Are acronyms really irregular? : preserved acronym reading in a case of semantic dementia

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Abstract: This paper describes the progressive performance of JD, a patient with semantic dementia, on acronym categorisation, recognition and reading aloud over a period of 18 months. Most acronyms have orthographic and phonological configurations that are different from English words (BBC, DVD, HIV). While some acronyms, the majority, are regularly pronounced letter by letter, others are pronounced in a more holistic, and irregular, way (NASA, AWOL). Semantic dementia at its moderate stage shows deficits in irregular word reading while reading accuracy for regular words and novel words is preserved. Nothing is known about acronym comprehension and reading ability in semantic dementia. Thus, in this study we explore for the first time the impact that semantic decline has on acronym recognition and reading processes. The decline in JD's semantic system led to increasingly impaired semantic categorisation and lexical decision for acronyms relative to healthy controls. However, her accuracy for reading aloud regular acronyms (i.e. those pronounced letter by letter such as BBC) remained near ceiling while reading irregular acronyms (i.e. those pronounced as mainstream words such as NASA) demonstrated impairment. It is therefore argued that consequences of semantic impairment vary across acronym types, a finding that informs our understanding of any reading account of this growing class of words.

*Response to Reviews

Dear Editor-in-Chief,

Please find enclosed our revised manuscript, “Are acronyms really irregular? Preserved acronym reading in a case of semantic dementia” by David Playfoot, Cristina Izura and Jeremy Tree, which we would like to resubmit for publication in Neuropsychologia.

We appreciate the time that the reviewers have spent considering our work, and have addressed the issues that they had raised in our resubmission. We thank them for their helpful comments and believe that the paper is stronger for their input. Below we detail our response to each individual comment. The material that we have added is indicated in bold in the manuscript to make it easier for the reviewers to see what we have done. All authors have approved the revised manuscript and agree with its submission to Neuropsychologia. Please address all correspondence to: Dr David Playfoot, Department of Psychology, Southampton Solent University, Above Bar Street, Southampton, SO14 7NN.

We look forward to hearing from you at the earliest possible convenience.

Reviewer 1: Marc Brysbaert

Point 1 “The main problem with the ms is that the authors have an underdefined view of regular/irregular. You can only have an irregular mapping when there is a set of rules governing the mapping”

So, if the Playfoot et al. want to maintain that acronyms are irregular, they should start by saying what the rules of acronyms are.

For instance, an interesting finding of the authors is that as soon as the orthographic rules are violated in a number of words, the patient seems to rely on the letter-by-letter rule, even for words that could be read differently. Indeed, the case could be made that this is the easiest way of pronouncing letter sequences. There is some evidence that acronyms are stored phonologically as sequences of letter names (Brysbaert, Slattery).

> **Response**: As recommended by Reviewer 1, Marc Brysbaert, a more precise view and therefore definition of regular/ irregular acronyms is provided in the last paragraph of page 5 and throughout the manuscript thereafter (i.e. each time a type of acronym, regular or irregular, had to be mentioned or labelled). In our opinion the majority of acronyms can be considered regular as defined by the rule of naming each letter aloud. We have also make a note later on in the paper about the available evidence showing that acronyms are stored phonologically as sequences of letter names.

Point 2: More has been done on acronyms and related stimuli by authors such as Federmeier, Ganushchak, and Slattery. It would be good to add these citations here, so that readers get a more complete view of the research done.

> **Response:** Studies by the suggested authors have been included to bring the literature up to date (e.g. pages 3 and 12)

Point 3: p. 3, bottom: You cannot say "regular or consistent". In Glushko's (1979) view, regular words can be both consistent (when there is only one mapping) and inconsistent (when there is another mapping besides the regular one). Same is true for irregular words.

> **Response:** The words “or consistent” and “or inconsistent” have been removed from the sentences at the bottom of page 3, beginning of page 4. In addition we have summarised an overview of what it is meant by regular/ irregular and consistent/ inconsistent.

Point 4: p. 4, bottom: people can read acronyms they don't know: Of course, they can! And it seems a strange comment to make here. What the authors want to convey, though, is that people easily revert to letter by letter reading, particularly in the presence of stimuli that induce such reading (i.e., that do not contain enough vowels).

> **Response:** The sentence ‘people can read acronyms they don’t know’ has been removed and a new statement to this effect has been added to the manuscript as clarification of what we intended to convey (page 5).

Point 5: p. 6 : typical vs. atypical acronyms: Here we again see the trouble the authors have by not properly define what irregular is. Here, acronyms suddenly seem to be typical vs. atypical. With typical, do the authors mean regular (and according to which rule) or consistent (with what)? To some extent, the pronunication of letters cannot be consistent, because this is not how one reads words. Incidentally, this creates an issue of why people pronounce HIV the way they do. Arguably this is because another orthographic rule of English has been broken: that words do not end on the consonant V (but see luv, gov, ...).

> **Response:** The acronym print to pronunciation patterns have been re-defined as regular or irregular according to one rule: naming each constituent letter aloud. See also response to point 1.

Point 6: p. 14 : not a good idea to have all words of length 3 when your acronyms either have 3 or 4 letters

> **Response:** This is a good point (we will bear it in mind for future experimental work). However, we would like to note that only three acronyms were four letters long

(NASA, NATO and UEFA) the remaining 11 comprised three letters only. On average acronyms were 3.2 letters long while words were 3.0.

Point 7: p. 19: a bit confusing to read "real word" when stimuli could be acronyms. There are indeed arguments to say that acronyms are part of the mental lexicon (Brysbaert et al.), but it still will be confusing for most readers. Replace by "existing combination of letters in English"?

Response: The wording suggested has been implemented in the revised manuscript (page 28).

Point 8: p. 20: Please add a column with the nonword data to Table 4

Response: In the two alternative forced choice task, non-words were never the target. On each trial JD had to choose the existing English letter combination from two simultaneously presented letter strings. By definition, every time JD did not select the word or acronym she had instead selected the non-word. This has been clarified in a note associated with Table 4

Point 9: p. 24-25: We need to know much earlier why JD pronounced so many words incorrectly. Better in the results section already to detail how many of these stimuli were read letter by letter.

Response: Following this comment, and a similar point made by reviewer 2, we have indicated the type of errors that JD made in the results sections to both naming experiments (pages 24 and 36).

Point 10: p. 31 : "lexical activation is unlikely to be of benefit" This is true, but it seems more likely that JD would follow nonlexical GPC rules at the later stages. Otherwise she would pronounce irregular words correctly.

Response: We agree with the reviewer's point. We have slightly changed the argument to acknowledge that the likelihood is that JD is sensitive to the context and as a result she was using a sub-lexical route (pages 34, 35 & 36).

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Reviewer 2:

Point 1: Introduction should introduce the tasks used and main hypotheses more clearly.

Response: As recommended the introduction has been modified to provide a stronger rationale and clearer definition of the factors assessed in each task (pages 8-10).

Point 2: Methods, Results, and Discussions are written separately for each task. Such structure makes it difficult to keep track of procedure and findings. For instance, how control groups were matched, were the items across tasks the same? Where all tasks administered on one session or spread through different sessions? Was order of the tasks counterbalanced? (see also below). I would recommend to write all tasks in one methods section (idem for results and discussion).

> **Response:** The methods, results and discussion sections have been reorganised according to the reviewer's request. We have also added a paragraph on page 12 as clarification that separate control groups were recruited for each task, and that the presentation of the acronym tasks was randomly ordered within single sessions with JD at each test time.

Point 3: The authors differentiate between pronounceable acronyms (e.g., NASA) and acronyms that are pronounced letter by letter (e.g., BBC). However, such differentiation is not analyzed for all tasks. Such analysis will reveal more about how acronyms are processed in general, and whether a patient with a semantic dementia processed such acronyms differently than a matched control group.

> **Response:** It would have been interesting to explore potential differences between the three acronym types in all the tasks. However, the acronyms differ fundamentally in their manner of pronunciation and to what extent the pronunciation can be guessed from their orthographic pattern (e.g. those acronyms with vowels in them become rather ambiguous at the time of pronunciation as in UCAS and AOL). For this reason a naming task was thought to be particularly suitable to observe differences between acronym types.
>
> In addition, a number of studies suggest that access to semantic from print is similar for acronyms and mainstream words (Brysbaert et al., 2009) and that lexical decision performance is not influenced by the spelling to sound regularity of the stimuli (Hino & Lupker, 1996). Therefore, differences between acronym types were investigated only in the naming task.
>
> Admittedly, research on acronym recognition processes is still in its infancy. Research still needs to replicate current findings to reassure investigators of the validity of the assumptions taken (such as those made in the present study).

Point 4: p.23. Authors state that JD's ability to perform on the semantic categorization and lexical decision tasks is affected by her semantic dementia, and that is clear that the patient had difficulties in retrieving information about acronyms from semantic or lexical systems. However, I cannot see how the authors came to those conclusions. To my opinion, the authors have clearly shown that the effects they have seen are most likely to be attributed to the strategic effects that JD used to perform the task.

> **Response:** We agree that the data suggest that JD has developed compensatory strategies with which to complete the task. However, adopting any kind of strategy for completing the lexical decision tasks would not be unnecessary, if the usual mechanisms for making such a decision were functioning correctly. Simply, if JD

could retrieve lexico-semantic properties of acronyms efficiently she would not need a response strategy. A passage on page 30 has been added to clarify this point.

Point 5: To make stronger conclusions about semantic and lexical processing the authors should have a control condition where they compare performance on acronyms with regular and irregular words. Here the critical comparisons would be whether acronyms are processed more like irregular or regular words. And then inferences could be made about how those are processed based on the reading models (DRC, PDP).

Response: We thank the reviewer for their suggestion. In this work we have couched our interpretation of acronyms as being different from words/nonwords and therefore we couldn't see what kind of items could act as controls (since irregular or regular words would be inappropriate)

Point 6: Additionally, an interesting comparison could be between performance on acronyms and matched non-words. If there is no difference between performance on those, then it is hard to argue that the patient knew/was familiar with acronyms she could have treated them as non-words.

Response: The proposed comparison would be something we would have liked to do. Unfortunately since this case has a neurodegenerative condition we are no longer in a position to do so given the current state of impairment seen in the case - we would however bring the reviewers attention to the comparison between performance on acronyms and matched nonwords conducted in the lexical decision task (see table 3 pages 20 and 21). As the table indicates there is a clear difference between the recognition of acronyms and legal nonwords (which were the most similar to the acronyms used in the lexical decision task).

Point 7: Control group participants are not well described. For different tasks are those the same participants or a new group of participants were recruited each time? How control groups were matched with JD.? Were from the same socioeconomic status, similar education, similar work experience? Etc. Why control group was not used for all tasks?

Response: It has been made clear that each task had a different set of control participants, all of which were of a similar age and level of education as JD. Page 26 now states that a control group was not used for the two alternative forced choice lexical decision task because control performance was near ceiling in the standard lexical decision task, and that bigram frequency was therefore not thought to be a factor in the control participants.

Point 8: Materials could be described more clearly as well. Were the same acronyms selected for each task? Or different acronyms were included for each task? In both cases, it should be explicitly stated in the methods section. And if different acronyms were included, to make performance in different tasks more comparable, the authors should explain how acronyms between tasks were matched and whether the differences between tasks couldn't be attributed to different items. Also, authors need to justify why they used different item lists rather than keep items the same across tasks.

> **Response:** We have added a passage on page 12 which indicates that the same acronyms were not necessarily used for all tasks. We also make it clear that the selection of the acronyms was driven by the characteristics that we needed to control for a particular task and mention matching of stimuli across conditions for each individual task.

Point 9: As for results section, accuracy appears to be important for the authors conclusions. However, it is not clear how accuracy was determined, how many errors were made in total, what type of errors were made, how the error distribution was different between patient's performance and control group? This should be clearly described for each tasks.

> **Response:** This is a good point and we believe that specifying the type of errors has help to clarify some crucial aspects of the paper. Therefore, the results section for each task now includes a definition of what was considered to be correct, and what was incorrect. Further, in the naming tasks, the types of errors that were made by JD and by the control participants have been stated explicitly.

Highlights

- We test acronym reading processes in a case of semantic dementia
- We track changes in accuracy longitudinally as the dementia progresses
- Semantic and lexical processing of acronyms declines markedly
- Reading accuracy remains high for some, but not all, types of acronym
- Presenting acronyms alongside words in mixed lists disrupts word reading

Are acronyms really irregular? Preserved acronym reading in a case of semantic dementia.

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Short title: Are acronyms really irregular?

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Keywords: Acronyms, Semantic Dementia, Regularity, Reading, Surface Dyslexia

Are acronyms really irregular? Preserved acronym reading in a case of semantic dementia.

This paper describes the progressive performance of JD, a patient with semantic dementia, on acronym categorisation, recognition and reading aloud over a period of 18 months. Most acronyms have orthographic and phonological configurations that are different from English words (BBC, DVD, HIV). While some acronyms, the majority, are regularly pronounced letter by letter, others are pronounced in a more holistic, and irregular, way (NASA, AWOL). Semantic dementia at its moderate stage shows deficits in irregular word reading while reading accuracy for regular words and novel words is preserved. Nothing is known about acronym comprehension and reading ability in semantic dementia. Thus, in this study we explore for the first time the impact that semantic decline has on acronym recognition and reading processes. The decline in JD's semantic system led to increasingly impaired semantic categorisation and lexical decision for acronyms relative to healthy controls. However, her accuracy for reading aloud **regular** acronyms (i.e. those pronounced letter by letter such as BBC) remained near ceiling while reading **irregular** acronyms (i.e. those pronounced as mainstream words such as NASA) demonstrated impairment. It is therefore argued that consequences of semantic impairment vary across acronym types, a finding that informs our understanding of any reading account of this growing class of words.

1. Introduction

The processes involved in single word reading have been the subject of extensive study in psychology, and investigations have identified a number of factors that can affect the ease with which words are read aloud such as frequency, age of acquisition, imageability and orthographic neighbourhood (Andrews, 1989; 1992; Brysbaert & Ghyselinck, 2006; Connine, Mullinex, Shernoff, & Yelen, 1990; Ghyselinck, Lewis, & Brysbaert, 2004; Izura, Pérez, Agallou, Wright, Marín, Stadthagen-González, & Ellis, 2011; Mathey, 2001; Sears, Hino, & Lupker, 1995; Strain, Patterson, & Seidenberg, 1995). The present study is concerned with reading for a class of word which has not been considered in any great detail to date, and never in the context of neuropsychological presentation; acronyms (e.g., BBC, HIV, NASA). A small number of studies have shown that acronyms and other abbreviations are integrated alongside mainstream words in mental lexicon (Besner, Davellaar, Alcott, & Parry, 1984; Brysbaert, Speybroeck, & Vanderelst, 2009; **Ganushchak, Krott & Meyer, 2012**; Prinzmetal & Millis-Wright, 1984) **and that there are considerable similarities between acronyms and words with regard to semantic processing (Ganushchak, Krott & Meyer, 2010; Laszlo & Federmeier, 2007a, 2007b, 2008; Playfoot & Izura, in press).** Assuming this is the case and that acronyms fit in the same mental space as common words, it is likely that they are both processed by the same system, although the exact details of the processes underpinning acronym reading are still open to debate. The current study seeks to further contribute to this discussion.

An important characteristic of English words is that their pronunciation is not always predictable from their spelling. For some words the conversion from print to pronunciation is relatively straightforward (MINT, TINT, HINT, etc.) and can be inferred with sufficient knowledge of the spelling and sound conventions of the language. **The rules governing**

spelling to sound conversion discussed in a great part of the psycholinguistics literature draw on the work by Venezky (1970). He grouped the written representation of sounds into 'graphemes' (a letter or combination of letters equivalent to one sound) and established two types of grapheme-to-phoneme correspondences; 'major' for those occurring with higher frequency and 'minor' for those occurring with lower frequency. As an illustrative example of Venezky's taxonomy, the pronunciation of *'ea'* as in *'seal'* was described as a major correspondence, while the pronunciations for *'ea'* in *'steak'* or *'bread'* were minor correspondences. In most cases words can be pronounced accurately by assigning the major grapheme-to-phoneme correspondences. When a word can be read accurately by applying this rule it is described as being regular. However, a proportion of English words have pronunciations which deviate from the major grapheme-to-phoneme correspondences. Words (e.g. PINT) which cannot be read correctly following the set of rules for spelling to sound conversion are referred to as irregular.

A common finding in the literature is that words with irregular spelling to sound correspondences are named at longer latencies than regular words (e.g. Hino & Lupker, 2000; Jared, 2002). It has been argued that this reflects a difference in the way that regular and irregular words are processed. The dual route cascaded (DRC) model (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) proposes two different methods (i.e. routes) to arrive at a pronunciation for a written word. Using the lexical route, the reader accesses the stored orthographic and phonological representations of the stimulus which guide them towards the correct pronunciation. Using the non-lexical route, the pronunciation of the stimulus is computed **by the application of the major correspondences described by Venezky (1970).** For irregular words the pronunciation outcome from the two methods is different and only the lexical route option would lead to the correct pronunciation. For non-words and unknown words there will be no stored representations available, hence the lexical route will not be able to offer any pronunciation and the non-lexical route must be used. An alternative view is offered by parallel distributing processing models (PDP, e.g. Harm & Seidenberg, 2004; Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989). In PDP theories, the conversion from orthography to phonology in all words is achieved by a single system based on patterns of pronunciation for word bodies. In irregular words pronunciation does not follow the general pattern, and input from the semantic system constrains the orthography to phonology pathway such that a less common pronunciation is generated.

A few recent studies have assumed that the unusual orthography and phonology of acronyms means that they are processed in a similar way to irregular words (Laszlo & Federmeier 2007; 2008). **However, acronyms exhibit a pattern of regularity different to that observed by Venezky (1970) for mainstream words. Regular acronyms obey one rule: being pronounced by naming each letter aloud. Irregular acronyms are the rest (e.g. BAFTA, FIFA, etc). An additional consideration when establishing the pronunciation of acronyms is their orthographic structure. Those acronyms consisting of a combination of vowels and consonants introduce ambiguity at the time of pronunciation. A person unfamiliar with an acronym such as REM will not know whether the correct pronunciation is /rɛm/ or /ar i ɛm/. The evidence reported by Izura and Playfoot (2012) seems to indicate that people have little difficulty in reverting to letter by letter reading, especially when the characteristics of the stimulus preclude alternative pronunciation. If these newly defined criteria are implemented, then acronyms, too, can be described as either regular (as in BBC or HIV) or irregular (as in NATO) according to whether the letter by letter rule is followed. An extra factor to keep in mind is the**

ambiguity that the presence of vowels introduces in acronyms. Thus, regular acronyms can be unambiguous (e.g. DVD) or ambiguous (e.g. AOL) while irregular acronyms will always be ambiguous (e.g. UEFA).

In this paper, the issue of the regularity of acronyms is explored in the context of surface dyslexia as associated with semantic dementia, a progressive degenerative disorder of the semantic system characterized by a semantic impairment while other aspects of cognitive performance are preserved (Hodges, Patterson, Oxbury, & Funnell, 1992; Snowden, Goulding, & Neary, 1989). In semantic dementia, accessing the information that has previously been stored about words becomes increasingly difficult and categorisation and picture naming performance is adversely affected (e.g. Bonner, Vesely, Price, Anderson, Richmond, Farag, Avants, & Grossman, 2009; Hodges et al., 1992). Semantic dementia is also characterised by an increase in errors when reading aloud irregular words (particularly low frequency irregular words such as suave), while reading words with regular spelling to sound correspondences is preserved; a condition known as surface dyslexia. (e.g. Coltheart, Saunders, & Tree, 2010; Graham, Patterson, & Hodges, 2000; Mendez, 2002; Patterson, Lambon Ralph, Jefferies, Woollams, Jones, Hodges, & Rogers 2006; Rogers, Lambon Ralph, Hodges, & Patterson, 2004; Woollams, Lambon Ralph, Plaut, & Patterson, 2007). Surface dyslexic reading is accounted for in the DRC model by a failure in the lexical route and an over-reliance on the non-lexical route. The asymmetric performance of surface dyslexic patients, that is, good reading of regular words and poor reading of irregular words has been studied profusely and it is one of the key symptoms that discriminate surface dyslexia from other types of reading difficulties.

In contrast to the wealth of research on how dyslexics read regular and irregular words, no one study to date has examined the naming performance of dyslexic patients when reading acronyms. This is striking since a comprehensive view of a reading disorder such as dyslexia, should offer an account of reading performance for all types of words, including acronyms. Acronyms have an added interest since they exhibit a combination of regular and irregular features. Thus, different predictions can be generated depending on whether the attention is focused on the irregular orthographic structure of acronyms (compared to English words) or on their regular spelling and pronunciation patterns (based on letter naming rules). The examination of reading performance in semantic dementia is therefore essential.

Here we present the first longitudinal investigation of acronym processing in a case of semantic dementia. It is a meticulous examination of acronym reading where all types of acronyms described to date have been considered (Izura & Playfoot, 2012**). T**hese are: **regular[1] ambiguous (e.g. HIV), regular unambiguous (e.g. PDF), and irregular, by definition always ambiguous (e.g. UEFA).**

The adherence to a letter naming rule confers unambiguous acronyms (e.g. BBC) with a form of regularity that should facilitate reading in surface dyslexia. In contrast, ambiguous acronyms would be prone to error once the lexical route has degenerated such that it could not be used to determine the appropriate pronunciation. The decline in naming accuracy for ambiguous yet regularly pronounced acronyms (i.e., HIV) would be attenuated by their adherence to the letter naming rule system in the same way as regular word reading is preserved relative to irregular word reading. If, on the other hand, the irregular orthographic

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Izura and Playfoot (2012) actually refer to "typical" versus "atypical" pronunciations for acronyms. Here we have adopted regularity according to the rules describe earlier in order to keep the comparisons between word and acronym reading processes clear.

structure of acronyms determines the need for lexico-semantic input, then reading accuracy would be expected to decrease for all types of acronyms as the dementia progresses.

Using the performance of a semantic dementia patient as a means to assess acronym reading makes the assumption that recognition and comprehension processes are affected in the same way for both acronyms and mainstream words. **Therefore JD was assessed on tasks relating to the semantic and lexical properties of acronyms.**

The intention of the semantic categorisation task was to determine whether the semantic representations for acronyms had been damaged by the semantic dementia. The semantic categorisation task used in this study required that JD classified acronyms according to whether or not their meaning related to science and technology. In order to achieve this categorisation accurately the patient must access stored semantic representations of the acronyms displayed and retrieve details of their meaning. Previous studies (Bonner et al., 2009; Laisney et al., 2011) have shown that categorisation performance decreases rapidly in semantic dementia. **As the semantic processing of acronyms appears similar to that of mainstream words (Ganushchak, et al., 2010; Laszlo & Federmeier, 2008; Playfoot & Izura, in press) it was assumed that the progressive impact of the dementia on the semantic representations for both types of stimulus would also be similar. Hence JD's categorisation accuracy was expected to deteriorate across sessions. According to the classic models of word reading (Coltheart, Curtis, Atkins & Haller, 1993; Seidenberg & McClelland, 1989), semantic access in semantic tasks proceeds in the same way for all written words (regular, irregular and, by extrapolation, acronyms). Thus semantic processing is not thought to be sensitive to**

the relationship between spelling and sound, and for this task the regularity of the stimuli was not manipulated.

In order to gather a comprehensive view of JD's lexico-semantic system when processing acronyms, she was also asked to complete a lexical decision task. In this task the participant is presented with a string of letters and his/ her job is to determine whether the letters make up an existing word, or whether the stimulus is a non-word. Previous findings suggest that word recognition performance in a lexical decision task can be adversely affected by the progression of semantic dementia (e.g. Moss, Tyler, Hodges, & Patterson, 1995; Tyler & Moss, 1998; Coltheart et al., 2010). **In this study JD was not only presented with words and non-words, but acronyms as well. The lexical processing of acronyms appears similar to that of mainstream words (Besner et al., 1984; Brysbaert et al., 2009; Ganushchak, et al., 2012; Prinzmetal & Millis-Wright, 1984) and it was assumed that acronym processing would be likely to be adversely affected by semantic dementia in much the same way as for words. Thus JD was expected to become increasingly inaccurate in distinguishing written acronyms from non-acronyms as the dementia progressed. While regularity effects are commonly found in the naming literature, lexical decision responses are not typically affected by regularity (Hino & Lupker, 1996; 2000; Seidenberg, Waters, Barnes & Tanenhaus, 1984; Waters & Seidenberg, 1985) unless the demands of the task particularly emphasise phonological processing. Lexical activation processes do not necessarily require phonological information, and hence, all other things being equal, the lexical decision responses for regular and irregular words are achieved with equivalent accuracy. The same was expected to hold for acronyms. Thus the regularity of the words and acronyms used in this task was not manipulated.**

To assess whether JD's reading of acronyms was more likely to proceed via the lexical or non lexical route it was necessary to examine JD's accuracy when reading aloud acronyms. Effects of spelling-sound regularity are most commonly observed in reading aloud, and indeed, a difference between reading accuracy for regular versus irregular words is a defining feature of semantic dementia (Hodges et al., 1992). Therefore we examined the relationship between the orthography and phonology of words and acronyms in the naming task. It was expected that JD would be more accurate in pronouncing written regular words than irregular words, consistent with the surface dyslexia associated with such cases (Coltheart et al., 2010). It was also expected that JD would be more successful in reading acronyms with a regular pronunciation (according to the letter naming rule) than those with word-like pronunciations.

2. Method

2.1 Patient JD

JD (born 1949) approached her GP in November 2007 with memory problems. In the next 3 months she was referred to a neurologist and then to a clinical neuropsychologist. JD was formally diagnosed with semantic dementia in November 2008. At the time of diagnosis, JD was 59 years of age. She was working as a legal secretary and had had a university education. JD is married and has two daughters in their 20s. JD was tested on the acronym tasks described in this study over a period of 18 months. The first session was in April 2009. JD had performed standardized tests examining the accuracy of her reading and her ability to complete semantic, phonological and perceptual tasks prior to the current experiments. She showed the characteristic language specific impairment associated with semantic dementia (see Table 1). Specifically, JD had difficulty in picture naming tasks, word comprehension and verbal fluency. Her accuracy in tasks of visual perception, rhyme judgment and word repetition ability remained high. One year later, JD's accuracy in a number of the standardized tests had decreased, particularly those tasks involving semantic processes.

Table 1 – JD's performance in standard tests (% accuracy) at two different points in time. The mean score for typical adult readers is also included.

		Feb-April 2009	Feb-April 2010	Normal mean
Semantic	**Pyramids and Palm Trees**	83	81	96
	Pyramids and Palm Trees (written)	79	56	96
	Picture Naming (PALPA)	75	53	100
Reading	**Regular**	98	98	100
	Irregular	65	63	100
	Non-words	98	83	98
Visual Perception	**BORB – foreshortened**	100	92	88
	BORB – minimal features	100	92	92
Phonology	**Non-word repetition (PALPA)**	100	100	99
	Word repetition (PALPA)	100	100	99
	Rhyme Judgement	92	78	100

	(PALPA)			

Note: Pyramids and Palm trees (Howard & Patterson, 1992), reading tasks (Castles & Coltheart, 1993), PALPA (Psycholinguistic Assessments of Language Processing in Aphasia, Kay, Lesser, & Coltheart, 1992), BORB (Birmingham Object Recognition Battery, Riddoch, & Humphreys, 1993).

JD's performance on acronym processing tasks was tracked over an 18 month period. The tasks related to the access of semantic representations for acronyms, the ability to recognise existing acronyms and the success with which they were read aloud. Accuracy was assessed relative to three different groups of 6 healthy control participants (one group for each task) of similar age and educational background to JD. The selection of acronyms was constrained by the nature of the task, the predictions and necessity to match their characteristics with items for other conditions in each task. Thus, the same acronyms were not used for all tasks. More detailed descriptions of the tasks are offered below. All three tasks were tested during single sessions with JD. We presented the tasks in one of three different orders (naming, lexical decision, categorisation; lexical decision, categorisation, naming; categorisation, naming, lexical decision). Which of the orders was presented at which test time was chosen randomly.

2.2 Semantic Categorisation task

2.2.1 Control group

Three male and 3 female native English speakers (age range 56 to 66 years, mean = 62) were recruited to complete the semantic categorisation task. All of them had normal or corrected to normal vision, and had successfully completed an undergraduate degree. None of the control participants had been diagnosed with any language deficit. **Control participants for the categorisation task were not included in other parts of this study.**

2.2.2 Materials

One hundred acronyms were selected from Izura and Playfoot (2012). The acronyms selected did not comprise numerical characters (e.g., 4WD), mixed case letters (e.g., kJ) or consecutive letters from any of the words it abbreviates (e.g., BSc, PhD) Acronyms were between 3 and 5 letters long (mean = 3.3). Fifty of the targets could be categorised as being related to "science and technology." This encompassed acronyms pertaining to medicine (HIV, MMR), computing (DOS, CPU) and electronics fields (FET, TFT). The remaining 50 acronyms were part of a "general" category. General acronyms included names of organisations (BBC, BDA), abbreviations used in correspondence (RSVP, PTO) and phrases in common use such as BLT or BYOB (see appendix A for details). **The two sets of acronyms were matched on printed frequency, rated frequency, and imageability from Izura and Playfoot (2012). Imageability has previously been shown to be influential in the semantic access of acronyms (Playfoot & Izura, in press) and hence needed to be controlled in this study. The means for each variable did not differ significantly between the science-related and the general acronyms as determined by independent t-test analyses (all $p > .1$).** The participants were given definitions of the categories and two two-letter acronym exemplars of each before the commencement of the experimental trials. JD categorised the same materials in three sessions: one in April 2009, the second in February 2010, and JD was tested for the final time in July 2010.

In order to minimise the number of errors due to lack of acronym knowledge an effort was made (see below) to select acronyms that JD and the control participants would be likely to know. Three methods were used to achieve this. Firstly, all acronyms were selected from a normative study comprising acronyms learned and therefore known by the majority of the participants (Izura & Playfoot, 2012). In addition, to ensure that the acronyms selected were encountered by people of JD's age, rated frequency measures for the acronyms were collected from a group of ten native English speakers ranging in age from 57 to 67 years (4 males and 6 females, mean age 60 years; none of the raters performed any of the experimental tasks described in this paper). Ratings were made on a 7 point scale (1 = "rarely/never encountered" to 7 = "encountered more than twice a day"). The minimum rating given for the acronyms selected was 2.1 (a rating of 2 indicated "on odd occasions"). The acronym rated most familiar was encountered once a week on average. Finally, another group of ten native English speakers (4 male and 6 female, age range 57-69, mean = 61.7, again none of these participants attempted the experimental tasks) were asked to indicate whether they knew the meaning of the acronyms. All of the acronyms chosen were known by at least 8 of the 10 participants.

2.2.3 Procedure

Acronyms were presented centrally in black uppercase letters, Times New Roman font, size 12 points, on a white background shown on a 15.1 inch laptop screen. Stimulus presentation was controlled using E-Prime (Schneider, Eschman, & Zuccolotto, 2002). Trials began with the presentation of a central fixation cross. The cross remained onscreen for 1500ms. This was replaced by a randomly selected acronym in uppercase letters. Targets remained onscreen until the participant had made a response. Responses were indicated by a button press on a serial response box. Participants pressed the button under their right index finger if the acronym was from the "science and technology" category. Pressing the button under the index finger of the left hand indicated that the acronym belonged to the "general" category. Buttons were labelled according to the category definitions. The programme logged the accuracy of the response automatically.

2.3 Lexical Decision task

2.3.1 Control group

Six native English speakers (2 male, 4 female) volunteered to complete the lexical decision task. They were aged between 56 and 66 (mean = 62). All participants had university education. None of the participants in the control group had been diagnosed with language impairment. **Control participants for the lexical decision task were not included in other parts of this study.**

2.3.2 Materials

A total of 28 words were used in the lexical decision task. Half were mainstream words, and half were acronyms. Fourteen acronyms were chosen from Izura and Playfoot (2012). Each acronym had 3 to 4 letters (mean = 3.2). The acronyms selected did not use any numerical characters (4WD), lower case letters (kJ) or consecutive letters from any of the words it abbreviates (BSc, PhD). Further, none of the acronyms chosen created a mainstream word (AIDS). **All of the acronyms had also been used as stimuli in the semantic categorisation task.** Fourteen regular words were also selected from the CELEX database (Baayen et al, 1993). All the words were 3 letters in length. **The regular words and acronyms were matched in printed frequency (from the AltaVista search engine, see Izura & Playfoot, 2012). Words and acronyms were also matched for imageability as this has been shown to be influential in the accuracy of lexical decision responses to acronyms (Playfoot, 2012). The imageability ratings for the acronyms were taken from**

Izura and Playfoot (2012) and for the words the imageability values were taken from Cortese and Fugett (2004). For the purpose of the lexical decision task 28 non-words were created. Half were illegal non-words and were formed by changing one letter from an acronym not used in the experimental stimuli. They were 3 letters long and consisted only of consonants. The other half were legal non-words obeying the orthographic and phonological rules of English. These were created by changing one letter of a real word not used as experimental targets. Legal non-words were 3 or 4 letters long (mean = 3.4). The stimuli remained the same in each of the three test sessions. Stimuli are presented in appendix B.

2.3.3 Procedure

The instructions were the same for JD and for the control participants. They were told that they were about to see a series of real words and invented words, and that they had to make a decision as to whether what they saw was meaningful or not. Stimuli were presented centrally in black ink and Times New Roman font (size 12 points) on a white background shown on a 15.1 inch laptop screen. All stimuli appeared in uppercase. Words and non-words appeared one at a time in a random order controlled by E-Prime (Schneider et al., 2002). Targets were separated by a fixation cross presented for 1500 milliseconds. The stimuli remained onscreen until the participant made a response. Responses were made via a 5 button serial response box. “Yes” responses were indicated by pressing the rightmost button on the response box with the right index finger. “No” responses required that the leftmost button was pressed with the left index finger. Buttons were labelled with the words “yes” or “no.” Response accuracy was recorded by the programme (E-Prime, Schneider et al., 2002).

2.4 Naming

Assuming that surface dyslexic reading reflects a dysfunction of the lexical system (Coltheart et al., 2001), if reading acronyms aloud requires lexical reading (Laszlo & Federmeier, 2007a; 2007b; 2008), JD's accuracy ought to be equally poor for all acronyms. However, the naming of **regular** unambiguous (e.g., BBC) and **regular** ambiguous (e.g., HIV) acronyms can be achieved by the application of a letter naming rule. This sub-lexical regularity might be unimpaired in semantic dementia and if so would enable JD to read accurately those acronyms which are pronounced naming each letter out loud irrespective of whether they are unambiguous (BBC) or ambiguous (HIV). JD's reading performance for those ambiguous irregular acronyms (e.g., NATO) is also expected to be preserved since these acronyms generally obey the grapheme to phoneme rules of the language.

The naming task also included regular and irregular words. The defining feature of surface dyslexia is a particular difficulty in reading irregular words while regular word reading is preserved (e.g. Graham et al., 2000; Mendez, 2002; Patterson et al., 2006; Rogers, et al., 2004; Woollams et al., 2007), thus it was expected that JD would be accurate for the regular words, but make errors in the irregular word trials. Furthermore, the inclusion of regular and irregular mainstream words would allow a comparison between JD's use of lexical and sub-lexical reading ability against which to assess acronym reading

2.4.1 Control group

Three male and three female native English speakers were recruited for the naming task. Control participants ranged in age from 56 to 65 (mean = 61 years) **and had had university level education. None had been diagnosed with language deficits or participated in the**

semantic categorisation or lexical decision phases of this study, and all had normal or corrected to normal vision.

2.4.2 Materials

The acronyms selected for naming were grouped following the classification system described earlier. The three subtypes of acronyms were equally represented. As ambiguous and irregularly pronounced acronyms are the least common, it was the selection of these that determined how many of the other stimuli were chosen. In total, 13 ambiguous irregular acronyms were listed in Izura and Playfoot (2012). **Ten of these items were included in the naming task (others were discounted due to low frequency ratings or lack of knowledge reported by age-matched normative samples described in 2.2.2).** To accompany them, 10 regular ambiguous and 10 regular unambiguous acronyms were selected from the same database. Twenty words (10 regular, 10 irregular) were also selected from Bird et al. (2001). **The mean frequency for stimuli of each type was not significantly different (all p > .1)**. The same items were used in February and July 2010 test sessions (see appendix C).

2.4.3 Procedure

Each target was presented in uppercase letters on a 15.1 inch laptop using black colour ink and Times New Roman (size 12 point) letters on a white background. Stimulus presentation was controlled using E-Prime (Schneider et al., 2002). Participants' responses were detected by a microphone placed 10 cm from the mouth. The detection of a response sent a signal to the computer programme which initiated the presentation of the next trial. Trials were separated by a fixation cross presented for 1500ms. Sessions were audio recorded to allow for the analysis of erroneous responses.

3 Results

3.1 Semantic categorisation

The percentage of correct responses given by JD and the control group in the categorisation task are presented below in Table 2. **In each trial, the participants had to choose between two alternative categories (science versus general) only one of which was appropriate for the meaning of the acronym.** Overall, JD's accuracy decreased between the first session in April 2009 and the third session in July 2010. JD's first session performance for those acronyms belonging to the 'science' category did not differ much from the control group performance. A more different outcome between JD and the control group can be detected for those acronyms belonging to the 'general' category. Nevertheless, taking the first assessment as a baseline it is possible to evaluate JD's progression of performance.

Table 2 – Accuracy rates for JD in the semantic categorisation tasks, along with mean percentage accuracy for the controls (standard deviation).

	Correct Responses (%)			
		JD		
	April 2009	Feb 2010	July 2010	Controls
Science	64	54	38	61 (3.0)
General	60	44	28	80 (4.2)
Overall accuracy	62	48	33	71 (2.5)

Chi square analyses for the category and time of test factors were computed separately. There was no significant difference in JD's accuracy for the science and general categories in any of the test sessions [April 2009, χ^2 (1) = .190, p >.1; February 2010, χ^2 (1) = 1.624, p > .1; July 2010, χ^2 (1) = 2.234, p > .1]. McNemar's test indicated that JD's overall accuracy was significantly poorer in July 2010 than it had been in both April 2009 (p < .001) and February 2010 (p < .05). The control participants were significantly less accurate in identifying acronyms as being related to science and technology that they were in responding to acronyms in general usage [χ^2 (1) = 8.797, p < .01]. The difference in accuracy between JD and the control participants was tested using Crawford's t-test. Controls were significantly better at the semantic categorisation task than JD in all test sessions [April 2009, t (1) = 3.333, p < .05; February 2010, t (1) = 8.518, p < .001; July 2010, t (1) = 14.702, p <. 001].

3.2 Lexical decision

The analysis here will address three basic issues. First JD's performance in terms of the type of word presented (word, acronym or non-word) will be examined. Second an examination of JD's performance at each of the three test sessions (April 2009, February 2010, and July 2010) will be performed using McNemar's test. This will indicate how her responses have been affected by the progression of her semantic dementia. Third JD's responses will be compared to those of the control group using Crawford's t-test. JD's accuracy (percentage correct) for each type of word in each of the test sessions is presented in table 3, along with the control group data. **In the context of the lexical decision task, a correct response on an acronym or word trial was to report that the letters formed an existing string in**

English. For non-word trials, the correct response was to indicate that the letter string did not exist in general English usage.

Table 3 – Percentage of correct lexical decision responses for each stimulus type in each of JD's test sessions. Mean accuracy from the control group is also included, with standard deviation in parentheses.

	JD			
	Apr 2009	**Feb 2010**	**July 2010**	**Controls**
Word (e.g., ADD)	93	64	93	95 (4.9)
Acronym (e.g., HIV)	79	79	86	91 (4.5)
Illegal non-word (e.g., RQP)	86	50	64	88 (2.3)
Legal non-word (e.g., PAG)	57	64	43	83 (4.1)
Overall % accuracy	81	64	72	89 (3.0)

Although JD's accuracy rate appears to change from test to test, a series of McNemar's tests indicated performance for each type of stimulus was statistically similar in all three sessions (all $p > .1$).

In April 2009, there was a significant difference between stimulus types in JD's performance [χ^2 (3) = 10.333, $p < .05$]. Single comparisons analyses showed that only the difference in performance with words and legal non-words was significant [χ^2 (1) = 9.975, $p < .05$]. No other comparisons reached statistical significance (all $p > .1$). In July 2010 a significant difference between stimulus types on JD's accuracy was also observed [χ^2 (3) = 10.5, p = .015]. This time JD's responses to both acronyms and words were significantly more accurate than for legal non-words [χ^2 (1) = 5.894, $p < .05$ and χ^2 (1) = 8.838, $p < .05$, respectively]. No other comparisons reached significance (all $p > .1$). No significant differences between stimulus types were observed in the February 2010 test session, in which $\chi^2(3) = 2.489$, $p > .1$. In this test session JD was equally accurate regardless of the type of item presented.

The control participants performed with equal accuracy for each stimulus type [$\chi^2(3) = 1.558$, $p > .1$]. The difference in accuracy between JD and the control group was approaching significance in the initial test session [$t(1) = 2.469$, $p = .057$]. JD's overall accuracy was significantly poorer than the control group in the following two sessions [February, $t(1) = 7.715$, $p < .001$; July, $t(1) = 5.246$, $p < .05$]. Closer inspection indicated that these significant differences in accuracy were the result of a greater number of false positive responses when JD was faced with non-words.

3.3 Naming

Methodological issues meant that the naming task was not administered in the April 2009 test session, and as such only two time points are represented in the data discussed here. JD's response accuracy in February and July 2010 sessions are shown below in Table 4, along with those of the control group. **Only a pronunciation of an acronym that matched with received pronunciation among the general population was counted as correct, even if other responses were plausible. That is to say, the response to HIV was only correct if it was named one letter at a time.** A striking decrease in accuracy was apparent in response to irregular and regular words, while performance for **regular acronyms (ambiguous and**

unambiguous) was near ceiling. Accuracy was poorest for **irregular and ambiguous acronyms** in both sessions.

Table 4 – Accuracy rates for JD in the naming task. Mean percentage accuracy (standard deviation) for healthy controls is also included.

	Correct Responses (%)		
	JD		
	Feb 2010	**July 2010**	**Controls**
Irregular& ambiguous acronym (NASA)	20	10	82 (4.0)
Regular & ambiguous acronym (HIV)	80	90	90 (6.3)
Regular & unambiguous acronym (BLT)	90	100	100 (0.0)
Regular word (DRUG)	80	30	98 (4.1)
Irregular word (DEBT)	90	30	100 (0.0)

Chi square analyses of the time of test and stimulus type factors were computed to analyse the data. In the February test session, JD's accuracy for regular words, irregular words, and **regular** acronyms were not significantly different (all $p > .1$). However, ambiguous **irregular** acronyms were more prone to error than any other stimulus type (all $p < .05$). In July, **regular** acronyms (ambiguous and unambiguous) were responded to with equivalent accuracy [χ^2 (1) = .392, $p > .1$], and both were significantly less prone to error than all other stimulus types (all $p < .005$). A significant decrease in overall performance between test sessions was observed (McNemar's test $p < .05$). Further tests revealed that JD's accuracy for naming word stimuli decreased significantly between sessions (both $p < .05$), but not for any of the acronyms (all $p > .1$). That is to say that JD was just as successful in naming

regular unambiguous acronyms in July 2010 as she had been in February 2010, and just as poor when faced with irregular **ambiguous** acronyms.

JD was significantly less accurate in her overall reading than the control group, both in February 2010 [$t(1) = 4.526$, $p < .01$] and July 2010 [$t(1) = 8.641$, $p < .001$]. In the first session, JD was significantly less accurate than healthy controls in reading **irregular and** ambiguous acronyms [$t(1) = 14.350$, $p < .001$], but equally able to read words and **regular** acronyms (all $p > .1$). In July 2010, her accuracy **reading regular** acronyms (ambiguous and unambiguous) was equal to that of the controls. In each of the other conditions, JD performed at lower levels of accuracy than healthy participants (all $p < .001$). **It was striking to note that in the July 2010 naming test, all of JD's errors resulted from an inappropriate application of letter by letter reading. Where errors were made by control participants, the letter string presented was inappropriately pronounced one letter at a time.**

4. Discussion

JD's performance on the semantic categorisation of acronyms was significantly poorer than that of the controls in all sessions. Although we do not know the extent of JD's acronym knowledge prior to the onset of the semantic dementia, it is likely that she knew the majority of the items since the stimulus selection took into account acronym familiarity among people of a similar age. That said, it is impossible to determine the extent to which the difference in accuracy between JD and the control group in the initial test session was attributable to loss of semantic representations for the acronyms presented. What is clear, however, is that her accuracy decreased markedly across test sessions. This decrease follows the pattern that would be predicted by a progressive degradation of the semantic system.

JD's lexical decision performance was only marginally poorer than healthy participants in the initial test session (April, 2009), but significantly worse than controls in February 2010 and July 2010. Her ability to recognise any type of stimulus that was presented did not change significantly across sessions. Although JD's level of accuracy in acronym recognition was significantly lower than in the control group, her performance remained considerably higher than chance. There are two potential interpretations for this finding. The first is that the representations of acronyms have been relatively spared by the dementia thus far. A second explanation is that JD developed a strategy by which to reach a lexical decision successfully, and that this strategy seemed to preserve acronym recognition. This possibility is supported by the significant levels of false positive responses to legal non-words. JD could have been relying on the presence of a vowel as a bias for a positive response. This strategy would generate correct responses for regular and irregular words and all but one acronym (PVC was the only acronym included that consisted of all consonants). The identification of vowels in the letter-string as JD's criterion of response would lead to incorrect responses for legal non-words since all of them were formed by consonants and vowels.

The results of the semantic categorisation and lexical decision tasks indicate that JD's ability to perform these tasks has been adversely affected by her semantic dementia. It also seems clear that she had difficulties in consistently retrieving information about acronyms from semantic or lexical systems. This provides a clear context for the predictions in relation to the naming tasks. Given JD's impoverished acronym knowledge, little lexico-semantic information would inform JD's pronunciation of written acronyms. Thus acronym regularity effects would be expected, particularly in the later test sessions.

The control participants were highly accurate in their reading of the words and acronyms presented, performing at or near ceiling for regular words, irregular words and **regular** unambiguous acronyms. JD's performance was also generally good in February 2010. The exception to this was irregular acronyms, which JD read accurately only 20% of the time. Interestingly, JD's accuracy was equal to the controls for **regular** acronyms (both ambiguous and unambiguous) in July 2010 in spite of the decreased accuracy in other conditions. We believe JD applied a letter naming strategy to the majority of the items in the naming task. For the **regular** acronyms, this resulted in near ceiling performance. This strategy, however, was inappropriate for the words and **irregular** acronyms. In fact, the error made in all incorrect word trials was to pronounce each individual letter in turn. This shows an over-reliance on a letter-naming rule for reading. JD's overall success in reading the presented items was significantly poorer than the control group in both test sessions, suggesting that her reading has been adversely affected by the progression of the semantic dementia.

Two of the findings discussed above warranted further investigation and each were examined with supplementary experiments. In both cases, the aim of the additional experiments was to assess the factors affecting JD's performance rather than to compare her with controls, who had already been shown to respond with near-perfect accuracy. Firstly, JD performed fairly well in the lexical decision task, responding correctly the majority of words and acronyms. However, her performance was also characterised by a high false positive rate in the legal non-word trials. It was possible, therefore, that the presence of a vowel (as in all the words, all but one of the acronyms and all of the legal non-words) was sufficient to elicit a "this exists in English" response from JD. In order to determine whether JD's performance in the lexical decision task resulted from this kind of strategy, JD was tested using a two alternative forced choice lexical decision task early in

November 2011. This protocol presents a word and a non-word simultaneously, and the participant is asked to decide which of the two is the real word (or acronym). If the accuracy in recognising words and acronyms and the high levels of false positive responses was the result of the perseveration of the yes response then JD’s performance should be roughly 50%. If, on the other hand, JD’s acronym knowledge has been relatively spared by the semantic dementia, she would be expected to successfully differentiate between acronyms and non-words.

5. Two alternative forced choice lexical decision task

5.1 Materials

A total of 56 pairs of target words and non-words were used in this task. Half of the targets were mainstream words, and half were acronyms. Rogers et al. (2004) reported that semantic dementia patients were likely to choose the member of the pair that had a higher bigram frequency in a two-alternative-forced-choice-lexical-decision. To avoid this potential confound 14 low and 14 high bigram frequency acronyms were chosen from Izura and Playfoot (2012). All the acronyms selected contained vowels, and were pronounced by naming each letter in turn. The low and high bigram frequency acronym sets were matched for length in letters and printed frequency. Fourteen low and 14 high bigram frequency words were selected from the CELEX database (Baayen et al., 1993). All sets were matched in terms of letter length and Google printed frequency (see appendix D). Mainstream words did not differ significantly from acronyms in letter length or printed frequency (all $p > .1$). The bigram frequency and orthographic neighbourhood size of the mainstream words and acronyms were also matched within bigram frequency conditions (i.e. the high bigram frequency words were of equal bigram frequency to the high bigram acronyms; the low bigram words equal to the low bigram acronyms).

A non-word was chosen to pair each of the word and acronym targets. The non-words were selected such that their bigram frequency differed from that of the target item. For low bigram frequency acronyms and words, the non-word in the pair was of higher bigram frequency. High bigram frequency targets were paired with low bigram frequency non-words. All non-words contained at least one vowel and matched the word and acronym targets in letter length. Thus the 56 target-nonword pairs formed 4 conditions based on the lexicality of the target and its bigram frequency relative to the non-word (acronym > non-word, acronym < non-word, word > non-word and word < non-word).

5.2 Procedure

JD was told that she was about to see pair of items presented **simultaneously** on-screen, and that each pair contained one **existing** word **or acronym** and one invented word**. Her task was to decide which of the items corresponded to an existing combination of letters in English (i.e. a word or an acronym)**. Stimulus pairs were presented in uppercase letters using black ink and Times New Roman font (size 12 points) on a white background shown on a 15.1 inch laptop screen. In each condition, half of the target words appeared on the left of the screen, and half on the right. Target-nonword pairs appeared one at a time in a random order controlled by E-Prime (Schneider et al., 2002). Trials were separated by a fixation cross presented for 1500 milliseconds. The stimuli remained onscreen until the JD made a response. Responses were made via a computer mouse. The left mouse button indicated that the real word was on the left of the screen and the right button indicated the target was on the right. Response accuracy was recorded using E-Prime (Schneider et al., 2002).

5.3 Results

Table 5 below presents JD's accuracy in correctly identifying the mainstream word or acronym in the pair. **By virtue of the fact that JD was required to choose which of two simultaneously presented stimuli was an existing letter string in English, all incorrect responses reflect trials in which the non-word was chosen.** In general, JD was more successful when the non-word was of lower bigram frequency than the target. Also of note is the similarity between levels of acronym and word recognition accuracy.

Chi square analyses were computed to examine JD's responses further. Her ability to identify the target item was statistically similar regardless of whether the target was an acronym or a mainstream word [$\chi^2 < 1$]. However, JD's accuracy was affected by the bigram frequency of the non-word. She was significantly better at identifying the target when it was higher in bigram frequency than the non-word in the pair [$\chi^2(1) = 19.113$, $p < .001$].

Table 5 – Percentage of targets correctly identified by JD in each condition in the two alternative forced choice lexical decision task.

		Target	
		Acronym	**Word**
Non-word bigram frequency	**Higher**	35	28
(relative to target)	**Lower**	50	56
	Overall % accuracy	42	42

Note: Each target was presented simultaneously with a non-word. Every time JD did not select the word or acronym she had instead selected the non-word, making a mistake.

Thus, every incorrect response in the two alternative forced choice task reflects a false positive for a non-word stimulus

5.4 Discussion

JD's accuracy in identifying words and acronyms in the two alternative forced choice task was significantly affected by the relative bigram frequency of the target and the non-word, replicating the findings of Rogers et al., (2004). However, as a whole JD performed at chance levels. This is supportive of the interpretation that the apparent increase in JD's accuracy in the standard lexical decision task was the result of a response bias to say 'YES' to most letter strings in the lexical decision task, and weakens the possibility that she had retained the ability to recognise acronyms. **Adopting a response strategy of any kind would not be necessary if normal lexical activation, generally fast and accurate, was still possible. Indeed, adopting a strategy based on bigram frequency would not make normal lexical decision responses much faster and would, in addition, considerably decrease their accuracy. Therefore we consider the use of bigram frequency information as a criterion for lexical decision, such as JD has employed, to be a means of compensating for dysfunction in the lexical system.**

6 Separate acronym and word naming

The second finding that required further examination related to the potential effect of context on word reading in the naming task. Low levels of accuracy in reading aloud regular and irregular words in session two could be interpreted as the result of the characteristics of the items in the list of stimuli to be named. Alternatively JD's reading performance could have been the result of a reading system so severely damaged that she was presenting a profile more akin to pure alexia than surface dyslexia. In order to assess this, the naming task was repeated only this time word and acronym reading were tested in separately presented lists. Thus JD read aloud the 20 mainstream words at the end of November 2011, and the 30 acronyms in mid-December 2011. If JD's reading had deteriorated to the point of alexia then all words and all acronyms would be pronounced letter by letter irrespective of whether they were in mixed lists or in distinct "word" and "acronym" lists. On the other hand, if an experimental context containing acronyms that must be pronounced one letter at a time caused JD to rely on a letter naming strategy for all items, then presenting mainstream words separately from acronyms should alter her responses. Specifically, the typical surface dyslexic pattern of word reading would be expected for the word list, such that regular words would be read with greater accuracy than irregular words. JD would still be expected to use a letter by letter strategy in the acronym list, and be more successful at reading acronyms with typical spelling to sound correspondences as a result.

6.1 Results

Table 6 shows the percentage accuracy for JD's reading of each type of stimulus when presented in separate lists (this experiment) and a combined list (July 2010 session above). **Accuracy was determined with regard to whether the pronunciation of an item offered by JD matched the received pronunciation among the general population.** JD exhibited the typical advantage for regular over irregular word reading. She also read the unambiguous acronyms at ceiling. Her accuracy in reading aloud acronyms containing vowels was relatively poor. Chi square analyses were performed to compare JD's accuracy in reading the different types of stimuli. She was significantly more accurate at reading regular words than irregular words in the word naming task [χ^2 (1) = 25.315, $p < .001$]. In the acronym naming task, the type of acronym had a significant effect on JD's accuracy [χ^2 (2) = 143.005, p < .001]. She was significantly less accurate when naming ambiguous acronyms than unambiguous acronyms [ambiguous irregular χ^2 (1) = 136.806, p < .001; ambiguous regular χ^2 (1) = 86.305, p < .001]. Regular and ambiguous acronyms were named with greater accuracy than irregular and by definition ambiguous acronyms [χ^2 (1) = 8.402, p < .01]. It was also apparent that JD was significantly more accurate in reading regular words [χ^2 (1) = 8.202, p < .01] in the separate than the combined task. The accuracy for other types of stimuli were not significantly affected by presenting words separately from acronyms.

Table 6 - Accuracy rates for JD in separate naming task for mainstream words and acronyms. Reading accuracy from the previous session using a combined word and acronym list are included as a comparison.

	Acronym naming %	**Word naming %**	**Combined naming %**
Irregular & ambiguous acronym (NASA)	30	-	10
Regular & ambiguous acronym (HIV)	50	-	90
Regular & unambiguous acronym (BLT)	100	-	100
Regular word (DRUG)	**-**	90	30
Irregular word (DEBT)	**-**	60	30

It is also pertinent to note that the type of errors that JD made in the separate word and acronym tasks were different. In the word naming task, JD's errors in irregular word reading were regularisations. In the acronym naming task, the errors were changeable. The majority of errors in the ambiguous irregular acronym trials were instances of inappropriate letter by letter reading (i.e. regularisations according to the acronym

reading rules). In two of the five ambiguous regular acronym trials in which JD made an error it was because she had pronounced an acronym as if it were a word (i.e. regularisations according to the word reading rules). The other three errors were acronyms which JD pronounced in the appropriate way (i.e. a letter at a time) but made transposition mistakes.

6.2 Discussion

When mainstream words were presented separately from acronyms, JD exhibited the typical surface dyslexic reading pattern associated with semantic dementia. Her reading accuracy for regular words was better in comparison to her performance during the July 2010 test session in which words and acronyms were presented together. This pattern of reading is a clear indication that JD's reading system is still intact enough to read regular words, and that she does not have pure alexia. What is also evident is that the presentation of acronyms which require letter by letter naming disrupted JD's reading system to the extent that mainstream word reading accuracy decreased dramatically. Clearly the context in which items are presented for reading aloud has a profound impact on the processes that are recruited to achieve a pronunciation in semantic dementia.

7 General discussion

The present study is the first to assess and offer an account for acronym reading in a case of surface dyslexia. Acronyms can be considered irregular in terms of their orthographic configuration but they often have regular spelling patterns. The combination of regular and irregular characteristics present in acronyms lead to different predictions as inferred from the pattern of performance reported for regular and irregular word reading. In the case reported here, accuracy data for semantic categorization, lexical decision and naming tasks were gathered in three test sessions between April 2009 and July 2010. Overall, the results from all three tasks and all three main test sessions can be summarized as follows. First, semantic decision performance and lexical decision performance for acronyms decreased over time. Secondly, JD's ability to read acronyms with an irregular acronym pronunciation deteriorated while **the regular** letter by letter acronym reading was preserved.

In previously published studies, acronyms have been considered as a type of word which requires lexical reading (Laszlo & Federmeier, 2007a; 2007b; 2008). We have argued that acronyms are neither irregular or regular, but often combine characteristics of both regular and irregular items (Izura & Playfoot, 2012). In the majority of cases, acronyms have irregular orthographic representations and patterns of letters which are either infrequent or orthographically illegal in English. However, the spelling to sound conversion is predictable (i.e. regular) for most acronyms. This regularity was used in the case of semantic dementia described in this paper to support reading. JD remained capable of reading regular acronyms even after her semantic system had become damaged. It appears that a non-lexical procedure for letter by letter reading of this type was preserved and unaffected by lexical decline. Accuracy for reading irregular acronyms (NATO) deteriorated considerably over the course of the data collection, which seems indicative of the involvement of lexical reading processes for this type of acronyms.

One striking finding in this study was that JD's accuracy in naming mainstream words was severely disrupted by presenting them in an experimental context that also included regular acronyms. This finding of an impact on word reading when the list includes

acronyms is consistent with other related studies examining mixed list presentations (Baluch & Besner, 1991; Monsell, Graham, Hughes, Patterson, & Millroy, 1992; Zevin & Balota, 2000). Baluch and Besner (1991) showed that Persian transparent words yielded frequency effects when they were presented in a pure list. However, when the Persian transparent words were mixed with non-words the frequency effect disappeared. Monsell et al., (1992) reported similar findings using the English language. Here participants read English exception words faster and with fewer regularisation errors when they were presented in pure block-lists than when they were mixed with non-words. Zevin and Balota (2000) using a different paradigm, priming, showed that the frequency and regularity effects exhibited by participants when reading target words were modulated by the nature of the primes. Thus, frequency and regularity effects were found when participants were asked to read aloud five exception word primes (prior to the target) but not effects emerged when participants had to read five non-words primes. These findings have been interpreted as the result of a sensitivity to the reading context. A flexible reading system reacts to the linguistic context by regulating the weight placed on lexical or sub-lexical modes of reading. Thus, reading pure lists of Persian transparent words was subjected to frequency effects because only in that context the system opted for a lexical reading. When the words were mixed with non-words the frequency effect vanished because a non-lexical reading route was more suitable for that particular context (Baluch & Besner, 1991). Similar explanations were put forward for the speed and lack of regularisation errors in pure lists of exception words (Monsell et al., 1992) and the priming effects observed by Zevin and Balota (2000).

This flexible view of reading might also account for JD performance when reading pure or mixed lists of acronyms and mainstream words. JD showed a typical surface dyslexic pattern in reading a list containing only words, but her accuracy suffered significantly when words and acronyms were intermixed. Adding regular and unambiguous acronyms to the reading task (e.g. CNN) presents a considerable challenge. Although acronyms have been found to be lexicalised with some evidence that acronyms are stored phonologically as sequences of letter names (Brysbaert et al., 2009; Slattery, Pollatsek, & Rayner, 2006), lexical reading is compromised for JD and therefore might not have been an option. In addition, regular unambiguous acronyms (e.g. PVC) do not admit the usual grapheme to phoneme conversions. Therefore, much as the presence of nonwords in a list of transparent words predispose the system towards a nonlexical mode of reading, the presence of unambiguous acronyms in a list, that also comprises mainstream words, tilts JD's reading system towards a method that allows the pronunciation of all of the stimuli. This letter naming strategy caused JD to exhibit near-ceiling accuracy for regularly pronounced acronyms, both when presented in pure acronym lists and when intermixed with words. The overuse of letter naming procedures had a detrimental effect on word reading accuracy in mixed lists.

In conclusion, our investigations have determined that the majority of acronyms (i.e., those read in the **regular,** typical letter-by-letter fashion) remain intact in semantic dementia. On the other hand, a small sub-class of acronyms (e.g., NATO) that do not involve regular acronym pronunciation are seen to deteriorate and we would suggest this is consistent with a lexical-semantic locus (which is disrupted in semantic dementia) for success in reading aloud such items. This demonstrates the key issue that not all acronyms are treated the same in reading, an issue that mirrors the regular/irregular pattern seen in reading mainstream words, with one type dependent on a non-lexical (letter-by-letter) system and the other type a lexical system. In effect, acronyms have a peculiar kind of ‘regularity’ based on letter naming procedures. Finally, we believe that the sensitivity of JD’s reading processes to the context of stimulus presentation warrants further investigation.

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Appendix A – Acronym stimuli for the semantic categorisation task

General		Science & Technology	
AGM	GPA	ACDC	IMDB
APR	HMS	ADHD	ISP
AWOL	HSBC	AOL	IVF
BAFTA	ITN	ATM	LCD
BBC	ITV	BMI	LSD
BHS	KFC	BMW	MDMA
BLT	MBA	BPM	MMR
BNP	MGM	BPS	MRI
BST	MTV	BSE	MRSA
BYOB	NATO	CBT	NASA
CEO	NBA	CCTV	NHS
CIA	NCIS	CJD	OCD
CSI	OBE	CPU	PDA
DHL	OCR	DNA	PDF
DIY	PTA	DOA	PSP
DUI	QVC	DVD	PTSD
ESP	RAF	DVT	PVC
ETA	RBS	EEG	RPG
FAO	RRP	ENT	SMS
FAQ	SAE	GPS	SPSS
FBI	SAS	HIV	STD
FIFA	TBA	HMO	TCP
FYI	TBC	HMV	TFT
GCSE	UEFA	HRT	UHF
GMT	UFC	IBM	USB

Appendix B – Stimuli for the standard lexical decision task

Acronyms	Words	Legal non-words	Illegal non-words
BMI	ADD	BERM	CNZ
CEO	AID	MAV	CRN
DNA	AIM	OIT	DTF
DOA	BAR	OND	FCL
ENT	BUY	PAG	HPB
HIV	CUP	PALT	LPF
MRI	CUT	ROAK	MRQ
NASA	DUE	SEP	MVF
NATO	EAR	SHET	NPL
NBA	FAT	SOGE	PNC
PVC	GOD	SUND	PVT
UEFA	HAY	THAM	RQP

UFO	HEY	WOSE	RRC
VIP	WET	WUSH	TNN

Appendix C – Acronym and word stimuli for the naming tasks

Ambiguous irregular acronyms	**Ambiguous regular acronyms**	**Unambiguous regular acronyms**	**Regular words**	**Irregular words**
ABBA	AOL	BHS	DEAL	BEING
ASBO	CEO	BLT	DRUG	BRIEF
AWOL	ENT	BPM	FAITH	CAST
BAFTA	ESP	CNN	FATE	DEBT
BOGOF	FAO	DVT	GRANT	DENY
FIFA	HIV	LCD	SHOCK	HEAD
NAAFI	IBS	RBS	SITE	HIRE
NATO	OCD	SPSS	THEME	HOST
UCAS	PAYE	TBC	TRAIN	LAYER
UEFA	SAS	TNT	TRUST	SWEAR

Appendix D – Two-alternative-forced-choice stimulus pairs

Acronym > Non-word		**Acronym < Non-word**		**Word > Non-word**		**Word < Non-word**	
USB	PON	ESP	RIS	AWLS	DOQ	NIB	MOU
FAQ	ENW	AOL	BIS	SAX	RIR	AMP	HEG
DIY	AIG	CIA	DIS	FOX	UGUS	IMP	TRE
DOB	ESA	IRA	NOM	SIX	IGF	IVY	OIS
ITV	JEN	ATM	BOU	NOR	UVD	AFT	BELF
ENT	IGM	CEO	YOX	AIL	EIG	EEL	CAY
HIV	GES	APR	VAD	SAG	POC	GYM	ALD
SAS	RUR	ETA	DOU	HUN	FAW	LYNX	DORD
FAO	USD	IMDB	NELG	DIB	KIO	OHM	DAR
AGM	KAO	ACDC	NOE	JIG	BEW	ODE	DUT
SAE	DAV	IVF	YOD	CRY	DAK	GNU	MER
USA	DOX	UFC	GER	FRY	PUR	APE	YOG
ITN	BIR	ISP	AIS	BID	SEG	TUB	SUT
USSR	UBUS	UHF	BUSG	BOP	JIN	HYMN	HAB

Note: The greater than and less than symbols refer to the bigram frequency of the stimuli e.g. acronym > non-word indicates that the acronym was the higher bigram frequency of the pair