in pure blocks [pseudohomophones first χ^2 (1) < 1; non-words first χ^2 < 1]. These findings therefore indicate that cases can show an orthographic similarity effect (consistent with three of five PD cases we identified from our literature review) – but that the presence or absence of the effect is sensitive to the manner in which items are presented.

3.3 Explicit instruction

Finally, we analysed whether JH and CL were more accurate when they were informed that the stimuli would include pseudohomophones – in this case a block of pseudohomophones were presented first followed by a block of non-words. Under such explicit instructions, JH (consistent with the earlier investigation) did not show a pseudohomophone advantage, although the difference was approaching significance [χ^2 (1) = 3.605, p = .058]. For CL the pseudophomophone advantage was clearly present under explicit instruction [χ^2 (1) = 19.940, p < .001]. The percentage accuracy for JH and CL in each condition is presented in Figure 5 below. Overall, these results suggest that in neither case did we see a fundamental change in the pattern of pseudohomophone versus nonword reading that we see in our earlier (non-explicit instruction) investigations.

[Figure 5 about here]

4. Discussion

We set out to investigate pseudohomophone reading performance in two cases of acquired phonological dyslexia, specifically examining whether success was affected by a) the presence of a generalised phonological impairment and b) the list context in which pseudohomophones were presented. We further assessed the effect of reading strategy on visual similarity effects in pseudohomophone pronunciation. Our findings can be summarised as follows. A pseudohomophone advantage was not observed in JH, a phonological dyslexic without general phonological processing deficits, but in a case of phonological dyslexia with concurrent phonological impairment, CL, pseudohomophones were read more accurately than non-words. This overall pattern for both JH and CL was not affected by list context or explicit instruction – JH never showed a pseudohomophone advantage while in CL an advantage was ever-present. However, list context *did* alter the pattern of responses to pseudohomophones with regard to the visual similarity effect. CL showed a visual similarity effect only when pseudohomophones and non-words were intermixed. The literature concerning pseudohomophone reading in phonological dyslexia has not produced a clear picture to date. The influence of phonological impairment and presentation context we have observed in this study may go some way to explaining why.

Setting aside considerations of presentation context for a moment, we will first consider the success of triangle models to account for the pattern of responses in our patients. The triangle account holds that PD is a consequence of an impairment of the phonological system. Damage to the phonological system in computational models has resulted in significant advantages in reading pseudohomophones versus non-words, and advantages for pseudohomophones which are orthographically similar to their base words (e.g. Harm & Seidenberg, 2001). This matches the performance of CL in our current investigation. However, triangle models have not yet been used in an attempt to simulate PD *without* phonological impairment. In the introduction we offered a potential mechanism by which triangle models could be lesioned to model these sorts of cases, namely that the O - P pathway was damaged and that semantic reading was always required. Under this assumption the hypothesis would be that non-word reading was severely impaired and that in fact only visually similar pseudohomophones would be pronounceable. The performance of JH does not fit this pattern. JH showed no pseudohomophone advantage versus non-words and no effects of visual similarity.

Borowsky et al. (2002) reported that the speed with which normal readers pronounce pseudohomophones is influenced by the context that they are presented in. In mixed blocks a pseudohomophone advantage in accuracy is common, but pseudohomophones take longer to name in pure blocks than non-words do (so long as non-words have not previously been encountered in the course of the experiment). Reynolds and Besner (2005) argued that this pattern could be accommodated by theorising that participants can vary the way that lexical knowledge is used to reach a pronunciation. They suggested that general lexical knowledge is employed by default, and a large number of lexical entries are activated by the presentation of a non-word. This suggests that the computation of a reading response is aided by orthographic and phonological overlap with many known words. Broad lexical activation of this type assists pseudohomophones more than nonwords because the former have an advantage of familiar phonology – there is therefore a pseudohomophone reading advantage. Moreover, when pseudohomophones are presented in isolation, the participant can determine that identifying the base word will allow them to make an appropriate pronunciation. In this case lexical activation is constrained so that the matching phonological representation is particularly influential in the reading response. This strategy will allow for a correct response to be generated, but it is slower to accumulate the necessary activation for output. Reynolds and Besner (2005) proposed that presentation context alters the way in which lexical information is recruited to provide support in pronouncing unfamiliar stimuli – lexical information boosts activation accrued in the non-lexical route. The nature of PD is such that the non-lexical mechanisms proposed to allow pronunciation for novel and non-word items are unavailable or inefficient. Under these circumstances, certainly in the most extreme scenario where the GPC route is completely destroyed, every item needs to be read using the lexical route. The consequence of this may be that contextual influences on reading are eliminated. The successful reading of all items is reliant on sufficient activation of the output phonology being provided via lexical activation, irrespective of presentation context or the characteristics of the stimuli. Whether the activation is achieved using a broad or narrow lexical scope has little overall effect. A further related point concerns Borowsky et al.'s (2002) finding that the pseudohomophone disadvantage only occurred when non-words had not yet been encountered in *any* list. In the current study both of our patients read a mixed list of pseudohomophones and non-words in the first instance. Even though there was a gap of several weeks between the presentation of the mixed list and the blocked lists we cannot be certain that there were no strategic effects carried over from one session to the next. This is an empirical question that merits investigation in future work in the area.

An alternative explanation of presentation context effects warrants mention. Perry, Ziegler and Zorzi's (2007) connectionist dual process (CDP+) model accounts for these effects by suggesting that the nature of the material presented prompts the reader to alter their response criterion. Essentially, Perry et al (2007) suggest that participants allow themselves more time to respond in pure blocks of pseudohomophones, and hence there is a greater opportunity for lexical activation to accrue. The response criterion is somewhat lower in mixed blocks such that lexical activation has less time to build up, and therefore base word effects are not observed. Thus the differences between the cases described in the current work could be attributed to the degree to which the orthographic information was activated in each individual. However, following the logic of the CDP+ model, the characteristics of the base word would be more likely to be a factor in pure blocks than in mixed blocks because the time allowed to reach a response is extended in pure blocks - this is the reverse of the pattern we observed in CL. In relation to the visual similarity manipulations, we note that it is possible to adjust the CDP+ model to alter the effect of orthographic overlap on pseudohomophone reading. Specifically, it is possible to change the parameters such that orthographic similarity with the baseword can be a significant factor in reading success (as in CL), or not (as in JH). However, as far as we are aware, the parameter sets required to manipulate the influence of orthography as above will produce a pseudohomophone advantage whether or not there is also a visual similarity effect. JH showed neither.

In contrast, relative success in reading pseudohomophones versus non-words is likely to be influenced by the characteristics of the individual PD case. Within the framework of the DRC, and informed by the simulations of Nickels et al. (2008), it is possible to hypothesise the circumstances in which a pseudohomophone advantage may arise in phonological dyslexia. When the patient has a problem with the phoneme system (phonological dyslexia with phonological impairment) it should be difficult to pronounce any stimulus correctly unless it has been strongly activated in the lexicon (i.e. the stimulus is a word). The overlap between pseudohomophones and the phonological lexicon entry relating to the base word would be likely to help cases to pronounce pseudohomophones more accurately than non-words. Under these circumstances a pseudohomophone naming advantage should be observed irrespective of presentation context – this is precisely the pattern we observed in CL, a PD case with a generalised phonological impairment. However, pseudohomophone advantages would not be predicted in cases of phonological dyslexia without concurrent phonological processing deficits. In Nickels et al's (2008) simulations, weakening the grapheme-phoneme correspondence system was sufficient to induce a non-word reading deficit in the DRC without affecting the pronunciation of other types of stimuli. If it is only the grapheme-phoneme correspondence system that is compromised in such cases, then advantages in the accuracy of pseudohomophone reading should be absent irrespective of presentation context, and explicit instruction should not alter reading performance[2] because the intact lexical route would potentially allow for the correct pronunciation of any pseudohomophone. This is what we observed in JH a case of PD without phonological impairment.

In addition to the above, we would like to highlight the patterns of our two cases' neurological damage. CL has damage to the left fronto-parietal lobes, while JH suffered an infarct in the circulation feeding the left frontal lobes. Damage to perisylvian areas are commonly reported in acquired phonological dyslexia (see Lambon Ralph & Graham, 2000, for example), but within that there is considerable scope for variability in both the location of the legion and the functional impact of the damage. CL's stroke affected Broca's area - an area that has been shown to be activated during phonological recoding (Fiez, Balota, Raichle & Petersen, 1999). If this is the case, it might make sense that CL's deficit is obvious in non-word reading, that it generalises to other phonological tasks, and that the presence of a pseudohomophone advantage was unaffected by presentation context. This also meshes neatly with the DRC model's suggestion that non-word reading problems stem from damage to a rule system designed to allow for letters to be recoded into sounds. On the other hand, JH's stroke left this area of the brain relatively untouched. This can easily be related to the difference between our cases in a) their general phonological skills and b) the presence or absence of pseudohomophone advantages in reading. However, on the face of it, it would appear that this lesion pattern is incompatible with the DRC account of phonological dyslexia. In response to this point, we highlight the arguments raised by Jackson and Coltheart (2001). They indicated that even given that phonological dyslexia is the result of impaired GPC route function, the same reading patterns could theoretically be caused by damage at multiple points along the processing

[2] We recognise that pseudohomophones may be pronounced more quickly than non-words, and that this difference in response latency could be modulated by visual similarity or explicitly instructing the patient that the list contains stimuli that sound exactly the same as words do. However, phonological dyslexia is defined in relation to reading non-words *correctly* rather than *quickly.*

route. Therefore there is "no reason at all to expect…any consistency in the brain region that is impaired" (Jackson & Coltheart, 2001, pp. 90).

Although it is possible to simulate the pattern of findings we report with the parameters of the DRC model (with respect to gross effects of pseudohomophone versus nonword reading) our findings relating to visual similarity effects are presently a challenge for this model (or any other) to capture (Coltheart, personal communication). For example, we might expect that a visual similarity advantage should be seen in cases of PD with a generalised phonological processing deficit – however, as has been stressed earlier, previous reports of such an advantage have been mixed, and the present work demonstrates that presentation context will have complicated this picture. In particular, we would suggest that presenting non-words and pseudohomophones in a mixed block of items might promote visual similarity effects for pseudohomophones. This is because it would be easier to identify the base word if the pseudohomophone was orthographically similar (making the orthographic lexicon useful too), and thus bolster the activation in the phonological output lexicon relative to visually dissimilar pseudohomophones. In pure blocks of pseudohomophones, on the other hand, phonological lexical activation would be emphasised and the search for a base word would continue until successful (Reynolds & Besner, 2005) such that all pseudohomophones (regardless of visual similarity) would receive an equivalent 'boost' - washing out any subtle orthographic effects. This again is precisely the pattern that we observed in CL – who showed a visual similarity effect for pseudomophones in the mixed block context but not in the pure block contexts. In sum, our findings demonstrate the critical impact that presentation context can have on more subtle orthographic effects being present or absence in acquired phonological dyslexia, and act as a note of caution for future researchers. We also highlight that in skilled readers, there is evidence of a speed-accuracy trade off which is not typically considered in neuropsychological research, and that this may also be a confounding factor. Furthermore it is possible, given the complexity of the pattern of pseudohomophone reading that is observed in normal readers with regard to the influence of the items that have previously been encountered during the experiment (Borowsky et al., 2002), that our cases may have been influenced by seeing the mixed presentation first. We think that this is unlikely because a) the first encounter with the stimuli occurred several weeks before the pure block presentations and b) current theory does not provide a priori reasons for expecting a carry-over effect across such a large gap. We acknowledge that this is perhaps an empirical question for future exploration. Similarly, our findings regarding the complexity of orthographic visual similarity effects provide a challenge for all current and future computational models of reading to capture. Although computational models of reading have been successfully used to simulate pseudohomophone reading in phonological dyslexia cases (Nickels et al., 2008) and context effects in normal readers (Reynolds et al., 2011) a simulation of context effects in phonological dyslexia is not currently possible by any, and we urge modellers to capture findings like ours in order to have a complete picture of the differing patterns of impairment seen in acquired phonological dyslexia.

Supplementary Material Online: Appendix A

High similarity pseudohomophones		Low similarity pseudohomophones	
ake	lanned	borle	phacked
artch	lardge	daw	phar
bayce	leace	glarce	pharme
bleek	lood	grede	pharst
blud	lorn	jem	pheal
charnce	meak	jurm	philme
cheeze	mowce	kain	phined
chiled	mowth	kaiv	phlarsk
chirch	munth	kamp	phocks
chork	nighce	kar	phond
deel	perce	karf	phrea
dett	pigg	kayr	phrord
dich	plarnt	kene	phyne
drabb	rainge	kepped	rec
duk	reech	kirce	rong
faice	shaut	klame	roth
fawce	skairce	kleigh	sarm
frend	skawn	kliph	seej
frunt	skowt	kloo	skwair
gerl	streat	klown	strore
ghoast	swomp	knek	toom
grean	teath	koak	url
hed	tence	koan	urth
hellth	thwort	korl	wraik
highnd	tipe	kossed	wrait
horlt	tirm	krool	wredd
hownd	virb	kult	wroap
inck	waun	kwak	wrok
jooce	whyte	nyphe	wrowned
kyned	wiphe	pessed	wunce

High similarity non-words		Low similarity non-words	
beel	raun	arl	poom
brabb	rett	arth	possed
chaut	rorn	blarce	prak
clarnt	rowce	blowned	rem
dayce	saice	broap	sar
derl	sellth	chilme	sayr
drean	serce	chyne	scrore
enck	sharnce	dorle	sharme
ghyte	shirch	drede	sheal
gich	skiled	drok	shrord
gleek	skreat	firce	starsk
glud	slomp	gaw	strair
guk	slowt	gredd	streal
jirb	spairce	grek	tain
kence	speeze	heej	taiv
kipe	stawn	kessed	tarf
kirm	stend	knaik	tarm
miphe	strorth	knait	tepped
nanned	thork	lunce	thacked
neak	tigg	murm	thar
neech	townd	myphe	tharst
nowth	tyned	nong	thined
nunth	uke	norl	thocks
ortch	vooce	pamp	thond
pawce	vood	pene	toak
peath	wainge	plame	trool
ped	weace	pliph	tult
porlt	whoast	ploo	tweigh
prunt	wighce	plown	woth
rardge	yighnd	poan	yec

References

Beauvois, M-F & Derouesne, J. (1979) Phonological alexia: three dissociations. *Journal of Neurology, Neurosurgery and Psychiatry,* 42, 1115–1124.

Berndt, R.S., Haendiges, A.N., Mitchum, C.C., & Wayland, S.C. (1996). An investigation of nonlexical reading. *Cognitive Neuropsychology,* 13, 763–801.

Bishop, D. V. (1989). *Test for reception of grammar (2nd ed.).* Age and Cognitive Performance Research Centre, University of Manchester, UK.

Bisiacchi, P.S., Cipolotti, L., & Denes, G. (1989). Impairment in processing meaningless verbal material in several modalities: the relationship between short-term memory and phonological skills. *Quarterly Journal of Experimental Psychology,* 41A, 293–319.

Borowsky, R., Owen, W., & Masson, M. (2002). Diagnostics of phonological lexical processing: Pseudohomophone naming advantages, disadvantages and base-word frequency effects. *Memory & Cognition,* 30*,* 969-987.

Bub, D., Black, S., Howell, J., & Kertesz, A. (1987). Speech output processes and reading. In Coltheart M, Sartori S, and Job R (Eds), *The Cognitive Neuropsychology of Language*. London: Lawrence Erlbaum Associates Ltd.

Caccappolo-van Vliet, E, Miozzo, M, & Stern, Y. (2004a). Phonological dyslexia without phonological impairment? *Cognitive Neuropsychology,* 21, 820–839.

Caccappolo-van Vliet, E, Miozzo, M, & Stern, Y. (2004b). Phonological dyslexia: a test case for reading models. *Psychological Science,* 15, 583–590.

Castles, A., & Coltheart, M. (1993). Varieties of developmental dyslexia. *Cognition,* 47, 149-180.

Coltheart, M. (1996). Phonological dyslexia: Past and future issues. *Cognitive Neuropsychology*, 13, 749-762.

Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: dual-route and parallel-distributed-processing approaches. *Psychological Review,* 100, 589–608.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review,* 108, 204–256.

Cuetos, F., Valle-Arroyo, F., & Suarez, M-P. (1996). A case of phonological dyslexia in Spanish. *Cognitive Neuropsychology,* 13, 1–24.

Derouesne, J. & Beauvois, M.F. (1979). Phonological processing in reading: data from alexia. *Journal of Neurology, Neurosurgery and Psychiatry,* 42, 1125–1132.

Derouesne, J. & Beauvois, M.F. (1985). The ‘‘phonemic’’ stage in the non-lexical reading process: evidence from a case of phonological alexia. In Patterson KE, Marshall JC, and Coltheart M (Eds), *Surface Dyslexia: Neuropsychological and Cognitive Studies of Phonological Reading.* Hillsdale, NJ: Erlbaum.

Fiex, J., Balota, D., Raichle, M & Petersen, S. (1999). Effects of lexicality, frequency, and spelling-to-sound consistency on the functional anatomy of reading. *Neuron,* 24, 205-218.

Friedman, R.B. (1995) Two types of phonological alexia. *Cortex,* 31, 397–403.

Funnell, E. (1983). Phonological processes in reading: new evidence from acquired dyslexia. *British Journal of Psychology,* 74, 159–180.

Goodall, W.C. & Phillips, W.A. (1995). Three routes from print to sound: evidence from a case of acquired dyslexia. *Cognitive Neuropsychology,* 12, 113–147.

Harm, M.W. & Seidenberg, M.S. (2001). Are there orthographic impairments in phonological dyslexia? *Cognitive Neuropsychology,* 18, 71–92.

Harm, M. W. & Seidenberg, M.S. (2004) Computing the meaning of words in reading: cooperative division of labor between visual and phonological processes. *Psychological Review,* 111, 662–667.

Heaton, R.K., Chelune, G.J., Talley, J.L., et al. (1993) *Wisconsin Card Sorting Test Manual: Revised and Expanded*. Odessa, Fla: Psychological Assessment Resources.

Howard, D. & Best, W. M. (1996) Developmental phonological dyslexia: real word reading can be completely normal. *Cognitive Neuropsychology,* 13, 887–934.

Jackson, N., & Coltheart, M. (2001). *Routes to Reading Success and Failure: Toward an Integrated Cognitive Psychology of Atypical Reading.* New York: Psychology Press.

Kay J, Lesser R, & Coltheart M. (1992) *PALPA: Psycholinguisitics Assessments of Language Processing in Aphasia*. Hove, UK: Lawrence Erlbaum Associates Ltd.

Lambon Ralph, M., & Graham, N. (2000). Acquired phonological and deep dyslexia. *Neurocase,* 6, 141-178.

Macoir, J., Fossard, M., Saint-Pierre, M., & Auclair-Ouellet, N. (2012). Phonological or procedural dyslexia: Specific deficit of complex grapheme-to-phoneme conversion. *Journal of Neurolinguistics,* 25*,* 163-177.

Manis, F.R., Seidenberg, M. S., Doi, L., McBride-Chang, C., & Peterson, A. (1996). On the bases of two subtypes of developmental dyslexia. *Cognition,* 58, 157-195.

McCann, R. S., & Besner, D. (1987). Reading pseudohomophones: Implications for models of pronunciation assembly and the locus of word frequency effects in naming. *Journal of Experimental Psychology: Human Perception & Performance*, 13, 14-24.

McDougall, P., Borowsky, R., MacKinnon, G.E., & Hymel, S. (2005). Process dissociation of sight vocabulary and phonetic decoding in reading: A new perspective on surface and phonological dyslexias. *Brain and Language,* 92, 185-203.

Nickels, L., Biedermann, B., Coltheart, M., Saunders, S. & Tree, J. J. (2008). Computational modelling of phonological dyslexia: How does the DRC model fare? *Cognitive Neuropsychology,* 25, 165-193.

Patterson, K.E. (1982). The relation between reading and phonological coding: Further neuropsychological observations. In A.W. Ellis (Ed.), *Normality and pathology in cognitive function*. London: Academic Press.

Patterson, K. (2000). Phonological alexia: the case of the singing detective. In Funnell E (Ed), *Case Studies in the Neuropsychological of Reading*. Hove, England: Erlbaum.

Patterson, K., & Marcel, A. (1992). Phonological alexia or phonological alexia? In Alegria J, Holender D, Junca de Morais J, and Radeau M (Eds), *Analytic Approaches to Human Cognition*. Amsterdam: North Holland.

Patterson, K., Suzuki, T., & Wydell, T.N. (1996). Interpreting a case of Japanese phonological alexia: the key is in phonology. *Cognitive Neuropsychology,* 13, 803–822.

Plaut, D.C., McClelland, J.L., Seidenberg, M.S., & Patterson, K. (1996). Understanding normal and impaired word reading: computational principles in quasi-regular domains.
Psychological Review, 103, 56–115.

Reynolds, M.G., & Besner, D. (2005). Basic processes in reading: a critical review of pseudohomophone effects in reading aloud and a new computational account. *Psychonomic Bulletin and Review,* 12, 622-646.

Reynolds, M.G., Besner, D., & Coltheart, M. (2011). Reading aloud: New evidence for contextual control over the breadth of lexical activation. *Memory and Cognition*, 39, 1332-1347.

Sasanuma, S., Ito, H., Patterson, J., & Ito, T. (1996). Phonological alexia in Japanese: a case study. *Cognitive Neuropsychology*, 13, 823–848.

Tainturier, M-J, & Rapp, B. (2003). Is a single graphemic buffer used in reading and spelling? *Aphasiology,* 17, 537–562.

Tree, J. J. (2008). Two types of phonological dyslexia – a contemporary review. *Cortex,* 44, 698-706.

Tree, J.J. & Kay, J. (2006) Phonological dyslexia and phonological impairment: an exception to the rule? *Neuropsychologia*, 44, 2861–2873.

Tree, J. J., Longmore, C., Majerus, S. &, Evans, N. (2011) SKOOL versus ZOOL: Effects of orthographic and phonological long term memory on nonword immediate serial recall. *Memory*, 19, 487-501.

Figure 1 – The architecture of “triangle” models of reading (adapted from Seidenberg & McClelland, 1989).

Figure 2 – The Dual Route Cascaded model of reading (Coltheart et al., 2001)

Figure 3 – Percentage accuracy in reading aloud non-words and pseudohomophones for JH and CL in each presentation context. * $p < .01$ ** $p < .001$

Figure 4 – Percentage accuracy in reading aloud non-words and pseudohomophones varying in orthographic similarity to the base word for JH and CL in each presentation context. * $p < .001$

Figure 5 – Percentage accuracy in reading aloud non-words and pseudohomophones for JH and CL under explicit instruction about the nature of the items presented. * $p < .001$