"Like déjà vu all over again"[a]: Patterns of perseveration in two people with jargon aphasia

Emma Eaton [1] (*), Jane Marshall [2], Tim Pring [2]

[1] NHS Grampian (North Aberdeenshire LCHP), Fraserburgh Hospital, Lochpots Road, Fraserburgh, Aberdeenshire, AB43 9NB
[2] City University, London (Department of Language and Communication Science, City University, London EC1V 0HB)

(*) Corresponding author:

Speech and Language Therapy Department
Fraserburgh Hospital
Lochpots Road
Fraserburgh
AB43 9NB
United Kingdom

Tel: +44 (0) 1346 585250
Fax: +44 (0) 1346 585180

Email: eeaton@nhs.net

[a] Attributed to Lawrence Peter "Yogi" Berra (1925-), baseball player for the New York Yankees

Abstract

Background: It has been argued that perseveration type corresponds to the level of breakdown so that total perseveration (the repetition of a whole word) involves the reactivation of a previous word at the lexical level when the target word is not sufficiently activated. A blended perseveration (the repetition of part of a previous response) results from a failure of target activation at the phoneme level (e.g. Martin & Dell 2007). This is challenged by the occurrence of non-word total perseverations, as these cannot be lexical retrievals (Hirsh 1998). A further problem is the occurrence of long intervals between perseverations and their sources. Some authors have invoked semantic relationships to explain these intervals (e.g. Martin, Roach, Brecher & Lowery 1998).

Aims: This study examines the perseveration of two individuals with jargon aphasia in order to explore the proposal that while some perseveration may result from the reactivation of a recent response via the mechanisms described above, another mechanism exists whereby perseverative responses are built around default phonology, resulting in stereotypical errors.

Methodology and Procedures: Tests of naming, reading and repetition were administered. Responses were analysed to determine: the extent of perseveration; the occurrence of long intervals between perseverations and their sources; patterns of phoneme use; the occurrence of non-word total perseverations.

Outcomes and Results: Both individuals produced large numbers of perseverative

responses. Lengthy intervals could not be explained by semantic relationships. For each participant, certain consonants were found to dominate the phoneme frequency distribution. Evidence was found of an interaction between the occurrence of perseveration and presence of these favoured consonants. The possibility that non-word total perseverations arose from a different source from word total perseverations was rejected because there was no significant difference in the use of the favoured phonemes between the two types.

Conclusion The findings support the theory of two mechanisms for perseveration. The first is local, occurring when residual activation overrides incoming activation. This is confined to a single speech act and occurs closely after the original occurrence. The second type is global, occurring across different contexts over time. It occurs because of default phonology, available in the event of a dearth of incoming activation at the phoneme level. Both total and blended perseverations may result from this mechanism. Word total perseverations may be favoured because of feedback from the phoneme level to the lexical level. Ideas for future research and implications for intervention are discussed.

Acknowledgements

We would like to thank RS and TK and their families for their patience, participation and support. We would also like to thank Lyndsey Nickels for her help in accessing the CELEX database. Funding for this project was received from Bexhill and Rother (NHS) PCT.

Introduction

Recurrent perseveration, the sub-type of perseveration in Sandson and Albert's (1984) taxonomy most closely associated with aphasia, has been defined as the unintentional repetition of a response in the absence of the stimulus that initially elicited it (Hirsh 1998). It can arise in both fluent and non-fluent aphasia, and has been found to be more prevalent when the aphasia is severe (see Moses, Nickels & Sheard 2004a, 2007; Moses, Sheard & Nickels 2007).

A distinction is made in the literature between total and blended perseveration. The first refers to the perseveration of a whole word or non-word (Hirsh 1998; Moses, Nickels & Sheard 2004b & c). The second (also known as partial perseveration) refers to the perseveration of part of a previous word or non-word, with the remaining phonological material being derived from other sources, such as the target or lexical competitors (ibid.). This type of perseveration is particularly associated with the non-word output of people with jargon aphasia (Buckingham 1990; Butterworth 1979 & 1992; Moses et al. 2004b & 2007a). It is also widely accepted that perseveration can occur over varying distances, with some responses repeated immediately after the source, and others recurring after much longer intervals (Martin, Roach, Brecher & Lowery 1998).

Two further characteristics of perseveration have been described. One is a tendency for some (but not all) perseverative responses to be semantically related to target words. Martin et al. (1998) found that whether or not there was a relationship depended on the distance between the perseveration and its source. Thus perseverations that occurred after

long distances were particularly likely to bear a semantic relationship to the target. Hirsh (1998) also documents a pattern of semantic relationship, although in this case between the targets sharing a response. For example, in her naming test, the stimuli "carrot" and later "pumpkin" both led to the response "myralin".

The other characteristic seen in some perseverative speakers is the use of stereotyped phonology. For example, TW (Blanken 1993) overused /g/ and /k/ as initial consonants and variations on "gel" word finally; and DW (Buckingham 2007) had a predilection for 'paper' and its phonological neighbours (see also Kohn, Smith & Alexander 1996).

Why does perseveration occur? Classical accounts broadly divide into those that see perseveration as either the primary or secondary impairment (see Stark 2007 for review). The former argues that perseveration occurs because a previously produced form is over-activated or fails to decay. The latter attributes the problem to the core deficit, in this case weakened lexical access. In effect it is agued that the required new response does not have the power to displace the old. The secondary account is preferred in most modern theories (eg see Buckingham, Avakian-Whitaker and Whitaker 1978), as articulated by Cohen and Dehaene (1998). They note that persistent activation from previous responses is a normal feature of the lexical system, as evidenced by priming effects. Normally such lingering activation cannot compete with new input. However, if a level of processing is disconnected from new input, or that input is abnormally weak, this will not be the case. Now, residual activation can become dominant, resulting in perseveration. Perseveration is most likely in severe aphasia, as here incoming activation

is least able to compete with the residue (Schwartz, Saffran, Bloch & Dell 1994; Dell, Schwartz, Saffran & Gagnon 1997).

The above theory predicts that a response is most likely to be perseverated soon after it is produced, before its residual activation has a chance to decay. This was indeed the pattern found by Cohen and Dehaene (1998). However, their data also included some very long distance perseverations, e.g. after 11 intervening trials. How can such enduring perseverations be explained? One proposal is semantic. It is argued that shared semantic features, either between the perseveration and the target or between targets, can sustain or refresh former activation (Martin et al. 1998; Hirsh 1998). Another explanation appeals to the notion of stereotyped phonology. It has been suggested that some speakers have a pool of "default" segments that fill gaps in the event of retrieval failure, with repeated use of these phonemes producing highly perseverative speech (Robson 1997; Moses et al. 2004b). These "default" segments may be available because of their very high frequency in the language. Additionally, some speakers may develop their own idiosyncratic patterns of phoneme frequency, whereby the perseverative overuse of certain segments permanently changes their resting levels of activation. This makes the segments increasingly dominant at the phoneme level, and makes their production likely whenever incoming activation is weak (ibid.). The outcome will be a global pattern of perseveration, whereby similar sounding words are produced whenever retrieval fails, with the phonological commonalities potentially spanning wide distances in the speech stream.

A theory of perseveration also has to explain why some perseverations are total and others blended. As Stark (2007) notes, many theories argue that the nature of the perseveration reflects the level of the impairment. So, people who have lexical or semantic impairments produce total perseverations, while those with deficits at the phonological level produce blended perseverations (see also arguments in Cohen & Dehaene 1998; Martin & Dell 2007; Moses et al. 2004a, b & c). Moses et al. (2004c) provide corroborating evidence from unimpaired speakers. They found that total perseverations occurred mainly in naming, which requires lexical semantic processing, while blended perseverations dominated in reading aloud, which, they argue, is more dependent on phonemic processing.

The above proposal has not gone unchallenged. One difficulty is that the mapping between the type of perseveration and the level of impairment is far from clear-cut. So, KVH (Moses at al. 2004b, 2007b) had a lexical impairment but produced mainly blended perseverations. The existence of total non-word perseveration is also problematic, since according to the above theory, total perseveration will involve the substitution of a previous word for a currently unavailable target (Hirsh 1998; Moses et al. 2004b, 2007b).

An alternative view is that total perseverations, like blends, arise at the phoneme level. Here, however, the entire phonemic content of a previous response is carried over, presumably because no new target activation is available (Santo Pietro & Rigrodsky 1982). A variant on the view suggests that total perseverations could be blended perseverations that are, by chance, the same as previous utterances (Moses at al. 2004b).

Such chance resemblances are most likely in cases where there is stereotyped phonology, since here responses are being generated from a limited pool of segments. In these cases total perseverations cold occur fortuitously at some distance from the source.

While non-word total perseverations clearly feature in the speech of some people with aphasia, production models that allow for feedback between levels predict that their occurrence should be rare. An example is the model proposed by Rapp and Goldrick (2000) which entails feedback from the phonemic to the lexical level. This feedback ensures that errors corresponding to real words receive some reinforcement from reverberating activation. Non-word errors cannot benefit from feedback to lexical items, so are not reinforced. As a result, perseverations that, by chance, correspond to real words are more likely to be produced than their non-lexical counterparts.

This paper documents the perseverative patterns of two speakers with jargon aphasia. First it is established that these speakers produced large numbers of both blended and total perseverations, including long distance total perseverations that occurred after four or more intervening stimuli. Patterns of stereotyped phonemic use are also explored, with the finding that both speakers had preferred default segments. Finally the paper explores the occurrence of non-word total perseverations.

We propose that there are at least two types of perseveration occurring in these speakers. The first can be described as local, occurring within a single speech act, usually close to its source. It may be explained as residual activation from a recent response overriding

weak incoming activation. The second type can be described as global, based around stereotypical phonological units and potentially occurring over long distances and in different speech acts. It is assembled at the phoneme level because of a dearth of incoming activation.

Our study does not provide a general explanation of perseveration in aphasia. For example, we acknowledge that there may be a second type of long distance perseveration, which is motivated by a semantic connection, either between the new target and the perseverative response (e.g. Santo Pietro & Rigrodsky 1986; Vitkovitch & Humphreys 1991; Martin et al. 1998) or between two targets (Hirsh 1998). While this remains a possibility, it was not observed here.

The Participants

RS

RS is a right-handed male whose first language is English and who was educated to secondary school level. He had a stroke in November 2001 when he was 60 years old. A CT scan at the time revealed a large area of infarction in the left middle cerebral artery area. An MRI scan carried out a year later in December 2002 showed that this was in the temporal and parietal lobes, extending towards the occipital lobe. He had suffered multiple transient ischaemic attacks during this period, and evidence was also found of deep white matter ischaemia, internal capsule infarction on the left, and lacunar infarcts in the right cortex and bilaterally in the thalamus.

RS spoke fluently and his utterances showed evidence of some syntactic structure. His expression, while mostly consisting of neologistic jargon, was peppered with intact phrases. These consisted mostly of common idioms, expletive expressions, and social or formal phrases. In addition, several phonologically related stereotypical words and non-words occurred across different contexts (e.g. “catapult”, “”caterpillar” and non-word variations of these). A sample of his connected speech (from a picture description task) is presented below:

“The toys are stirring to keep their /təˈðɒt/ the keeping of /ˈtidraɪv/ (it is unclear what he was referring to in this utterance). Him pushing his bike (pointing to a man carrying a suitcase). He’s got his books to take to the car (pointing to a boy carrying a bucket and spade). .. A /ˈstɛdli/ pin, crystal, two /pəˈlidmənz/ and a dustman” (pointing to a bunch of safety pins, a nailbrush, a mug and a spoon).

RS’s comprehension was moderately impaired, with the suggestion of some central semantic damage. On Psycholinguistic Assessments of Language Processing in Aphasia (PALPA) (Kay, Lesser & Coltheart 1992), he scored 24/40 on subtest 47: Spoken word to picture matching and 16/40 on subtest 48: Written word to picture matching. He also scored 45/52 on Pyramids and Palm Trees (All Picture version) (Howard & Patterson 1992). His naming was severely impaired. He scored just 1/40 on PALPA 53: Oral Naming (Kay et al. 1992). Although he did not show evidence of monitoring in his connected speech, he often attempted to correct his responses in single-item tasks such as this, frequently making multiple errors to a single response. However, there was no

tendency for responses to move closer to their targets. Of his errors in this test 33 were non-words that appeared to be unrelated to their targets (e.g. heart: /lɛprə/; scissors: /tɛrəbInt/) and 11 were apparently unrelated word errors (e.g. arrow: "photograph"; horse: "fire engine"). There was a single non-word that was clearly target-related (horse: /hunəs/), and a single semantic/visual error, where glove was named "hand". Perseveration was also a feature (e.g. screw: /pIldΛm/ followed by anchor: /pɛdrΛm/). Furthermore, 5 unrelated non-words began with the onset /kr/ (e.g. shoe: /kræsnæt/; yacht /krIsmΛn/).

Reading was also poor: RS scored just 5/80 on PALPA 31: Reading x Imageability and Frequency (Kay et al. 1992) and 0/24 on PALPA 36: Non-word Reading (ibid.).. Although his repetition was impaired, it was stronger than his naming or reading. He scored 33/80 on PALPA 9: Repetition x Imageability and Frequency (ibid.) and 19/80 on PALPA 9: Non-word Repetition (ibid**).**

TK

TK is a right-handed male whose first language is English and who was educated to a tertiary level. He had three strokes, the third and most severe in June 2002 when he was 67 years old. A CT scan at the time revealed a large infarct in the left middle cerebral artery region. He presented with fluent aphasia consisting of non-words and inappropriate words in sentence-like structures. Perseveration was a clear feature of his connected speech. For example when asked to describe a picture of a man walking a dog, he replied:

“Here it’s a bark (pointing to the dog) with a hole which is a talk (the man?) and he catches a cork with two barks along a road where a large chard (a tree stump) and leeks (reeds) with one two three four five six seven eight nine ten /rɑf/ and bits of /hɒmz/ (counting individual reed plants). We’re still here as /ˈgɜkɪŋ/ boat (a canal boat) ‘cos we like along here, and going round, we see the reed of the rude…”

Like RS, TK’s comprehension was moderately impaired, with some likely semantic damage. He scored 18/40 on PALPA 47 (Kay et al. 1992), 28/40 on PALPA 48 (ibid.) and 47/52 on Pyramids and Palm Trees (All Picture version) (Howard & Patterson 1992). In naming, TK scored 4/40 on PALPA 53: Oral Naming (Kay et al. 1992). Also like RS, TK showed some attempts to self-correct his responses in tasks such as this while not showing evidence of monitoring his connected speech. Of his errors, 16 were unrelated non-words (e.g. mountain: /fɜklz/; ladder: /sɛrənd/) and 16 were unrelated words (e.g. comb: “sugar”; thumb: “bird”). There were 2 related non-word errors (cow /kaʊnd/; lemon: /rəmənd/), 2 related word errors (foot: “fate”; bird: “bowed”). Perseveration was also noted (e.g. “foul”; /gaʊl/; “goals” and “bowels” were produced to consecutive targets).

TK scored 36/80 on PALPA 31: Reading x Imageability and Frequency (ibid.) and just 2/24 on PALPA 36: Non-word Reading (ibid.), demonstrating some unwillingness to attempt items in this test. He scored 21/30 on PALPA 8: Non-word Repetition (ibid.). Word repetition was not carried out during preliminary testing.

Methodology

In order to explore the hypothesis put forward in the introduction, the following questions were posed:

1. What is the extent of perseveration exhibited by the participants task-by-task?
2. How large were the intervals between perseverative responses and their origins, and could large intervals be explained by semantic relationships?
3. What were the patterns of phoneme use in these speakers? Were there patterns of stereotypical phonology, and if so, how did these relate to perseveration?
4. Did non-word total perseverations occur?

Picture naming, reading and repetition tests were prepared, consisting of the 20 high frequency and 20 low frequency stimuli in PALPA 54 (Kay et al. 1992). These materials were chosen because of their clinical availability, making them easily replicable. A single test was carried out in a session, a new random order being generated for each task type. Both participants were tested on 4 occasions over the course of a year. On each occasion the 3 tests were carried out over 3 consecutive sessions. In the case of RS, testing commenced at 6 months post-onset, and in the case of TK, at 3 months post-onset. For both participants, intervention during the testing period consisted of a range of general semantic therapy tasks (such as sorting items into categories, selecting the "odd one out") and encouraging strategies such as drawing and gesture.

Question 1: Extent of total and blended perseveration in each task

In this and in all subsequent analyses, only the initial error response to each target was included, whether it was an error or a correct response. The numbers of total perseverations and blended perseverations in each task (with all four trials combined) were found. This count did not include the initial instance (or source) of the word/non-word or segment(s). We used the criteria of Moses and colleagues (2004b) when coding blended perseverations, so permitting future cross data comparisons.

It should be noted that responses were included even if the repeated phonemes were also shared with the target. It could be argued that these criteria were too broad and lacking in sensitivity. This may be tested by comparing RS and TK with other people with aphasia who are less likely to perseverate. Ten control participants with non-jargon forms of aphasia carried out each of the 3 tasks once. They had less severe aphasia than RS and TK (the range of success on naming was 11/40 to 37/40) and tended to be less fluent than them. Therefore we might expect less perseveration.

The findings from the tests carried out with RS and TK are shown in Table 1. Perseverative responses are shown as proportions of the total number of error responses on that task (again, counting only the initial response to each target). The total number of correct responses in each task across all 4 trials is also shown, in order to explore the relationship between task success and the extent of perseveration.

(Table 1 about here)

Both RS and TK produced striking numbers of perseverative responses. Of RS's total number of errors across the trials of each task, 76% (246/323) were perseverative, while for TK, this accounted for 77% (244/318) of his errors. These proportions were found to be much higher than those produced by the 10 aphasic control participants, whose mean perseveration rate was 36% of the total number of errors (range 16-58%). In addition, both participants produced blended perseverations at levels exceeding those of the aphasic control participants. Across all three tasks, 217/323 (67%) of RS's error responses and 186/322 (58%) of TK's error responses were classified as blended perseverations. When the error responses of the control participant with the greatest number of total perseverations were examined, 23/61 (38%) across the three tasks were classified as blended perseverations. This was significantly less than the proportion of blended perseverations produced by RS ($\chi^2 = 19.02$, $p < 0.001$) and TK ($\chi^2 = 8.32$, $p < 0.01$). This demonstrates that the criteria for blended perseverations, though broad, are nevertheless able to distinguish RS and TK from another group of participants with less severe and less fluent aphasia.

Question 2a: Intervals between perseverative responses and their sources

The interval (i.e. the number of intervening stimuli) between each total perseveration and its most proximate source was found. Blended perseverations were not included because the criteria for classification as a blended perseveration were confounded with interval size. That is, the more remote a response was from another, the less likely it was to be counted as a blended perseveration. The findings are presented below in Table 2.

(Table 2 about here)

In the case of RS, a striking number of total perseverations did not occur immediately. In naming, 7 out of 11 total perseverations occurred after an interval of at least 4 stimuli, and in reading, this proportion was 7 out of 16 total perseverations. There were only 2 total perseverations in repetition, one occurring immediately and the other after an interval of 2 stimuli. When the tasks were combined, 14 out of 29 total perseverations (48%) occurring at gaps of at least 4 stimuli.

For TK, 9 out of 36 total perseverations in naming occurred after an interval of at least 4 stimuli. There were no such long distance perseverations in reading and just 1 out of 17 in repetition. In total, 10 out of 58 total perseverations (17%) occurred at gaps of at least 4 stimuli.

Question 2b: Semantic relationships between targets and perseverative responses

As discussed in the literature review, it has been suggested that responses may be sustainable over longer intervals if they benefit from a semantic relationship with the new target (Martin et al. 1998). The following analysis examines this possibility. Both semantic errors and phonological distortions of semantic errors were analysed. The judgement as to whether an error was semantic was made by two arbitrators. Where there was a disagreement, a third arbitrator had the "casting vote". In order to be judged as a phonological distortion of a semantic error, a response had to share at least half its phonemes with a semantic co-ordinate (adjudicated as above). Only total perseverations in naming were taken into account, because there were very few semantic errors in

reading and repetition. Just 1 of RS's 29 total perseverations had a semantic relationship with its target /kætəpold/ (caterpillar?) for snail). This occurred immediately after its source. Five out of TK's 58 total perseverations had such a relationship. Two of these occurred immediately after their source, 1 after a gap of 1 response, 1 after a gap of 3 responses and 1 after a gap of 5 responses.

Question 2c: Semantic relationships between targets sharing a perseverative response

This follows Hirsh's (1998) analysis, as discussed in the introduction. As with the previous analyses, this analysis considered only total perseverations in naming. Pairs of targets that shared a response were examined for semantic relationships. When a perseveration occurred more than once, this led to multiple pairings. For example, in TK's first naming test, the response /hist/ occurred 7 times, to the targets butterfly, church, nut, bottle, snail, thumb and leaf. This rendered 21 pairs of targets sharing this response (butterfly with church; butterfly with nut; butterfly with bottle; butterfly with snail; butterfly with thumb; butterfly with leaf; church with nut etc.).

In the case of RS, there were 17 such pairs of targets across the 4 naming trials. Only one pair was semantically related: window and house shared the response /cup/. For TK, there were 66 such pairs across the 4 trials, of which 5 were semantically related (butterfly and snail; door and church; glove and sock; butterfly and leaf; door and window). However, when the items in each pair were randomly reassigned, 3 of the new pairings were semantically related. It is clear that there is no significant difference between the

occurrence of semantic relationships in actual pairings (5/66) and that of the randomly reassigned pairs (3/66), indicating that semantic relationships between targets sharing a response occurred at no more than chance rates.

Interim summary

RS and TK both produced perseverative responses at strikingly high rates. These were often far from their sources. For RS, long distance perseverations occurred in both naming and reading. For TK they featured only in naming, which was also his most perseverative task. The semantic hypothesis of long distance perseveration was not supported. The question of how activation persisted without being erased by subsequent responses remains. The following section explores the second hypothesis, that long distance perseveration arises from stereotyped patterns of phonology.

Question 3a: Patterns of phoneme usage and favoured consonants

The phoneme frequency distributions of RS and TK's initial responses in the 3 tasks were examined.whether or not they were perseverative. Responses coded as semantic errors, phonological distortions of semantic errors or multi-word responses were removed. All other word and non-word responses in the combined 4 trials of each task were analysed for the consonants used. When ranked in order of frequency of occurrence, and compared to the CELEX Lexical Database (Baayen, Piepenbrock & Gulikers 1995) using the Spearman rank correlation coefficient test, all sets of responses for both participants (with the exception of TK's non-word errors in repetition) correlated highly with the English phoneme frequency distribution . It seems that, as in other cases of jargon aphasia

(Robson 1997; Robson et al. 2003), these speakers' output obeyed the normal phoneme frequency distribution of English.

Despite this finding, it was noted that in both cases, certain consonants were over-represented. To examine this in more detail, the sets of word and non-word error responses on each trial of each noun task were inspected for their most frequently occurring consonant. For both participants, certain consonants were the most frequent in at least a third of the 24 error sets (word errors and non-word errors on the fours trials of the three tasks). In the case of RS, /l/ was the most frequent consonant in 12 error sets and /k/ in 8 error sets. In the case of TK, /h/ was the most frequent consonant in 10 error sets. It is noteworthy that this was the case in 7 of the 8 error sets in the naming trials, but in just 1 in reading and 2 in repetition.

Question 3b: Interaction between favoured consonants and perseveration

It has been hypothesised that certain phonemes may be overused because of changes in their resting levels of activation following the onset of aphasia, making them readily available as "gap-fills" (Moses et al. 2004b). The use of such phonemes as defaults to construct perseverative responses in the event of a failure to retrieve target phonology may explain why these responses can occur even with large intervals between them.

This hypothesis predicts an interaction between over-used phonemes and perseverative errors. In other words, such phonemes should occur at greater rates in perseverative responses than in non-perseverative responses. To investigate this, the participants'

perseverative (blended and total) and non-perseverative error responses were examined for the occurrence of their favoured consonants (i.e. /k/ and /l/ for RS, and /h/ for TK). This is shown below in Table 3[1].

(Table 3 about here)

For RS, there were consistently higher proportions of the favoured consonants in perseverative than non-perseverative errors in all tasks. When the totals across all tasks were compared using the Chi square test of significance, /k/ and /l/ both occurred in significantly higher proportions in perseverative than non-perseverative responses (χ^2 = 21.32, $p < 0.001$ and χ^2 = 8.21, $p < 0.01$ respectively). This points to an interaction between perseveration and the use of favoured consonants. That is, there was high chance of a perseverative response containing such a consonant. The consonants in question, /k/ and /l/, did not necessarily have to occur together: they did so in 61 out of the 246 perseverative responses (25%), forming an initial consonant cluster in 24 of these (10% of the total). A further analysis sought to examine whether there was any tendency for this initial cluster to dominate in total perseverations. The fact that this was not the case is disappointing, as such a finding may have pointed towards a preferred or default syllable structure as well as the use of preferred phonemes.

In the case of TK, /h/ appeared exclusively as an initial consonant. This demonstrates that as well as conforming to the phoneme frequency distribution of English, TK's production also conformed to phonotactic constraints, as /h/ can only appear as a syllable-initial in

English. (It should be noted that this was also true of RS's production which again did not show any evidence of the violation of phonotactic constraints). It occurred significantly more frequently in perseverative than non-perseverative responses when all three tasks were combined ($\chi^2 = 15.26$, $p < 0.001$). However, this difference can be attributed to naming alone. There was little difference between the two types of responses in reading and repetition. While it is clear that in naming, TK's use of /h/ is much greater in his perseverative than non-perseverative responses, there is some danger of circularity here. TK has a strong preference for starting words with /h/. Given that our first criterion for coding blended perseverations is repetition of the first phoneme (see Question 1) this will result in many of his responses being classed as perseverative. It is hardly surprising, therefore, that when we return to these perseverative responses, we find that they feature the favoured sound. However we found that when his *total* perseverations were examined in isolation, /h/ still featured in significantly more of them (31/36) than it did in non-perseverative responses (2/23) ($\chi^2 = 34.12$, $p < 0.001$). This is an important finding because in the case of total perseverations, classification did not simply hinge on the first sound. The concern regarding circularity does not apply to RS because his favoured consonsonants, /k/ and /l/ did not have a particular tendency to occur in the initial position (and, unlike TK's /h/, they are not constrained by phonotactics to do so).

Interim summary of phoneme usage

Certain consonants were found to dominate RS and TK's error responses. These were /k/ and /l/ in the case of RS and /h/ in the case of TK (although this was only evident in naming). The favoured consonants were found to be more likely to occur in perseverative

than non-perseverative responses in all tasks in the case of RS and in naming in the case of TK. It is noteworthy that for TK, naming was the only task in which the pattern of favoured consonants occurred, and also the only task in which perseveration occurred over long distances.

Question 4: Origin of total perseverations

This final section presents further data on RS and TK's total perseverations. First we explore their lexical status, as this has implications for their origins. If total perseverations arise at the lexical level, they should consist of real words. Non-word total perseverations, as have been observed in some previous speakers with jargon aphasia (e.g. Hirsh 1998; Moses et al. 2004b) would challenge the lexical hypothesis.

An examination of the participants' error responses showed that both participants did produce non-word total perseverations, albeit in smaller numbers than word total perseverations. Across all 3 tasks, RS produced 25 total perseverations that were words and just 4 that were non-words. This difference was highly significant ($\chi^2 = 28.57$, $p < 0.001$). Of the latter, 2 were in naming and 2 were in reading. TK produced 43 that were words and 15 that were non-words ($\chi^2 = 24.14$, $p < 0.001$). Of the latter, 12 were in naming, with the other 3 in repetition. It is notable that these findings are not in line with the participants' general error patterns (regardless of perseveration): when all 3 tasks were combined, RS produced significantly more non-word than word errors ($\chi^2 = 24.35$, $p < 0.001$) while for TK, there was no significant difference between rates of word and

non-word error production ($\chi^2 = 0.50$). This suggests that there is something specific to total perseverations that makes them more likely to be words.

It could be that word and non-word total perseverations arise from different sources; i.e. words may be generated at the lexical level and non-words at the phoneme level. If this is the case, they may differ with respect to their phonemic content, with only non-word total perseverations being based around default phonemes. This prediction was examined by comparing the proportions of /k/ and /l/ (in the case of RS) and /h/ (in the case of TK) in word and non-word total perseverations. In the case of RS, /k/ occurred in 33% (8/24) of word total perseverations and 50% (2/4) of non-word total perseverations, while /l/ occurred in 71% (17/24) of word total perseverations and 100% (4/4) of non-word total perseverations. In the case of TK, /h/ occurred in 61% (25/41) word total perseverations and 80% (12/15) of non-word total perseverations. When compared using Fisher's Exact Test, there was no significant difference in the proportions for either participant.

In summary, both participants produced word and non-word total perseverations, although the former significantly outnumbered the latter. There were no differences between these items with respect to default phonemic content. Implications of these and the other findings are considered in the concluding discussion.

Discussion

This study described the perseverative speech of two individuals with jargon aphasia, RS and TK, who produced total and blended perseverations in tasks of naming, reading and repetition. Both speakers produced local and long distance perseverations. The analysis here was restricted to total perseverations, as the criteria for blended perseverations were confounded with interval size. In the case of RS long distance perseverations predominated. For TK this situation reversed, in that 32 total perseverations occurred immediately after the source, compared to only 13 occurring after three or more intervening stimuli.

The introduction considered two possible explanations for long distance perseverations. One account suggests that shared semantic features, e.g. between a target and a previous response, help to sustain residual activation even after long intervals, so allowing long distance perseveration to occur. There was no evidence for this account in the current study. Very few of the total perseverations produced by RS and TK revealed a semantic connection with the source. On the rare occasions when this did arise, perseverations were as likely to be local as long distance. There was also no evidence that perseverative responses arose from semantic relationship between targets (Hirsh 1998).

The alternative explanation for long distance perseverations argues that they reflect idiosyncratic and distorted patterns of phonology. It is suggested that some speakers have long-term changes in the resting levels of activation for certain phonemes. As a result, these phonemes dominate output, particularly when target activation is weak (Moses et al. 2004b). This sets up a global pattern of perseveration, whereby similar

sounding stereotypical responses are produced whenever retrieval fails. Such similarities can span long distances. There is also a strong likelihood of total perseverations, given that responses are being generated from a restricted range of phonemes.

There was considerable evidence to support this view. Although the phonemic content of the errors made by RS and TK correlated significantly with the normal English ranking, this concealed idiosyncratic patterns. Both speakers had preferred phonemes that featured heavily across tasks and speaking occasions. There was evidence that perseverative responses were particularly likely to draw upon the stereotypical sounds. For both RS and TK the favoured sounds were significantly more common in perseverative than non-perseverative errors. However, there were also important differences between the participants. RS's perseverative errors were highly dependent on the favoured sounds across all tasks. TK, in contrast, only showed this pattern in naming.

The latter finding sets up a striking correspondence between participants' interval data and phoneme use. RS showed a pattern of long distance perseveration and stereotypical phoneme use across all tasks. TK, on the other hand, only produced long distance perseverations in naming, and it was here also that stereotypical phonology predominated. Thus the data are consistent with the two mechanisms of perseveration hypothesised in the introduction. One is local, and generates a response from the residual activation of a very recent utterance. The other is global and generates a response from a limited stock of default segments. This latter mechanism is particularly associated with

stereotyped phonology and enables perseverations to span wide gaps in the speech stream.

The above proposal predicts that long-distance perseverations may be more reliant on stereotypical phonology than local ones. This was difficult to investigate in the current study, mainly because only long distant total perseverations could be analysed. TK produced 18 immediate total perseverations, compared to 18 long distant ones, and of these similar numbers contained /h/ (14 vs 17). It seems that /h/ is so pervasive in his system that it is likely to occur both locally and globally.

A further consideration is whether global perseveration reflects the overuse of segments, or syllable constituents. TK's data may suggest the latter, given his predilection for a particular onset. However, this could also reflect the phonotactic constraints of /h/, his preferred sound. The sounds favoured by RS had a wider potential distribution. Although there was some evidence of their stereotyped syllabic use, with 25% occurring as clusters, this did not clearly emerge from the data. Further explorations of this question are clearly merited. These should also consider the role of stress, which has been found to play a role in local sound perseverations (Buckingham et al 1978).

A final observation about total perseverations is that they were more likely to be words than non-words. This can be explained in a model of speech production in which there is feedback between levels, affording a privileged status to word errors (Rapp & Goldrick 2000). This lexical bias arises because combinations of phonology that correspond to

words are able to feedback to a lexical item, and so receive supportive reverberating activation. Non-word errors benefit from no such reinforcement. In the case of these participants, when a word is produced, this privileged status may make it more likely to result in a total perseveration. Furthermore if a word response is produced that also contains the stereotypical phonology, the effect may be double reinforcement, increasing the chances of the response being perseverated.

Future Directions

This investigation raises questions which merit further research. Firstly, why might certain phonemes become unusually high in frequency in the output of individuals with aphasia? It was noted in the introduction to the participants that RS had the stereotypical words "catapult" and "caterpillar", which occurred in his spontaneous speech, as well as in the experimental tasks. The fact that both words contain his favoured sounds /k/ and /l/ raises the possibility that such stereotypical words are based around a backbone of default phonemes and they become lodged in the system because of their lexical status. Alternatively, the stereotypical words may come first, with their phonemes becoming high frequency because of their overuse. Further research could examine the longitudinal relationship between stereotypical words and stereotypical phonemes in order to shed light on this.

A further question relates to perseveration as a prognostic marker. There is evidence that perseveration is associated with negative long-term outcomes (Kohn & Smith 1994; and see Graham, Patterson & Hodges 2001). However, this may depend on type.

Longitudinal follow up of TK showed improvement over time (see Eaton 2006). For example, there was a significant increase in correct responses, particularly in naming tasks, and a significant decline in non-word errors. There were also fewer perseverations, although this failed to reach significance. Follow up testing with RS was not possible, as he suffered further infarcts. However, there was no evidence of improvement even before these events and anecdotal reports suggested that his speech became more, rather than less perseverative. It may be that global, long distance perseverations, pervasive in RS's speech, are a particularly negative prognostic marker, whereas local perseverations, more evident in TK, are less so. Clearly more longitudinal data are needed to address this question.

Finally we should consider intervention. The local and global mechanisms of perseveration described in this study may call for different therapeutic responses. Where perseveration is local, it is hypothesised that incoming activation is too weak to override the residual activation of a previous response. This suggests that well established naming therapies (see Whitworth, Webster and Howard 2005 for examples), aiming to improve activation at the semantic &/or phonological levels of the lexical system, may overcome the difficulty. This proposal mirrors Basso (2004), who argues that perseveration does not require specific therapy, but should decline if naming capacities increase.

Whether global patterns of perseveration would similarly respond to naming therapy requires testing. The evidence that this is a particularly negative prognostic marker may suggest not. There is the further concern that errors made during naming tasks could

reinforce the perseverative pattern, or further raise the dominance of the stereotyped phonemes. In these cases intervention focussing on non-verbal forms of communication, such as drawing or gesture, might be preferred (see similar arguments in Moses et al 2004a). Clearly further research is needed to help clinicians apply theoretically motivated and evidenced based therapies in these difficult and frustrating cases.

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Footnote

[1] There is a discrepancy between the numbers of non-perseverative errors in Tables 1 and 3. For example, in Table 1, 113 of 150 errors in RS's naming trials were perseverative, implying that 37 errors were non-perseverative. However, in Table 3, there are 29 non-perseverative errors in RS's naming. The reason for this is the removal of semantic errors of phonological distortions of semantic errors at the start of the phoneme frequency distribution analysis (Question 3a). The subsequent analyses in this section (Question 3b-3c) also removed this group of errors. This is a cautious treatment in this analysis: by removing semantically motivated errors from the non-perseverative errors, we would expect to increase the proportions of stereotypical phonology, thus making the finding of a significantly higher rate of stereotypical phoneme occurrence in the perseverative than the non-perseverative errors less likely.