ACCESS TO ORTHOGRAPHIC FORMS IN LETTER-BY-LETTER READING:
EVIDENCE FOR ONE UNDERLYING READING SYSTEM

by

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ACCESS TO ORTHOGRAPHIC FORMS IN LETTER-BY-LETTER READING:
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ABSTRACT

Reading in pure alexia occurs by means of a so called letter-by-letter (LBL) strategy, which makes reading a slow and effortful process and leads to a length effect. In the literature some cases are described where people who read via this sequential spelling strategy, do, nevertheless, have some form of parallel access to orthographic forms, as demonstrated by performance above chance on a lexical decision task or semantic categorization task. Some authors argue that this residual reading ability can only be explained as a different reading strategy that can only be used when the sequential, letter-by-letter, spelling strategy is inhibited, by presenting items too briefly for this strategy to be used. This thesis presents a single case study of a man, BML, with pure alexia who shows a different pattern, where both strategies do not seem to exclude each other. This man shows lexical and semantic access to written forms while spelling aloud individual letters of the item at the same time. His responses on a lexical decision task and reading aloud task are analyzed to investigate the nature and constraint of this lexical and semantic access. Evidence is given for an explanation of both this reading ability and a sequential reading strategy within one reading system and the importance of this case study in the debate on the underlying impairment of LBL reading is discussed.
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Chapter 1

Introduction

*Pure alexia* is an acquired language disorder that mainly affects reading abilities and leaves other language abilities such as writing intact. This can lead to the striking observation that people with pure alexia are often unable to read back a sentence or word they wrote down just a few minutes ago.

Reading in pure alexia often occurs by means of a so-called *letter-by-letter (LBL)* strategy. People with pure alexia often spell aloud individual letters of a word, which makes it a slow and laborious process. This strategy also leads to their reading performance being characterised by a word length effect. Naming latencies increase significantly when the number of letters in a word increases (Montant & Behrmann, 2000). There are individual differences in relation to the size of this word length effect, but a three-letter word can take up to four seconds to read, and adding an extra letter might require another two to three seconds (Bowers, Bub & Arguin, 1996). LBL reading can also be accompanied by other deficits in reading, such as surface dyslexia or dysgraphia (Behrmann, Plaut & Nelson, 1998).

Research has focused on two major topics concerning LBL reading. The first issue is concerned with the underlying impairment, with different theories about the nature of the impairment that leads to this LBL strategy. A second research focus is concerned with what
have been called ‘covert’ reading abilities. This refers to the fact that a number of LBL readers have some access to lexical and semantic information, despite their inability to overtly read words. This is evident in lexical decision tasks and semantic tasks that require access to the lexicon.

In the next section these two issues will be discussed, and subsequently another case of LBL in pure alexia will be introduced who can further inform these debates.

1.1 Underlying impairment of pure alexia

In normal readers, effects of word length on word reading are only minimal, which leads to the assumption that reading in normal readers is a parallel process: the different elements (letters or graphemes) which make up a word are processed at the same time (see Figure 1.1). However, when the reading conditions are degraded and reading becomes more effortful, for example when letters are presented vertically or below or above their normal position on a horizontal line, a more sequential reading strategy is needed (Howard, 1991).
In LBL reading, parallel processing seems to break down (Howard, 1991) and LBL readers appear to use a sequential reading strategy. Reading is characterised by spelling aloud the individual letters of a word. Previous studies have lead to different theories about the exact nature of the disorder that causes this LBL strategy.

Behrmann, Plaut et al. (1998) provided an overview of the theoretical accounts for the nature of LBL reading. A *peripheral* view of pure alexia locates the impairment at a low level of visual processing, before the activation of an orthographic representation. Within this view different theories exist about whether this impairment is specific to the reading system, or whether it could be attributed to a more general visual impairment.

*Figure 1.1. A model of normal word recognition (from: Howard, 1991; p.35)*
This early processing deficit impairment degrades the quality of visual input, which causes insufficient activation for the retrieval of an orthographic representation. Bowers, Arguin and Bub (1996) argued for a similar account in their *orthographic access theory*. This theory also proposes that access to the orthographic system breaks down at the level of retrieving visual stimuli. This is especially relevant for reading, which requires a parallel processing of multiple visual forms (i.e. letters).

Behrmann, Nelson and Sekuler (1998) argued that pure alexia is caused by a general visual processing deficit. The authors conclude that their patient EL, a LBL reader, was impaired in object identification. When identifying pictures, EL’s reaction times increased significantly compared to two matched control subjects as the picture got more complex. Hence, they suggest that the same visual impairment was causing EL’s problems in object recognition and in reading.

Similarly, more recently Mycroft, Behrmann and Kay (2009) conducted an experiment where a LBL reader had to judge whether a pair of checkerboards was the same or different. The patient performed worse than a control group consisting of healthy control subjects and a brain damaged patient (who had a lesion to the right parietal cortex but showed no reading impairment). The authors concluded that the LBL reading strategy was a compensatory response to a general visual impairment.

A different theory of the impairment underlying pure alexia is a more *central* theory mentioned by Behrmann, Plaut et al. (1998). According to this view problems in LBL readers arise after orthography is activated. The representation can therefore be accessed normally, but the output is disconnected from consciousness. This means semantic and lexical information is only accessible via implicit reading mechanisms. Bowers, Arguin et al. (1996) call this the *disconnection theory*. This view argues that there is a breakdown between the visual representation and the phonological and semantic codes, after the word form is
retrieved. More specifically, there is a disconnection between the visual fields in the right hemisphere and the language oriented areas in the left hemisphere (Howard, 1991).

A similar account was developed by Saffran and Coslett (1998). They reason that the disorder is caused by left hemisphere damage and that the right hemisphere therefore takes over the reading process. This means early visual information is processed by the right hemisphere and LBL reading can then be seen as a residual reading attempt from the left hemisphere to explicitly identify the letters of a word, using information transmitted by the right hemisphere.

Doctor, Sartori and Saling (1990) report a study of a LBL reader, which also argues against the assumption of an early visual processing deficit. The authors reason that a number of lexical effects are difficult to explain with this early deficit theory. If the deficit is located at a low level of processing, before the lexicon is accessed, it would be unlikely that reading in LBL readers would be affected by lexical factors, such as a word superiority effect or a word class effect. However, Doctor et al. found an effect of lexicality (words were processed better than non-words) and concreteness (concrete words were processed better than abstract words) in their LBL reader DR. They conclude that the impairment must be located in the reading process after the lexicon is accessed, which is more consistent with the central theory.

Other research has found more evidence for lexical effects. Bowers, Bub et al. (1996) report a word superiority effect in IH, a LBL reader. The effect extended to words presented in mixed case (e.g. fAdE was processed better than gAdE). The word superiority effect is considered to be mediated by orthography, and the presence of this effect means that IH has some access to orthographic forms. The fact that IH had trouble reading words but did show a word superiority effect leads, once again, to the assumption that the deficit occurs after the activation of orthographic forms.
In addition, Bowers, Arguin et al. (1996) investigated a possible priming effect in IH. In an experiment of letter priming, IH did show an effect of priming for single letters in the same case (“A” did prime “A”). But in a cross-case priming experiment, unlike normal subjects IH did not show an effect of priming for single letters (“a” did not prime “A”). However, in an experiment of cross-case word priming (read/READ), IH showed a strong effect of priming, even at prime durations too briefly for single letter priming to occur. The authors explain this discrepancy by saying that different representations are supporting the different types of priming. Single letter priming is mediated by phonological codes, and word priming by orthographic forms. The authors therefore conclude that the absence of a letter priming effect reflects poor phonological access but the word priming effect shows that IH has relatively normal access to orthographic forms. Bowers, Arguin et al. further state that this disconnection between orthographic forms and phonological forms leads to the use of a LBL reading strategy in reading.

IH also showed another lexical effect, namely a facilitatory effect of the number of orthographic neighbours (N) on naming (Arguin, Bub & Bowers, 1998). An increased neighbourhood size reduced reaction times and improved accuracy in reading. The authors argue that this effect can not be explained by the use of a sequential reading strategy only. This means that covert orthographic lexical activation contributes to whole word recognition. So for this facilitatory N-size effect to occur, a form of parallel processing has to take place.

However, other authors have provided a different explanation for these lexical effects, that does not exclude a peripheral view of pure alexia. Behrmann, Shomstein, Black and Barton (2001) investigated eye movements in two people with pure alexia, during a reading and non-reading task. On the non-linguistic task no major differences were found between the two LBL readers and control subjects. However on the reading task there was a difference, where the pure alexia group showed longer fixations and more regressive saccades.
According to the authors these different eye movements are evidence for a peripheral view of pure alexia, because processing visual stimuli is more difficult. The people with pure alexia also fixated more on words that were low in frequency and imageability. There also was an interaction between these lexical factors and the length of the words, meaning that the effect of these factors increased with longer words.

Previous similar results led authors to conclude that this is evidence for a more central view of the impairment (e.g. Doctor et al., 1990; Bowers, Bub et al., 1996). However Behrmann et al. provide an explanation that is compatible with a peripheral view. In their explanation Behrmann et al. (2001) refer to a previous explanation from Behrmann, Plaut et al. (1998). In this paper the authors provided a theoretical account of LBL reading in an interactive model. This model, framed as the Interactive Activation Model (IAM) from McClelland and Rumelhart (1981), divides the reading process into three levels. There is a visual feature level, a letter level and a level of the orthographic lexicon. The impairment that causes LBL reading is located either at the letter level, or at the connection between the visual feature level and the letter level.

This means that the activation of single letters is weak, and this impaired orthographic representation leads to a LBL reading strategy because more focus on the individual letters is needed. This is reflected in the eye movements from the people with pure alexia (Behrmann et al., 2001). This reading performance is similar to what has been found in normal readers in different reading conditions (cf. Howard, 1991). Reading times increase and more regressive saccades are shown because the quality of the input has to be enhanced.

But even though the activation of single letters is weak, it is enough for higher-order lexical effects in imageability and frequency to occur. This is possible because of a cascaded and interactive reading system. Orthographic input activates lexical and semantic information through the system. Even though the partial information of individual letters is not sufficient
for word recognition, it can activate certain lexical information which explains the lexical effects found. The longer a word is, the more time there is for this information to be activated, which explains the interaction with length found by Berhmann et al. (2001).

Behrmann, Plaut et al. (1998) therefore concluded that the impairment in pure alexia leads to activation that is too weak for reading to occur normally, but that the reading system in itself is not a different reading system. This seems consistent with what Howard earlier concluded. He argues that LBL reading is probably no ‘exotic variety of dyslexic reading’ (Howard, 1991; p.73). Howard claims that LBL reading is in fact a similar process that can occur in reading in normal readers when reading conditions are not optimal. When stimuli are presented in the left visual field, normal readers tend to read via a similar sequential strategy. This means that in LBL readers the parallel processing is not intact enough and therefore the LBL strategy has to be adopted in order to identify letters and words.

In addition to the debate on where in the reading system processing breaks down in LBL readers, research has also tried to further specify the nature of the impairment that causes the parallel processing to break down and leads to sequential processing. Arguin, Fiset and Bub (2002) report a number of experiments conducted on IH. They conclude that parallel activation leads to background noise which makes full identification of the word impossible. The cause of this background noise is visual similarity between letters. The impairment can therefore be characterized at the level of letter encoding.

This result is replicated by another study done by Arguin and Bub (2005). They replicated the effect of neighbourhood found by Arguin et al. (1998) in three other LBL readers. However, they also found an interaction of this effect with a letter confusability effect. Letter confusability is defined as the likelihood that a letter is mistaken for another letter that is visually similar. Letters differ in their ‘confusability scores’, where a letter with a more unique shape (e.g. R) has a low letter confusability score, in contrast with for example a
D. In normal readers with normal reading conditions these confusability scores do not have an impact on reading, but they do have an effect on the performance of LBL readers. Arguin and Bub found that this effect was even stronger than the word length effect, which is the hallmark feature of the impairment. This means that high confusible words were more difficult to process than low confusible words, independent of the number of letters in a word.

Fiset, Arguin and McCabe (2006) also found an effect of visual similarity between letters. They therefore argue that the parallel processing breaks down at the level of letter encoding. This causes a certain noise in the reading process, and the LBL strategy is used to avoid confusion while reading. Arguin and Bub (2005) give a similar conclusion. In LBL reading there appears to be a difficulty at the letter discrimination level. Therefore, processing letters in parallel is not sufficient enough to recognize whole words, and a sequential letter-by-letter strategy has to be used to overtly identify words.

1.2 Residual reading abilities

When reading words, people with pure alexia seem to adopt a sequential strategy to identify the single letters of a word. This means that the longer a word is, the more effortful the reading process will be. But despite their problems with reading single words or letters, research has shown that some patients with pure alexia have residual word reading abilities. In a number of studies, stimuli were presented too briefly (around 100-250 ms) for the patient to read the word aloud letter by letter. However, the patients performed above chance on lexical decision and binary semantic categorization tasks (e.g. living / non living). This reading ability is called implicit or covert, because it is a rapid access that takes place when stimuli are presented too briefly for patients to be able to overtly identify the word.
Sometimes patients find it hard to perform on a task because they claim that they are unable to read and recognize the words (Coslett & Saffran, 1989). However, a number of patients has performed above chance level on these tasks. This has provided more evidence for the possibility that LBL readers are able to access the lexicon by means of a parallel strategy, next to their sequential LBL reading strategy.

One of the first extensively reported cases of such covert lexical processing in pure alexia was described by Shallice and Saffran (1986). ML, a man with pure alexia, read via a sequential strategy and showed a significant word length effect in reading. However, when ML was presented with stimuli too briefly for him to use his LBL strategy, he performed above chance on lexical decision and a semantic categorization task, despite being unable to explicitly identify the words that were presented.

A similar result was found in four other patients who also performed above chance on a visual lexical decision task and a semantic categorization task (Coslett et al., 1989). Aggjaro, Crepaldi, Ripamonti and Luzzatti (2005) investigated implicit reading abilities in CM, an English-Italian bilingual patient. CM used a LBL strategy in both languages, with some lexical effects in reading English. In both languages, she had implicit lexical knowledge, which was evident in a lexical decision and semantic judgment task. Sage, Hesketh and Lambon Ralph (2005) reported patient FD, who was also able to do a lexical decision task and semantic categorization task, while using a laborious LBL strategy for explicit reading.

Behrmann, Plaut et al. (1998) give an overview of 57 cases of LBL reading described in the literature (see their table, p.20-21). They conclude that implicit reading is not found in all patients with pure alexia, but that in two thirds of the cases there is at least some form of implicit reading possible.
This gives rise to the question whether the covert and overt reading in LBL readers are two different processes. Shallice and Saffran (1986) argue that there is not a single process underlying oral reading and semantic access, but that LBL readers use two different processes in reading. The semantic system is accessed in a parallel strategy, compared to a serial strategy when identifying single letters. Saffran and Coslett (1998) also say that there are two reading mechanisms, suggesting that these are moderated by the different hemispheres: the right hemisphere is used for implicit reading, and the LBL reading is mediated by the left hemisphere.

Coslett, Saffran, Greenbaum and Schwartz (1993) tested the hypothesis that patients who read letter by letter use two different reading strategies: a sequential and laborious one for single letter identification, and an implicit reading strategy for whole word recognition. Results from their single case study supported this hypothesis. Their patient with pure alexia was able to ‘switch’ between the two strategies, according to what the task required. When identifying words, the patient used a sequential reading strategy. However, in an implicit reading task the patient was able to suppress this strategy and read whole words via a parallel strategy. The authors reason that the LBL reading strategy has to be inhibited for the implicit reading to take place. Patients have to alternate between the two strategies according to what the specific task requires.

In addition, Coslett et al. argue that this can explain part of the inconsistency found in the literature, where not all patients show this covert processing. Apart from individual differences in processing, the patient has to be convinced that it is possible to perform a certain task even when the patient feels he is unable to do so. It is important that patients are explicitly told not to try to read what is presented to them, but basically to rely on intuition when making a lexical decision or semantic categorization.
This theory of two reading strategies was the basis of a number of therapy studies of pure alexia (e.g. Maher, Clayton, Barrett, Schober-Peterson & Gonzalez Rothi, 1998; Sage et al., 2005). Maher et al. (1998) used two different therapy methods with their patient. A restitutive therapy was used to exploit their patient’s implicit reading abilities. After that, treatment concentrated on improving the identification of single letters (a substitutive therapy). Of the two therapies used only the substitutive therapy was found to improve their patients reading ability. Maher et al. argue that when using the restitutive therapy, the patient was not able to inhibit the sequential strategy, which caused the implicit reading therapy to be unsuccessful.

However, this theory is not universally accepted. For example, Howard (1991) examined oral reading and comprehension in two patients who read via a LBL strategy. He found no evidence to support the two different reading systems suggested by Shallice and Saffran (1986). Instead, Howard argued that people with pure alexia can show variable reading responses. One of the two subjects described by Howard, PM, takes on average more than 15 seconds to read a nine letter word. However, sometimes he showed a so called ‘fast response’ and was able to read a word of nine letters in less than 3 seconds. This can not be explained by the use of a sequential reading strategy. Howard then argues that reading is a parallel process, but one that is not functioning perfectly. To compensate, a sequential strategy is used when parallel processing is not sufficient enough.

A similar conclusion is drawn by McKeeff and Behrmann (2004). They report the results of a Stroop task in patient EL. In this task the name of a colour does not correspond with the colour of the ink (e.g. the word GREEN in blue ink). This leads to interference when naming the colour of the ink. EL showed the same interference as normal controls. However, when orthography was manipulated (e.g. when stimuli were degraded by using a cursive font), EL no longer showed Stroop interference. The authors conclude that parallel activation
does take place and can be sufficient for implicit reading tasks, but it is not strong enough for word recognition to take place, and a sequential reading strategy is therefore needed. These results oppose the view that reading in patients with pure alexia stems from two separate mechanisms. McKeeff and Behrmann conclude that the LBL readers use one reading system, which is not fully intact.

This thought is in line with what Lambon Ralph, Hesketh, and Sage (2004) concluded. They argued that LBL reading can be adopted as a compensatory strategy, when the single underlying reading system is only partially functioning, which is the case in pure alexia.

This is similar to the explanation given by Behrmann, Plaut, et al. (1998) with the Interactive Activation Model. The activation of single letters might not be sufficient for overt word recognition to take place, but it can support covert processing. This means that the LBL reading and implicit reading abilities can be explained within a single reading system.

1.3 Current study

There appears to be an inconsistency in the literature about the presence and nature of preserved reading abilities. Implicit reading is sometimes said to be only possible when the LBL reading strategy is not available, because the stimuli are presented too briefly for this strategy to be used (Coslett et al., 1993). Arguin et al. (2005) phrase it as ‘rapid but unconscious access’. Sage et al. (2005) say that implicit reading is very unlikely to occur when given unlimited time to respond, because a LBL strategy will then be used. However, the individual reported here (BML) shows a different pattern. This man with pure alexia uses a letter-by-letter strategy in reading, but also seems to have access to orthographic forms. While reading a word aloud, he switches between spelling aloud single letters with a LBL
strategy and giving semantic information about the whole word, even when given unlimited 
time to respond. These results contradict Shallice et al. (1986) because it does not seem to be 
the case that the LBL strategy has to be inhibited in order to access the lexicon.

Analyses of BML’s reading aloud responses were conducted to investigate the exact 
nature and constraints of this preserved reading ability. An interesting question here is 
whether there is a link with the occurrence of semantic errors in deep dyslexia. Gerhand and 
Barry (2000) investigated which lexical factors influence semantic errors in deep dyslexia. 
They found that frequency did not have an effect on the occurrence of semantic errors in their 
deep dyslexic patient LW. However concreteness, age-of-acquisition and length played a 
more important role. In this study it is also investigated whether lexical factors influence the 
expanded reading abilities.

Data from 7 weeks post-onset were compared with data from a later phase (around 35 
weeks post-onset) to see if the type of preserved reading changes over time. In the discussion 
it is described how this case-study relates to other cases described in the literature.

BML’s results can give extra support for the existence of one underlying reading 
system. Furthermore, it can shed light on the specific underlying deficit of LBL reading in 
pure alexia. In the next section the current study will be introduced.
Chapter 2

Case study

In the next section BML, a man with pure alexia, will be described. First background details are provided of BML’s case history and an overview of his language processing abilities. Test results from lexical and semantic tasks are discussed and a response analysis is described to investigate BML’s lexical and semantic access to written forms. The results are further discussed in the general discussion in the next chapter.

2.1 Subject BML

2.1.1 Medical History

BML is a university graduate who worked as an electrical engineer. He was 47 years old at the time of this study. He has a ten year history of (uncontrolled) hypertension, high cholesterol and kidney failure. He suffered from a left occipito-temporal CVA which caused a complete infarction in the territory of the left posterior cerebral artery. BML’s stroke caused a right homonymous hemianopia and BML reports that parts of his vision are blurred. His retrograde and working memory were impaired, but his anterograde memory for nonverbal material was intact.
2.1.2 Neuropsychological assessment

A neuropsychology report made two weeks post-onset stated that BML had some memory problems. Some were word finding difficulties, however he also had difficulties describing parts of his past. Furthermore a poor digit span was reported, however BML did remember well which test items were already presented to him in earlier sessions. He also reported problems retaining information such as remembering the topic of conversation. The speech therapist had the impression that some of his memory problems might in fact be language problems.

BML scored within normal limits on a object decision task (deciding whether the object on the picture is a real thing; Birmingham Object Recognition Battery (BORB), Riddoch & Humphreys, 1993). There seemed to be no problems with giving object descriptions, however the speech therapist had the impression there might be a problem in accessing semantics from vision.

2.1.3 Language abilities

On the Pyramids & Palm trees test (Howard & Patterson, 1992) BML made one error in the first 20 items. He did feel that he had to guess many of the items and did not know what the relationship between items exactly was.

Shortly after his CVA his speech was fluent with anomia and BML presented with an impaired reading ability. His writing was intact, but his object naming was impaired and he showed some semantic deficits. He was unable to discriminate letters from numbers and he could not read single words or letters. The striking observation was made that BML was able to write words and whole sentences to dictation but was unable to read these back to himself shortly after. BML was diagnosed as having pure alexia. Early intervention focused on letter
identification and naming, because it was important to increase the speed and accuracy of single letter identification for his letter-by-letter strategy in reading to improve.

2.1.3.1 Semantic tests

Formal assessment at six to eight weeks after his CVA investigated whether BML was able to access semantics from print. Two tasks were administered. In a semantic categorization task he had to judge if items could be categorized as living or nonliving. In the word picture matching task one word was presented with four pictures, consisting of the target (e.g. bus), a semantically related distractor (bike) and two unrelated distractors which shared the initial letter with the target and were semantically related to each other (bee, beetle). Both tasks were presented in two formats: either with the target presented briefly (for 200 ms) or with the target presented for an unlimited time. Both times he was encouraged to make the decision or to guess before reading the item aloud.

The results from this semantic categorization task (living/nonliving) and the matching task are summarized in Table 2.1. BML performed above chance on the categorization task (Binomial test exact $p < 0.001$). When given unlimited time to respond, BML was able to categorize more items correctly than when given 200 ms to respond, but this difference was not significant (McNemar, $p > .05$). At the matching task BML did not show a different result at different durations of presentation but did perform above chance (Binomial test exact $p < 0.001$).
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<thead>
<tr>
<th>Semantic categorization living / nonliving (n=40)</th>
<th>Correct</th>
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<tr>
<td>200 ms</td>
<td>31</td>
</tr>
<tr>
<td>Unlimited</td>
<td>34</td>
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</table>

<table>
<thead>
<tr>
<th>Word picture matching (n=40)</th>
<th>Correct</th>
<th>Sem. Related</th>
<th>Unrelated</th>
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<td>200 ms</td>
<td>21</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Unlimited</td>
<td>21</td>
<td>7</td>
<td>12</td>
</tr>
</tbody>
</table>

### 2.1.3.2 Reading

Formal assessment at 6 to 8 weeks post-onset showed that BML was now able to identify single letters. When naming letters that were presented for 200 milliseconds, BML immediately named 31 out of 52 letters correct, and named another 20 items correct when he was given more time to respond.

When naming single letters BML’s responses were slow and he drew almost every single letter in the air with his right hand after it had disappeared from the computer screen. Secondly, BML was aware of abstract letter characteristics such as font, case and position in the alphabet. His knowledge of the different fonts that are possible is clear from the following example.
Oh that awful character. That one you can’t write properly. Which is which one? A-B-C-D-E-F-G... See the problem I’ve got now is with whether my writing matches yours, which it doesn’t. Funny character. So that’s D-G-H, could it be g? I’ll just say g for the moment. Not really happy with that.”

**BML naming single letters at 8 weeks post-onset**

Here BML drew the shape ‘g’ in the air, but the letter on the computer screen was a ‘g’. So he is aware of the fact that ‘g’ and ‘g’ are two different versions of the same grapheme.

For other letters BML could sometimes give information about a letter’s position in the alphabet. Data from single letter naming at 8 weeks post-onset show that without being able to immediately name the letter, he knows that an ‘F’ is “about the 5th one”, an ‘e’ is “near the front”, an ‘N’ is “just after half way”, an ‘r’ is ‘past half way on the right’ and the ‘R’ is “near the R in the alphabet”. He is also able to recognize whether a letter is presented in upper case or in lower case (‘G’ – “that’s a capital for sure”).

BML’s abstract letter identification was further tested in a cross-font matching task. Printed letters in different fonts were presented to him for 250 milliseconds and BML was asked to judge whether the letters presented to him were the same or different (e.g. a-a; a-o; g-g; g-q). BML made 48 out of 52 correct judgements. The fact that he still made four errors in this simple task indicates an impairment.

Reading aloud was tested with the PALPA (Psycholinguistic Assessment of Language Processing in Aphasia (1992); Kay, Lesser & Coltheart), subtest 29. BML named each letter individually. His performance showed a clear length effect in reading where his accuracy and reaction time dropped when the number of letters in a word increased, which can be seen in Table 2.3 and Figure 2.1.
Table 2.2. Word reading in BML at 7 weeks post-onset.

<table>
<thead>
<tr>
<th>Number of letters</th>
<th>Accuracy (n=6)</th>
<th>Mean reaction time (secs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>6</td>
<td>25.83</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>44.00</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>52.75</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>82.00</td>
</tr>
</tbody>
</table>

When BML read the items from the PALPA word list it became apparent that he had access to some information about the written word, when he was not able to read the word aloud. Two examples of this are shown below in (1) and (2).
It is clear that despite being unable to read the word ‘wheat’ aloud, BML does have access to its semantics and knows it is something you can find on farms.

In the literature more cases are reported where patients were able to access semantics of a written word, despite their problems with reading those words aloud. For example Shallice and Saffran (1986) reported patients who were able to have access to information about a written word when it was presented too briefly to read aloud by a letter by letter strategy. This can be information resulting from lexical access (knowing whether an item is a word or not) and semantic access (categorization task).

As already noted, on the PALPA word list, BML showed some responses that might indicate lexical and semantic access from written words. Therefore further investigation was undertaken into the kind of lexical and semantic access BML has for written words even when he is unable to read them aloud. This was tested with a lexical decision task and a semantic categorization task. Both will be described below, where first the procedure and materials are described followed by a short result section. In the general discussion the implications of these results will be further discussed.

2.2 Lexical and semantic access

Stimuli and procedure A visual lexical decision task was administered to test BML’s ability to access lexical representations of written words. For this test the PALPA Imageability x
Frequency list was used (PALPA subtest 5). This list consists of 160 items: 80 words and 80 non-words. The words are controlled for imageability and frequency. The words were presented in lower case on a computer screen for an unlimited period of time. BML was asked to make a lexical decision first, as quickly as possible. He was then asked to read aloud those items he judged to be a word. The test was recorded on audio and video.

The test was administered at the sub acute phase at 7 weeks post-onset (T1) and later at 35 weeks post-onset (T2). At both assessments, a comparison was made between accuracy on the matched sets of 40 high frequency and 40 low frequency items, and between the 40 high and 40 low imageable items. This is done for lexical decision and reading aloud. Results from both times are compared and differences will be discussed.

Results

The results from the lexical decision task are shown in Table 2.3. BML performed above chance on a lexical decision task when tested at both 7 and 35 weeks post-onset (Binomial test exact $p < .001$ for both sessions).

The overall accuracy for lexical decision did not change between the two testing sessions (McNemar, $p > .1$). At 7 weeks BML showed an effect of imageability (Fisher exact, $p < .01$) and frequency ($p < .05$) on lexical decision accuracy but not on reading aloud. At 35 weeks the effects on lexical decision remained significant (Fisher exact, both comparisons $p < .01$) and this time there was an effect of these factors in reading aloud as well (Fisher exact, both comparisons $p < .005$). The results also show that the reading aloud scores have improved significantly: at 35 weeks post-CVA he was able to read aloud more items (McNemar, $p < .001$).
Table 2.3. *Proportion correct in lexical processing at 7 and 35 weeks post-onset.*

<table>
<thead>
<tr>
<th></th>
<th>Lexical decision</th>
<th>Reading aloud ¹</th>
<th></th>
<th>Reading aloud ¹</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 wks (T1)</td>
<td>35 wks (T2)</td>
<td>7 wks (T1)</td>
<td>35 wks (T2)</td>
<td></td>
</tr>
<tr>
<td>Overall accuracy (n=160)</td>
<td>.75*</td>
<td>.71*</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>High imageability n=40</td>
<td>.92</td>
<td>.85</td>
<td>.23</td>
<td>.83</td>
<td></td>
</tr>
<tr>
<td>Low imageability n=40</td>
<td>.68**</td>
<td>.55**</td>
<td>.13</td>
<td>.50**</td>
<td></td>
</tr>
<tr>
<td>High frequency n=40</td>
<td>.85</td>
<td>.88</td>
<td>.20</td>
<td>.88</td>
<td></td>
</tr>
<tr>
<td>Low frequency n=40</td>
<td>.65*</td>
<td>.53**</td>
<td>.15</td>
<td>.45**</td>
<td></td>
</tr>
<tr>
<td>Words n=80</td>
<td>.75</td>
<td>.70</td>
<td>.18</td>
<td>.68</td>
<td></td>
</tr>
<tr>
<td>Nonwords n=80</td>
<td>.81</td>
<td>.71</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

¹ Only for those items that were correctly identified as words

* significant above chance p<.001

** significant comparison low to high imageability and low to high frequency at p<.05

n/a: not applicable

In sum, BML had lexical and semantic access from print for items even when presented so briefly that he is unable to read them aloud and that are presented for an unlimited period of time.

### 2.3 Parallel and sequential reading

In the results described above it is evident that BML has some form of lexical and semantic access to written items before reading aloud. In addition, from BML’s responses it seems that despite his use of a letter-by-letter strategy, he has access to semantic and lexical information while he is spelling aloud individual letters. An example of this can be found below when he reads aloud the word ‘monkey’.
(3) monkey

“Yes, it’s a word, an animal, M-O-N, have it in a zoo, M-O-N-K-E-Y, hang on Y, E-Y, won’t have one of these at home”.

As mentioned in the introduction, according to research from Coslett et al. (1993) spelling aloud individual letters and giving semantic information about the word can not occur at the same time. When given unlimited time it is very unlikely for semantic access to take place, because the patient will use his LBL strategy (Sage et al. 2005). But for BML the occurrence of semantic information does not seem to be limited to the brief presentation of the stimuli. In the next example it is clear that BML sometimes even reads aloud the word correctly without instantly realizing.

(4) fire

“An animal I think. Or something to do with a fire engine... Ah that’s interesting: fire! F-I-R-E it was! I said it miles before I thought of it.”

It seems to be the case that BML is able to use different reading strategies within one item and that the two reading strategies do not exclude each other. Most cases described in the literature have looked at accuracy or reaction times of this implicit reading. It is therefore interesting to further investigate the constraints on lexical and semantic access for BML by looking at his responses. If semantic information is present in the response to a single item when the spelling strategy is used at the same time, this would be evidence for the fact that a
letter-by-letter strategy does not block the access to lexical or semantic information. An example as (3) shows that the getting to the final answer provides with a lot of information about the reading strategies BML uses and what type of information he has access too. Therefore another analysis of his answers on a word list is conducted. This time not only the accuracy is taken into account but also the leading up to reading aloud an item.

**Stimuli and procedure** BML’s reading responses on the same Imageability x Frequency list described above (PALPA, n=160) were analyzed. For this analysis only the items that were real words and that BML correctly identified as words were coded.

An overview of the different response categories can be found in Table 2.4. There are four main categories of responses. The first category is spelling aloud which included any responses where BML attempted to spell aloud single letters of the target. This category is divided into those responses where spelling attempts were correct, those where they were incorrect spelling, and a sub-category for the cases where BML attempted to read the whole word and then checked his response by spelling it aloud. Sometimes BML named the letters of the alphabet, for example when he had to read an E he said ‘A-B-C-D-E’. This is scored under this category as well.

The second category consists of correct and incorrect reading aloud attempts. The incorrect responses were further divided according to the relationship of the error to the target: visual, semantic or unrelated. For example, the incorrect attempt could result in a non-word or a word that was visually related to the target. A response was counted as a visually related word when the response shared the two initial letters of the target item, or two or more letters in any other position.

The next group of responses consists of semantic information. This differs from the former category Reading Aloud because the response is not a single word provided as a
reading attempt, but a description of part of the meaning of the word. The category has sub-categories according to the type of semantic information that is given.

The fourth category included comments on a specific letter (letter comments) or a more general comment about the word (general comments) that BML gave while reading an item aloud. For this category only specific comments about a letter that showed BML’s difficulty with the particular letter were included. For example, when BML said that the first character of the word ‘letter’ (i.e. the letter L) was always a problem for him, this was scored as a comment. Other comments that were too general or not relevant for the item were excluded from analysis (for example ‘I know that one’ or ‘I have to practice more’).

Table 2.4. Categories of reading aloud responses.

<table>
<thead>
<tr>
<th>Category</th>
<th>Explanation / criteria</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Spelling aloud</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SA</td>
<td>Spelling attempt to spell single letter aloud, questions included</td>
<td>\textit{t – ‘it’s a t right?’}</td>
</tr>
<tr>
<td>SA_I</td>
<td>Incorrect attempt to spell single letter aloud, questions included</td>
<td>\textit{t – ‘is it a p?’}</td>
</tr>
<tr>
<td>SA_check</td>
<td>Spelling aloud to check a reading aloud attempt.</td>
<td>\textit{key – ‘is it key? K – E – Y, yes it is.’}</td>
</tr>
<tr>
<td>2. Reading aloud</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA</td>
<td>Word is read aloud correctly, questions included</td>
<td>\textit{face – ‘is it face?’}</td>
</tr>
<tr>
<td>RA_NON</td>
<td>Word is read aloud incorrectly, response is a non-word</td>
<td>\textit{realm – ‘riəlm’}</td>
</tr>
<tr>
<td>RA_VIS</td>
<td>Response is a visually related word</td>
<td>\textit{clue – ‘club’}</td>
</tr>
<tr>
<td>RA_UN</td>
<td>Response is incorrect, not clearly visually or semantically related</td>
<td>gravy – ‘village’</td>
</tr>
<tr>
<td>RA_SEM</td>
<td>Response is a semantically related word (not a description)</td>
<td>letter – ‘envelope’</td>
</tr>
<tr>
<td>RA_VIS_SEM</td>
<td>Response is both semantically and visually related</td>
<td>hand – ‘head’</td>
</tr>
</tbody>
</table>

### 3. Semantic information

| SEM_D       | Semantic description of the word                                    | potato – ‘it’s a fruit’ |
| SEM_M       | Semantic information that is related to patient’s episodic memory   | village – ‘related to the movies’  
(Village cinemas is an Australian cinema chain) |
| SEM_VIS     | Semantic information of a visually related word                     | feather – ‘family related’ (via ‘father’) |
| SEM_UN      | Description of the item that is not clearly visually or semantically related | fire – ‘an animal I think’ |

### 4. Comments

| LC          | Information or comment about a specific letter                      | ‘I don’t like that first character’ |
| GC          | General comment about the word                                      | ‘It’s a common word’ |
Each full response could result in a number of different category scores. An example of the scoring method is shown below in Table 2.5. A response was scored as one example of a category until there was a change to another category type. For example, if BML spelled aloud single letters, no matter how many letters he spelled they would count as one instance of SA, until, for example, he produced a semantic description about the whole word, which would then be coded as SEM_D.

Table 2.5. Example of scoring.

<table>
<thead>
<tr>
<th>Item</th>
<th>Response part 1</th>
<th>Category</th>
<th>Response part 2</th>
<th>Category</th>
<th>Response part 3</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato</td>
<td>Something like</td>
<td>SEM_D</td>
<td>It’s a common</td>
<td>GLC</td>
<td>P O P O</td>
<td>SA</td>
</tr>
<tr>
<td></td>
<td>fish and chips</td>
<td>word</td>
<td>word</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Results For each item that BML attempted to read aloud after a correct lexical decision it was counted if more than one of the four main categories (Spelling Aloud, Reading Aloud, Semantic Information and Comments) was present. So the example shown in Table 2.5 was counted as more than one category being present.

The results are summarized in Table 2.6. At 7 weeks post-onset BML used more than one type of response in 80% of the items that he attempted to read aloud. At 35 weeks BML used less different response types, where in only 46% of the items he attempted to read aloud he used more than one strategy. It is also clear that BML read more words correctly at T2 compared to T1. Furthermore at T1 he was never able to immediately read the word aloud correctly, which he could in almost 50% of the items he started to read aloud at T2.
Table 2.6. *Different reading strategies within one item.*

<table>
<thead>
<tr>
<th></th>
<th>7 weeks post-onset (T1)</th>
<th>35 weeks post-onset (T2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of items correct in lexical decision</td>
<td>60</td>
<td>56</td>
</tr>
<tr>
<td>Number of items where first response is the correct response</td>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>Number of items read aloud correctly</td>
<td>14</td>
<td>54</td>
</tr>
<tr>
<td>Items where different strategies are present</td>
<td>48</td>
<td>26</td>
</tr>
</tbody>
</table>

This analysis clearly indicates that BML was able to use different reading strategies during one response. The category ‘Spelling Aloud’ reflects BML’s use of a letter-by-letter strategy. When BML gives a semantic description of the meaning of an item, he uses a ‘whole word reading strategy’. The presence of these two categories ‘Spelling Aloud’ and ‘Semantic description’ in one item, is evidence for the fact that BML can use the two strategies at the same time.

2.4 Effect of lexical factors on type of response

The previous analysis shows that BML does not use each type of response for every item. An interesting question is whether the properties of the stimuli influences the type of response BML gives. As mentioned in the introduction, it is interesting to see whether there is a link with the occurrence of semantic errors in deep dyslexia. Research done by Gerhand et al.
(2000) concluded that frequency does not influence the occurrence of semantic errors in reading in deep dyslexia. Also Nickels and Howard (1994) did not find a frequency effect in the production of semantic errors in aphasic naming.

In the case of BML a possible question concerning this effect is whether BML uses a letter-by-letter spelling strategy more often than a full word reading strategy in low frequency words. To answer this, the frequency of the different response categories was counted. However some of the different subcategories consist of only a few responses, so in order to be able to make appropriate comparisons, the presence of the four major categories Spelling Aloud, Reading Aloud and Semantic Information and Comments were used. The different subcategories (e.g. SA_I or SA_check) were counted as one category (SA). For each item type the frequency of the four categories was calculated. A comparison was made between T1 and T2 and between the different types of items.

**Stimuli and procedure**

The previous analysis showed a frequency and imageability effect for lexical decision and reading aloud. For example BML made less correct lexical decisions for low frequency items and therefore read aloud fewer low frequency items correctly. This means that by counting the amount of ‘Spelling Aloud’ in each response, the fact that BML has fewer responses for low frequency items will lead to the same effect of frequency. So the fact that he identified less low frequency items correctly, automatically means he reads aloud less low frequency items. This means that comparing the number of responses in each category across the different subgroups (for example the number of SA for low frequency words to the number of SA for high frequency words) is not an appropriate comparison. Therefore the relative distribution of the different categories is measured. The occurrence of each category
(SA/RA/SEM/COM) is therefore provided as a proportion of the reading attempts in each category.

For this analysis it is most interesting to look at what kind of information BML can give about a word when he is not able to immediately read it aloud correctly. The accent in this analysis is therefore his response for items where he has no direct access to its meaning. So under the type ‘reading aloud’ those items where BML’s first and only response was the correct response (e.g. head – ‘head’) were excluded.

**Results**

The total numbers of the occurrence of each response type for T1 and T2 is shown in Table 2.7 and Figure 2.2. (these are absolute numbers). What can be read in table 2.7 is that for example for the 60 items BML read aloud at T1, he used the spelling aloud strategy in 56 of the items.

| Table 2.7. Total of different response types in reading aloud at T1 and T2. |
|---|---|---|---|---|
| Spelling aloud | Reading aloud | Semantic information | Comments |
| T1 (n=60) | 56 | 20 | 16 | 34 |
| T2 (n=56) | 20 | 27 | 9 | 3 |
The effects of frequency and imageability on the presence of different types of responses are summarized in Table 2.8 (for T1) and Table 2.9 (for T2). These numbers show that for example in all of the 19 high imageability – high frequency (HI HF) items, spelling aloud was used as a strategy (100%) and that of almost half of these 19 items BML gave semantic information.
Table 2.8. Distribution in percentages of response categories in item types (T1).

<table>
<thead>
<tr>
<th></th>
<th>Spelling aloud</th>
<th>Reading aloud</th>
<th>Semantic information</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (n=60)</td>
<td>93.33</td>
<td>33.33</td>
<td>26.67</td>
<td>56.67</td>
</tr>
<tr>
<td>HI HF (n=19)</td>
<td>100</td>
<td>31.57</td>
<td>47.36</td>
<td>57.89</td>
</tr>
<tr>
<td>HI LF (n=18)</td>
<td>83.3</td>
<td>44.4</td>
<td>38.88</td>
<td>61.11</td>
</tr>
<tr>
<td>LI LF (n=8)</td>
<td>100</td>
<td>25</td>
<td>0</td>
<td>62.5</td>
</tr>
<tr>
<td>LI HF (n=15)</td>
<td>93.3</td>
<td>26.67</td>
<td>0</td>
<td>46.67</td>
</tr>
</tbody>
</table>

Table 2.9. Distribution in percentages of response categories in item types (T2).

<table>
<thead>
<tr>
<th></th>
<th>Spelling aloud</th>
<th>Reading aloud</th>
<th>Semantic information</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (n=56)</td>
<td>35.71</td>
<td>48.21</td>
<td>16.07</td>
<td>5.36</td>
</tr>
<tr>
<td>HI HF (n=19)</td>
<td>21.05</td>
<td>42.11</td>
<td>10.53</td>
<td>5.26</td>
</tr>
<tr>
<td>HI LF (n=15)</td>
<td>46.67</td>
<td>26.67</td>
<td>26.67</td>
<td>6.25</td>
</tr>
<tr>
<td>LI LF (n=6)</td>
<td>50</td>
<td>66.67</td>
<td>16.67</td>
<td>0</td>
</tr>
<tr>
<td>LI HF (n=16)</td>
<td>37.5</td>
<td>43.75</td>
<td>12.5</td>
<td>6.25</td>
</tr>
</tbody>
</table>

In the graph can be seen that at T1 the category Spelling Aloud is used the most and at 35 weeks post-onset BML used the reading aloud strategy the most. At 35 weeks post-onset BML attempts to read aloud more items than at T1, the difference between T1 and T2 however is not significant ($\chi^2 (1)=2.08; p > .1$). The difference between the amount of semantic information between T1 and T2 is not significant either ($\chi^2 (1) = 1.35, p > .1$). However BML uses a spelling strategy more often at T1 than at T2, and this difference is
significant ($\chi^2 (1) = 40.05, \ p < .001$). Furthermore BML gives more lexical comments at T1 than at T2, which is also significant ($\chi^2 (1) = 30.04, \ p < .001$).

In Table 2.8 can be found that there is a difference between high and low imageability words in the presence of semantic information. When reading aloud the 23 low imageable items semantic information is never given. However in almost half of the number of high imageable items BML gives semantic information. This effect of imageability is found to be significant ($\chi^2 (1) = 11.44, \ p < .01$). A significant effect is not found for frequency ($\chi^2 (1) = 0.02; \ p > .5$). Furthermore there is no significant effect found for imageability and frequency for any other response type (all comparisons Chi square $p > .1$; see Appendix). At T2 there are no significant effects of frequency or imageability on the type of response.

In the next chapter the results described here will be further discussed.
Chapter 3

Discussion

3.1 Parallel and sequential reading in BML

Pure alexia is characterized by the use of a letter-by-letter (LBL) strategy, in order to understand written words or to read words aloud. Nevertheless, several studies have described people with pure alexia who do have some form of lexical and semantic access for written words, despite their inability to explicitly identify them without use of the letter-by-letter strategy. This study has reported results from a man with pure alexia (BML) who also shows this ability but differs in interesting and important ways to most cases described in the literature. In particular, whereas previous cases could only access lexical or semantic information when words were presented extremely briefly, BML was not affected by length of presentation. In this Discussion, first, the main results are summarised and then the implications are discussed for theoretical accounts of pure alexia.

BML suffered a CVA which resulted in an inability to read single letters and words fluently, but even early on it was clear that BML was able to access lexical and semantic information from a letter string despite being unable to explicitly identify the word. Formal testing showed that he was able to perform above chance on a lexical decision task, at both 7 and 35 weeks post-onset. BML did not only have access to lexical information, but also to
semantic information: he performed above chance on a semantic categorization task. This indicates that BML had partial access to lexical and semantic representations.

A different analysis was concerned with the effects of imageability and frequency on the accuracy of BMLs lexical decision and reading aloud. At 7 weeks post-onset BML showed an effect of both these factors for accuracy, indicating that the deficit occurred after BML had access to orthographic representation that carried higher order orthographic information, such as lexical and semantic information. At 35 weeks these effects were also found for reading aloud.

Shallice et al. (1986) and Coslett et al. (1993) argued that above chance performance on a lexical decision task and/or semantic categorization task is evidence for lexical and semantic access to written words. Coslett et al. (1993) and Sage et al. (2005) defined this access to lexical and semantic information as ‘covert’, because it is a rapid access that can take place when stimuli are presented too briefly for patients to overtly identify the word.

However, BML differs from the other cases reported in the literature because lexical and semantic access for BML did not rely on brief presentation of the items. For example, he did not show a difference in accuracy on the semantic categorization task for items briefly presented (200 ms) and items that were presented for an unlimited period of time. The same was true for the lexical decision task. While BML was asked to make the lexical decision as quickly as possible, the items were presented for an unlimited period of time. Indeed, sometimes BML even started to spell the letters of the item aloud, then remembered that he had to do the lexical decision first, and still performed this accurately.

BML provides clear evidence against Sage et al. (2005) and Coslett et al. (1993) who argued that the ability to process letters in parallel ‘disappears’ if items are presented for an unlimited period of time, because the sequential LBL reading strategy will then automatically be used. BML’s lexical and semantic access is more extensive than any previous reported
cases: evidence for lexical and semantic access was not only evident in above chance performance on a lexical decision task and a semantic task, he also clearly had access to the meaning of items he was trying to read aloud. This is obvious from his reading responses, such as the example shown earlier (1)

(1) wheat

“You find it on farms.”

In the literature different case studies lead to the conclusion that access to lexical and semantic information via a parallel reading strategy is only possible when the sequential spelling strategy is inhibited by presenting items too briefly for this strategy to be used. An example is patient ML, described by Shallice et al. (1986). The authors concluded that for ML the two reading strategies were mutually exclusive and the strategies were differently effective for different goals. ML reported cases where he was not able to perform a categorization task because he did not concentrate fully, and therefore started using his spelling strategy which prevented him from performing this task. Therefore, Shallice et al. concluded, the LBL strategy has to be inhibited to be able to use the other strategy.

This is incompatible with BMLs data from reading aloud, where he was able to use both strategies within one item. His responses on the word list (Palpa subtest 29) were coded in order to get a better idea of whether BML is able to use different strategies within one single item. The results clearly show that the semantic access was not impaired by the use of a sequential spelling strategy because different strategies could be used within one item. At 35 weeks post-onset BML read aloud more items immediately, however while reading aloud he still had access to other information about the word. Once BML started using his LBL strategy, he could still access lexical and semantic information. The analysis of his reading
responses clearly showed that BML was able to use a sequential spelling strategy and have lexical access to the item at the same time. An example of the fact that the sequential and parallel reading strategies were not mutually exclusive is repeated below in example (2).

(2) monkey

“Yes, it’s a word, an animal, M-O-N, have it in a zoo, M-O-N-K-E-Y, hang on Y, E-Y, won’t have one of these at home”.

BML reading aloud from PALPA word list at 7 weeks post-onset

3.2 Impairment underlying LBL reading

Hence it is clear that BML differs compared to other cases of pure alexia with lexical and semantic access described in the literature. This section addresses what BML’s data can tell us about the underlying deficit responsible for the inability to read aloud without LBL reading in pure alexia.

Behrmann, Plaut et al. (1998) described two classes of theories concerning the underlying impairment of pure alexia. A peripheral view locates the deficit early in the visual processing system, which can explain the difficulties with identifying single letters. Within this account of an early processing deficit, different views on the exact deficit exist: the impairment can be seen as specific to reading, or as a more general impairment to process visual stimuli. However all share the assumption of an early deficit in visual processing, which prevents the retrieval of a complete orthographic representation.

However Doctor et al. (1990) and Bowers, Bub et al. (1996) argued that this early processing deficit can not explain the presence of lexical effects in reading, such as an effect
of lexicality or concreteness. The presence of these effects is an indication that the lexicon is accessed, which is incompatible within the account of an early visual processing deficit.

Furthermore, the residual reading abilities that some people with pure alexia, like BML, have, can not be explained within this model. A different account on the underlying impairment is a more central theory where the deficit is located after the activation of an orthographic representation. Behrmann, Plaut et al. (1998) suggest that even though orthography can be accessed normally, this orthographic representation is disconnected from consciousness, which is similar to the ‘disconnection theory’ from Bowers, Arguin et al. (1996). This disconnection delays phonological access and the orthographic representation is not available for production but can only be accessed by implicit reading mechanisms, so called ‘covert reading’. However as BML was able to access semantics explicitly and overtly, this theoretical account cannot hold, or at least not for all cases of pure alexia.

Lambon Ralph et al. (2004) also argued that a peripheral view can not account for the implicit reading abilities found in some pure alexic patients. An alternative theory is the ‘two systems’ account, introduced by Saffran and Coslett (1998). Within this account the different strategies of the reading process (e.g. sequential and parallel) are separated and explained as two reading systems, represented by each of the two hemispheres. The right hemisphere processes visual information and supports implicit reading, and the left hemisphere is used to explicitly identify single letters. With an impaired left hemisphere, patients are forced to use the right hemisphere. The notion that the left hemisphere can inhibit the right hemisphere further supports the idea of two separated processes (Lambon Ralph et al., 2004).

The data described in this study do not argue against the view that the different hemispheres contribute to the reading process. However Saffran and Coslett argued that the two different reading strategies are a product of the two hemispheres and therefore that there exist two different reading systems. BML’s data clearly shows that regardless of the
hemispheric localisation of the reading process, the two reading strategies do not interfere with each other and the LBL reading and whole word reading do not mutually exclude each other. The two strategies can therefore still be accounted for within one single reading system.

The alternative theory to the ‘two systems’ account explained by Lambon Ralph et al. (2004) is the ‘two processes’ account. The idea here is that visual input is impaired and that there is one, single whole-word reading system, and a separate, compensatory LBL strategy. Actually three processes are involved in the reading system. First there is the overt whole-word reading system, manifested by the left hemisphere, which is impaired in pure alexia. Secondly, there is right hemisphere reading, which is reflected by implicit or covert reading abilities. Next to this, there is a compensatory LBL reading strategy, supported by the left hemisphere.

Within this explanation, the implicit reading abilities that some patients have shown, reflect residual abilities from an impaired whole-word reading system. Lambon Ralph et al. point out that people with pure alexia do perform above chance on lexical decision and semantic tasks but their performance is never perfect, which can be explained by assuming that the reading system is only partially functioning. The way partial information can still activate lexical and semantic processes can be explained well within an interactive activation model, as explained by Behrmann, Plaut et al. (1998).

Behrmann Plaut et al. (1998) stated that it seems as if the peripheral theory and the central view are incompatible because the central view does not address the problems with single letter identification, and a peripheral view does not account for the semantic and lexical access some people with pure alexia do have. However, they argued that within an interactive activation account it is possible to explain both the impairment at the letter identification level and the presence of higher-level semantic and lexical processes within one
model. This interactive activation model contains three levels of processing units: a visual feature level, a letter level and a level of the orthographic lexicon. The two basic principles in this type of model are that processing is *cascaded* and *interactive*. This means that activation continuously flows from one level to the other, and that activation flows two ways: from lower to higher levels (bottom-up) and feedback from higher levels back to lower levels (top-down). The impairment that causes LBL reading is located either at the letter level, or at the connection between the visual feature level and the letter level. LBL reading occurs when the activation of single letters is not sufficient enough for explicit identification to take place.

Despite this activation being impaired, it can activate certain lexical and semantic information through the system because orthographic information is ‘cascading’ both ways, which can cause the frequency and imageability effects in reading to occur. These effects were also found in LBL reading in BML (see Table 2.3), and Behrmann, Plaut et al. explain these effects by arguing that words of high frequency and high imageability provide more top-down activation. Lambon Ralph et al. (2004) also argue that high frequency and high imageability words are more readily activated, even with reduced visual input, which explains the presence of frequency and imageability effects in reading.

The most important account of this theory is that the reading system itself does not differ that much from a normal reading system. The impairment causes reduced activation, and to compensate this impaired input, people with pure alexia are forced to use a sequential processing mechanism in order to support the impaired parallel activation. This impaired activation however can access lexical and semantic representations partially, which can explain the presence of higher order processes such as an effect of imageability.

Not only were effects of these lexical factors found in reading performance, but they were also found to partly influence the type of responses in reading aloud. At 7 weeks post-onset an effect of imageability on the occurrence of semantic information in reading was
found. When reading aloud low imageability items, BML did not give any semantic information about the word, compared to the presence of semantic information in about fifty percent of the high imageability items. At 35 weeks post-onset this effect of imageability has disappeared. An effect of frequency was not found at neither of the two phases.

The effect of imageability on the occurrence of semantic information and absence of a frequency effect seems compatible with the influence that lexical factors have on the presence of semantic errors in deep dyslexia, studied by Gerhand et al. (2000). The authors concluded that concreteness and age-of-acquisition are indicators for semantic errors to occur in reading in deep dyslexia. They found no reliable effect of frequency, which is similar to BML’s results.

Nickels and Howard (1994) reported a study on factors affecting the production of semantic errors in aphasic naming. They found a significant effect of imageability on the production of semantic errors. However, Nickels et al. argued that the frequency effect that was found was in fact caused by an interaction with other confounding factors such as imageability and length.

Within the interactive activation model an effect of imageability can be explained by defining high imageability items as having more extensive semantic representations, and these items are therefore more readily activated, even with reduced visual input. Words that are high in frequency provide a more stable level of activation and are therefore more likely to be selected within the model.

BML’s results from the lexical decision and reading aloud task did show significant effects of frequency and imageability, but on the type of response in reading aloud only an imageability effect was found for the occurrence of semantic info, and no frequency effects were found. In the case of BML the richness of the representation seems to predict the occurrence of semantic information in reading aloud, so semantic information seems more
accessible for high imageability words. The absence of a frequency effect on the type of response seems more difficult to explain within an interactive activation model. Also it would be expected that he would use his spelling strategy for items he can not read aloud, which would be the low imageability or low frequency words.

It would therefore be interesting to conduct more extensive response analyses in different patients where the reading aloud responses are taken into account as well, to provide more insight in the factors influencing the availability of semantic information and other lexical factors influencing the type of responses.

To shed more light on the underlying impairment it can be interesting to have a closer look at another type of an interactive model that is used to explain the occurrence of semantic errors in deep dyslexia.

Deep dyslexia is an acquired reading disorder that is characterized by the production of semantic errors in reading and an inability to read aloud nonwords (Colangelo & Buchanan, 2006). Different models have been used to explain the underlying deficit of the reading disorder, although most models share the assumption that people with deep dyslexia have a problem in processing subword phonology (as demonstrated by the fact that they are unable to read aloud nonwords) and usually also infer an additional problem at some level of lexical processing.

Buchanan, McEwen, Westbury and Libben (2003) explain the error pattern in deep dyslexia with the failure of inhibition hypothesis. When a written word is read, its concept activates an orthographic representation in the orthographic lexicon and this subsequently activates the corresponding representation in the semantic system. This target representation also activates semantic neighbours in a network of connections. The word ‘dog’ for example would activate neighbours like ‘bark’, ‘cat’ and ‘pet’. Semantic errors in deep dyslexia occur when all these representations are activated in the phonological output lexicon, but the
irrelevant items are not inhibited, as would happen in the normal reading system. It is therefore more likely that representations semantically related to the target are produced, resulting in the semantic errors.

Buchanan et al. (2003) then introduced a framework that distinguishes between implicit and explicit access to lexical representations to further explain the error pattern in deep dyslexia. This PEIR framework (see Figure 3.1) assumes that word Production depends onExplicit access, which depends on Implicit access which in turn depends on intact Representations.

Figure 3.1. PEIR framework, reflecting the hierarchical relationship between production, access and representations (from: Buchanan et al, 2003; p. 69)

Within each level, there are three distinct but interactive components of lexical representation and processing: phonology, morphology and semantics. In this PEIR framework, different types of impairment can occur. Patients can be impaired at producing phonological,
morphological or semantic information, at their ability to explicitly or implicitly access this information, or the representations themselves can be impaired.

Buchanan et al. (2003) suggested that the distinction between explicit and implicit access can account for the error pattern found in deep dyslexia. Errors in production (e.g. reading) stem from impaired explicit access to phonological, morphological and semantic information about the word, shown by an impaired ability to assembly phonology explicitly (e.g. reading nonwords). However Colangelo et al. (2006) argued that deep dyslexic patients can be influenced by phonology at an implicit level. The authors discuss data from priming studies, where in a lexical decision task, faster responses were found for a word (e.g. ‘chair’) when it was preceded by a pseudo-homophone (e.g. ‘taybul’) compared to a regular nonword (e.g. ‘tarbul’).

This priming effect indicates that dyslexic patients can be sensitive to phonological information for words and nonwords, in an implicit task that does not require production. Priming represents implicit access that depends on intact representations, but when explicit access is required, for example in reading, errors occur because of a failure of inhibiting the other possible activated representations. Buchanan et al. (2003) therefore concluded that the impairment in deep dyslexia is not a complete inability to access phonology. Implicit access to representations is unimpaired, but a failure of inhibition causes impaired explicit access and therefore errors in production.

Can this theory account for BML’s different reading strategies as well? Within the PEIR framework it seems plausible that BML’s representations are intact, because he was able to give semantic information about the item. The fact that BML performed above chance on a lexical decision task (which requires implicit access) and a forced choice semantic decision task (which requires explicit access without production) shows that a failure of inhibition does not have an impact on the availability of lexical information, However he is not able to
read these items aloud, because this production task requires explicit access, and therefore his LBL reading can be seen as a way of compromising impaired explicit access. His intact residual reading abilities reflect a parallel implicit access, and his sequential spelling strategy is used to compensate for impaired explicit access.

Lambon Ralph et al. (2004) give more support for the fact that LBL is no more than a compensatory strategy next to a reading system that is no different to a normal reading system that is only partially working. They refer to a therapy study done by Sage et al. (2005), where data from a treatment study of a letter-by-letter reader (FD) is reported. The treatment focused on errorless whole-word reading, where patient FD had to learn not to use his LBL strategy anymore when reading. After whole-word treatment FD gave up his LBL strategy and changed his reading style. Furthermore, his error pattern changed, and FD started to show some characteristics of deep dyslexia in his reading, when a significant increase of the amount of semantic errors in reading was reported.

Lambon Ralph et al. (2004) show that the fact that this LBL-reader turned into a deep dyslexic after therapy, is extra support for the idea of one underlying reading system, because apparently the LBL reading can be adopted as a strategy and can also be discarded. Furthermore, without the LBL strategy being used as a compensatory strategy, FD’s reading responses can be explained as produced by a partially intact overtly producing reading system. This reading system is also influenced by lexical factors, such as imageability and frequency, as indicated by the error pattern of FD. This is supporting the assumption of one whole-word reading system, and in parallel there is a compensatory LBL spelling strategy used.

BML’s results are compatible with this account. His reading pattern changed over time: at 35 weeks post-onset he did not use his LBL spelling strategy as much as he did at 7 weeks post-onset. He was also able to read words aloud immediately more accurately,
however he still made some errors and needed more time to read words aloud. This reading pattern reflects an impaired whole-word reading system, with the use of a compensatory LBL strategy that is needed more at 7 weeks than later at 35 weeks post-onset.

It therefore seems that serial and parallel letter processing can contribute together to identification of the letters or word in pure alexia, as in normal readers. In the case of BML parallel processing is present, does not rely on brief presentation and is not impaired by the use of a letter by letter strategy. However it is not sufficient to enable the production of the whole word. As BML’s reading ability improved he no longer had to rely on a more sequential spelling strategy. This means that BML’s sequential reading strategy is a result of a parallel reading process that is not sufficient for word production to take place. The data described here can therefore be explained within one single reading system, as proposed by Lambon Ralph et al. (2004). The fact that LBL reading as well as implicit reading were influenced by lexical factors such as imageability and frequency shows that the whole word reading and the LBL strategy are used in parallel.

An interesting question addressed by Lambon Ralph et al. (2004) is why not all people with pure alexia show residual reading abilities, or to a different degree. One factor that can play a role is the severity of the impairment. Within the interactive activation model the remaining activation in a severely impaired reading system might not be enough for lexical and semantic access to occur. This is in line with what Behrmann, Plaut et al. (1998) found, namely a significant correlation between the severity of LBL reading and the frequency and imageability effects found in reading. Another explanation is that other co-occurring impairments in the underlying reading system can cause more difficulties in accessing semantics and lexical information (Lambon Ralph et al., 2004).

It is therefore not essential to search for one underlying locus of impairment in all patients with pure alexia. BML’s results are obviously different to other cases described in
the literature. His lexical and semantic access is more extensively than for other patients described. However, what is most important is that BML’s results as well as other case studies with a varying degree of semantic and lexical access can all be explained within a single underlying reading system that is impaired, and therefore a compensatory LBL strategy is needed. This view argues against Saffran and Coslett’s two-system theory, and is in line with what Lambon Ralph et al.(2004) describe as a theory of one system, two procedures.
References


Appendix

Analysis 2.3 Parallel and sequential reading

Data added on cd-rom
### Analysis 2.4 Effect of lexical factors on type of response

<table>
<thead>
<tr>
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<th>Spelling aloud</th>
<th>Reading aloud</th>
<th>Semantic information</th>
<th>Comments</th>
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</thead>
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<td><strong>T1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\chi^2$ (1)</td>
<td>$p$</td>
<td>$\chi^2$ (1)</td>
<td>$p$</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>$\chi^2$ (1)</td>
<td>$p$</td>
<td>$\chi^2$ (1)</td>
<td>$p$</td>
</tr>
<tr>
<td>High – low imageability</td>
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<td>0.567</td>
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<td>High – low frequency</td>
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<td>0.249</td>
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<td>0.448</td>
</tr>
</tbody>
</table>

* = significant at level $p < 0.01$

# = not valid because expected value < 5 for 50% of cells

### Comparison

<table>
<thead>
<tr>
<th></th>
<th>Spelling aloud</th>
<th>Reading aloud</th>
<th>Semantic information</th>
<th>Comments</th>
</tr>
</thead>
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<td>$\chi^2$ (1)</td>
<td>$p$</td>
<td>$\chi^2$ (1)</td>
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* = significant at level $p < 0.01$