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Dynamic aphasia: an inability to select between competing verbal responses?

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Summary

In this study we report a patient (A.N.G.) who, following a malignant left frontal meningioma impinging upon Brodmann area 45, presented a 'pure' dynamic aphasia. Her spontaneous speech was markedly reduced in the absence of any syntactical impairment. Her naming, repetition and reading skills were completely normal. Two experimental investigations were carried out. The first investigation found that A.N.G. had a profound impairment in phrase and sentence generation tasks given a verbal context. However, her verbal generative skills were normal when she was asked to describe pictorial scenes and complex actions. Moreover, it was found that A.N.G. had no difficulty ordering the constituent words of a sentence. Thus, it was concluded that her verbal planning skills were intact. The second investigation tested a hypothesis that dynamic aphasia is due to an inability to select a verbal response option whenever the stimulus activates many competing verbal responses. Predictions based upon this hypothesis were confirmed on three different verbal generation tasks. It was found that our patient's grave verbal generative impairment was present for tasks involving stimuli which activate many potential responses. However, it was absent for tasks involving stimuli which activate few or only a single 'prepotent' response. The findings are discussed with reference to traditional interpretations of dynamic aphasia and more general interpretations of prefrontal cortex functioning. On the basis of a computational model of prefrontal cortex functioning, we propose that pure dynamic aphasia may be caused by damage to a 'context' module containing units responsible for selection of verbal response options. Moreover, it is suggested that our findings support the view that Brodmann area 45 is involved in verbal response generation to stimuli which activate many potential response options.

Keywords: dynamic aphasia; executive functioning; prefrontal cortex; Brodmann area 45

Abbreviations: NART = National Adult Reading Test; WAIS-R = Wechsler Adult Intelligence Scale—revised

Introduction

Over 100 years ago, in 1885, Lichtheim described a language output disorder characterized by extremely reduced spontaneous speech in the context of well-preserved nominative (i.e. naming and reading) and speech-production skills (i.e. articulation, prosody and repetition). This was referred to as 'transcortical motor aphasia'. According to Lichtheim's conceptualization, transcortical motor aphasia was due to a disconnection of 'conceptual processes' from the output motor areas.

Luria investigated a particular subtype of transcortical motor aphasia which he termed 'dynamic aphasia' (Luria and Tsvetkova, 1968; Luria 1970, 1973). He reported its main characteristic to be a disturbance in propositional language such that spontaneous speech was severely reduced, particularly if long narratives were required. For example, Luria (1970) reported that when patients with dynamic aphasia were engaged in a task requiring them to tell a story they complained of an '... emptiness in the head...' as if their thoughts '... stand still and don't move...' (p. 208). In contrast, their ability to answer direct questions was satisfactory. Luria showed that patients with dynamic aphasia did not have any naming, reading or repetition impairments. However, the extent to which other linguistic processes, in particular syntactic and grammatical processes, were found to be intact is difficult to ascertain. Luria only provided us with qualitative descriptions of his patients with dynamic aphasia. However, from these descriptions it seems clear that at least some of the patients presented with grammatical and syntactical impairments. For example, he described case 8 who had suffered a penetrating injury in the inferior part of the premotor area (Luria, 1970), who could still repeat single words and name objects but had a noticeable disturbance in his spontaneous speech; he was unable to '... carry out any kind of involved narration...'. In addition, he presented with a grammatical impairment; '... his speech was limited to disconnected grammatically disordered word sequences...' (Luria, 1970, p. 207). Thus, it appears that some of Luria's patients with dynamic aphasia presented with a propositional language impairment complicated by grammatical and syntactical difficulties. In contrast, others presented with a 'pure' propositional language impairment.

Luria's account of dynamic aphasia focuses on an inability to form a 'linear scheme of the sentence'. According to Luria, propositional speech is initiated by a 'plan'. This is translated through the transitional stage of 'internal speech' into the linear scheme of the sentence. Dynamic aphasia results from a breakdown in this transitional stage. While the plan is initiated, the breakdown in internal speech results in a failure to form the linear scheme and thus, a disturbance of propositional speech.

Costello and Warrington (1989) conducted a detailed investigation of a patient with dynamic aphasia (R.O.H.), who presented with intact naming, comprehension, repetition and reading skills, but an almost complete lack of spontaneous speech. For example, when asked to describe his last holiday he produced only 'I'm...' in 30 s. One of the prominent features of his performance was his poor verbal generative capability. In phrase and sentence generation tasks he either failed to produce a response or his response latencies were extremely slow. However, the few responses that he did succeed in producing were normal in both form and content. In particular, no morphological or syntactic errors were present. R.O.H. also showed a marked impairment in a sentence construction task where he was requested to order constituent words to form a meaningful sentence. This poor performance was in stark contrast to his preserved ability to order constituent pictures to form a meaningful story in the Picture Arrangement subtest of the WAIS. The authors argued that Luria's conceptualization of dynamic aphasia could not account for R.O.H.'s performance. They attributed R.O.H.'s difficulties to a selective impairment of verbal planning. They considered verbal planning to be a 'high order stage' which is prior to the construction of a phrase and/or sentence.

Recently, there have been two further reports of patients who have been considered to present with dynamic aphasia. Esmonde *et al*. (1996) reported three patients with progressive supranuclear palsy who showed reduced propositional speech in the context of preserved naming and comprehension skills. In narrative and picture description tasks these patients presented with reduced verbal output that was characterized by morphological and syntactic deficits (unlike R.O.H.). Two of these patients were given sentence generation tasks and their performance was found (like R.O.H.'s) to be very poor. The authors concluded that their patients' pattern of performance most resembled Luria's concept of dynamic aphasia.

Snowden *et al*. (1996) reported a patient (K.C.) who had a progressive language disorder associated with frontal lobe degeneration. This patient presented with a profound impairment of propositional language despite well-preserved naming and phonological skills. Similar to that of the patients described by Esmonde *et al*. (1996), K.C.'s profound disorder of propositional language was not only characterized by a severe reduction in speech output but also by some mild syntactic difficulties. But K.C., unlike the previously reported patients, was unimpaired in phrase and sentence generation tasks. K.C., like R.O.H., was impaired on a sentence construction task. However, her deficit was output modality specific. Unlike R.O.H., she could verbalize the sentence correctly even though she could not manually order the constituent words on the table. In addition, she presented grave difficulties in tasks requiring temporal integration. The authors concluded that K.C.'s impairment was in the temporal, sequential, aspects of propositional speech, which in many ways conforms to Luria's concept of a stage that allows the transcoding of a plan or intention into the linear scheme of a sentence.

The neuro-anatomical correlates of the documented cases of dynamic aphasia cluster in the left frontal lobe. Luria thought the associated structures were in the lower part of the left frontal lobe just anterior to Broca's area, with the premotor cortex remaining intact. R.O.H. had a lesion in the left posterior-frontal region. Frontal lobe atrophy was noted in two of the three patients reported by Esmonde *et al.* (1996) and a SPECT scan indicated that K.C. had a reduction in the uptake of tracer in the frontal regions.

In this paper, we report the case of a right-handed woman with a left malignant frontoparietal parafalcine meningioma who presented with a 'pure' dynamic aphasia. Her spontaneous speech was markedly reduced while her syntactic, naming, reading and repetition skills were completely normal. The purpose of this paper is to investigate the underlying mechanism responsible for pure dynamic aphasia.

Case report

A.N.G. was a 59-year-old, right-handed, woman who was a retired lecturer in genetics. In 1991 a malignant left frontoparietal parafalcine meningioma was diagnosed and subsequently excised. Recurrences of the tumour were excised in 1994 and 1995 followed by radiotherapy. In September 1996 a further partial removal of the parasagittal meningioma was undertaken at the National Hospital for Neurology and Neurosurgery. At that time a meningioma was also present in the left frontal area. Postoperatively she developed language difficulties and a right-sided weakness which improved with steroid therapy. A follow-up MRI scan showed that her left frontal meningioma was impinging upon Brodmann area 45 (see Fig. 1). The patient died in February 1997.

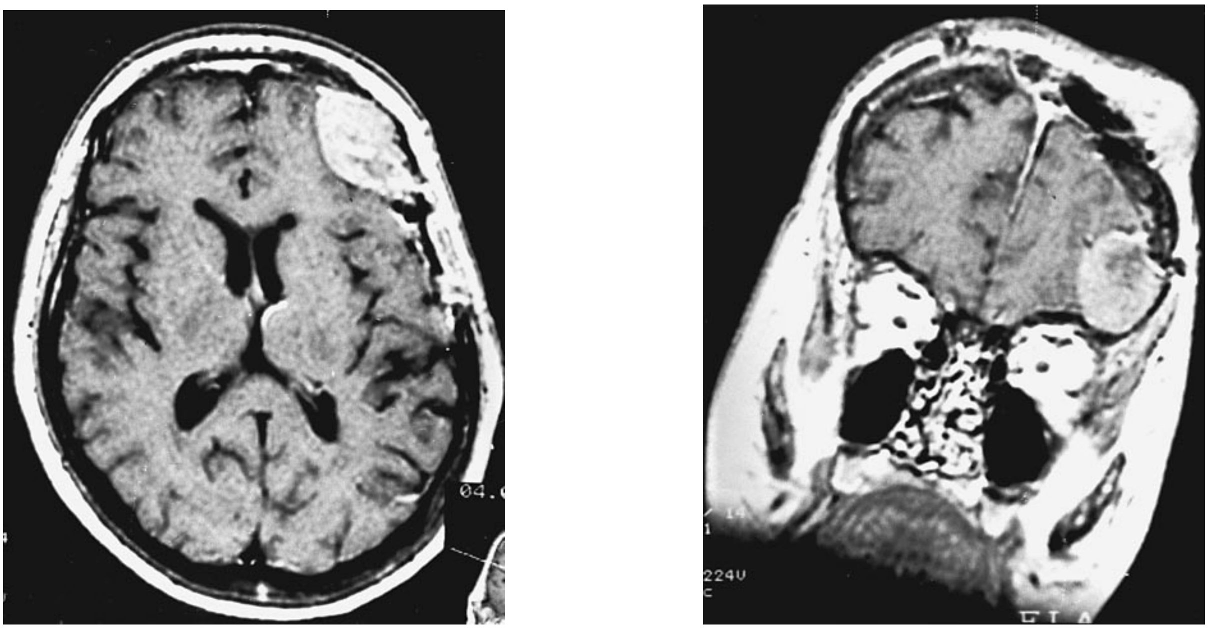

Fig. 1 Gadolinium enhanced T_1-weighted MRI in the horizontal (left) and coronal (right) planes showing a meningioma in the inferior left frontal region.

A.N.G. was referred to the Department of Neuropsychology for assessment of her cognitive functions. The present investigation was conducted over 1 week (October 7–13, 1996), with a follow-up investigation 2 weeks later.

Table 1 *Cognitive test scores*

Cognitive test	Score
Verbal IQ	83
Performance IQ	83
NART IQ	124 (> 75 percentile)
RMT words	31/50 (<5 percentile)
RMT faces	28/50 (<5 percentile)
Incomplete letters	19/20 (>5% cut-off)
Cube analysis	8/10 (>5% cut-off)
Weigl colour form sort	Pass
Trail making B	Fail
Stroop Test	Fail
Cognitive estimates	Fail
Hayling sentence completion	Fail
New verbal switching test	Fail

NART = National Adult Reading Test; RMT = Recognition Memory Test.

Neuropsychological assessment

A.N.G. was assessed on a shortened form of the Wechsler adult intelligence scale—revised (WAIS-R) and her verbal and performance IQs were in the low average range (see Table 1). Reading performance on the National Adult Reading Test (NART) gives an estimated premorbid level of functioning in the superior range. On the recognition memory test her performance was impaired, which is in keeping with the performance of frontal lobe patients on these tasks (Warrington, 1984). Visuoperceptual and visuospatial skills, as assessed by two subtests of the Visual Object and Space Perception Battery, were within normal limits (Warrington and James, 1991).

Frontal executive functions

Her performance on a series of tests considered to be sensitive to frontal lobe damage was severely impaired. She had no difficulty with the Weigl Colour Form Sorting Test (1941). However, on the Trail Making B Test (Army Index Test Battery, 1944) she was unable to alternate between numbers and letters. On the Stroop Test (1935) when she was required to name the colours of the printed words, while ignoring the content of the word, her performance was extremely slow (e.g. 3 min for the first six items) and grossly inaccurate (e.g. five errors on the first six items). All errors were due to reading the word instead of naming the colour of the ink. Furthermore some of her responses on the Cognitive Estimates Test (Shallice and Evans, 1978) were weak (e.g. when asked for the 'height of an average English woman' she answered '5 feet'). On the Hayling Sentence Completion Test (Burgess and Shallice, 1996) she performed flawlessly on the response initiation section. However, on the response suppression section she was unable to produce words that were unrelated to the sentence. For example, for 'The captain wanted to stay with the sinking...' she replied 'I can't think of anything but ship...'. On a new Verbal Switching Test in which she was required to retrieve more than one meaning of homophones, in contrast to controls, she could only give one meaning for each of the words (E. Warrington, personal communication). For example, for 'tick' she said '... like

Table 2 *Language test scores*

Test	Score
Three-syllable low frequency words	30/30
Sentence repetition	15/15
Cliché repetition	15/15
Reporter's test (modified)	14/14
Graded naming test	23/30 (75th percentile)
Synonyms, concrete words	20/25 (25th–50th percentile)
Synonyms, abstract words	19/25 (25th percentile)
Fluency tests (number in 1 min):	
'S' words	0
'F' words	5
Animals	5
Foods	3
English politicians	6
Books of the Bible	12

Tourette's have them... I am sure there are other meanings . . . but I can't think . . .'.

Language assessment

A.N.G. was assessed on a wide variety of language tests (see Table 2). She demonstrated a quite striking dissociation between severely impaired spontaneous propositional speech output and well-preserved use of language in nominative and comprehension tasks.

Speech production tasks

A.N.G.'s spontaneous speech was extremely reduced. She rarely initiated conversation and her responses to questions were sparse, consisting either of single words or single sentences. For example, when asked about what had happened in former Yugoslavia, she only produced, after a long pause '. . . civil war . . .'. Similarly, when invited to describe the contents of 'Awakening' by Oliver Sacks, one of her favourite books, she replied, after a long pause, '. . . it's about a sleeping sickness epidemic . . . it's a wonderful book . . .'. She also had pronounced difficulties defining words that were well within her vocabulary. For example on the vocabulary subtest of the WAIS-R she could not define words such as 'repair' for which she replied '. . . difficult to express' and 'fabric' for which she replied '. . . it's a . . .'. However, when she did produce sentences in response to simple questions or in the word definition task her speech was fluent, well articulated with normal prosody and syntax. No morphological, phonological or semantic errors were noted.

Sentence repetition and production

In contrast to her markedly reduced speech output, her performance was flawless in a task requiring her to repeat three-syllable low frequency words, sentences and clichés. On an adaptation of the Reporter's Test (De Renzi and Ferrari, 1978) she had no difficulty describing complex actions carried out by the examiner (e.g. 'you have selected four squares and four circles, you have then tapped the circles harder than the squares . . .').

Word retrieval

Her nominal skills were intact. Her performance was prompt, effortless and in the high average range on the Graded Difficulty Naming Test (McKenna and Warrington, 1980). In contrast to her well-preserved naming skills, her verbal fluency was severely impaired for both phonemic and semantic categories. Remarkably, for more restricted categories her verbal fluency was satisfactory (English politicians and books of the Bible)

Word comprehension

A.N.G.'s single word comprehension was within the average range on a stringent Synonym Test for concrete and abstract words (Warrington *et al*., 1998).

Summary

A.N.G.'s language disorder can best be characterized by a severe impairment of propositional language in the absence of impaired nominal, phonological and synctactical skills. This pattern invites the clinical designation of dynamic aphasia (Luria, 1970, 1973). In the following experimental investigation we explored the basis of A.N.G.'s dynamic aphasia.

Experimental Series 1

The first series of tests were partly based on those used by Costello and Warrington (1989), Esmonde *et al*. (1996) and Snowden *et al*. (1996).

Single words and phrase generation tasks

Test 1. Generation of single words to complete a sentence

A set of sentences with the final word omitted was selected from Bloom and Fischler (1980). The patient was given the stem of a sentence and asked to generate an appropriate single word to complete it (see Table 3). She was unable to generate an appropriate word for 25 out of 91 sentences. She responded '. . . I can't do it . . .' or '. . . I can't think . . .' after long delays (>10 s). The reason for her difficulty with these sentences was explored. Interestingly, it was noted that the sentences she failed to complete had significantly more alternative completion words (e.g. 'Helen reached up to dust the . . .' with 16 listed alternative verbal response options) than those she did complete (e.g. 'dogs have a good sense of . . .' with four listed alternative words) (Mann–Whitney $U = 434.5$, $P < 0.0001$). Thus, it appears that A.N.G.'s

Table 3 *Experimental Series 1: summary of scores on verbal generation tasks*

Test		Number correct
Test 1	Generation of single words to complete a sentence	66/91*
Test 2	Generation of a phrase to complete a sentence	3/20
Test 3	Generation of a sentence from a single common word	2/15
Test 4	Generation of a sentence from a given sentence context	3/20
Test 5	Generation of a sentence from a single picture	0/6
Test 6	Generation of a sentence given a pictorial scene	34/34
Test 7	Generation of sentences from a given pictorial scene	3/20
Test 8	Story generation from a pictorial context	0/5
Test 9	Sentence construction task	14/15

*All her correct responses were given in <2 s.

ability to complete sentences with single words was influenced by the number of potential response options.

Test 2. Generation of a phrase to complete a sentence

This task consisted of 20 phrases, including 10 used by Costello and Warrington (1989). A.N.G. was required to complete each phrase with a second phrase to form a meaningful sentence (e.g. ‘ They went to the . . .’). A.N.G. had great difficulty with this task, with only three out of 20 responses correct (see Table 3). She was unable to produce any response for 12 phrases, even after very long pauses (>10 s) (e.g. ‘The children were . . .’. . . ‘No I just can’t do it . . . It’s ridiculous . . . but I can’t’) and she produced a single word in response to the remaining five phrases (e.g. ‘Sally and Peter were . . .’. . . ‘free.’).

Sentence generation tasks

Test 3. Generation of a sentence from a single common word

Single common words (eight verbs and seven common nouns, e.g. ‘run’ and ‘phone’) used by Costello and Warrington (1989) were presented to A.N.G., who was asked to produce a whole sentence incorporating the target word. A.N.G. was able to generate grammatically complete and correct sentences for only two out of 15 stimulus words (e.g. her response to ‘phone’ was ‘You haven’t got a phone in this room.’ and to ‘tall’ it was ‘I am tall’; see Table 3). Her response times for both were long (>10 s). She made no response to nine words (e.g. with ‘dropped’ she said ‘I can’t sort out how I can do it . . . I can’t quite cope.’). She started a sentence that she was unable to complete for the remaining four (e.g. ‘ran’ was followed by ‘The boy ran with the . . . can’t do it . . . can’t think any further.’ and ‘green’ by ‘The green . . . I can’t do it.’). Her performance was severely impaired for both common words and verbs.

Test 4. Generation of a sentence from a given sentence context

A.N.G. was presented with 20 complete sentences, including the 10 used by Costello and Warrington (1989) and asked to generate a second sentence around the theme of the first. A.N.G. produced a correct response for only three out of 20 sentences (e.g. ‘The children went down to the beach’ was followed by ‘They played on the sand’; see Table 3). No response was produced for eight sentences (e.g. ‘Jenny read her book at the library’ was followed by ‘. . . I can’t . . .’). For seven sentences, she simply added to the initial sentence, rather than generating, as requested, a separate sentence (e.g. ‘The piano was out of tune’ was followed by ‘. . . but not too badly . . .’). For the remaining two sentences she generated only one word (e.g. ‘After the movie they went out to eat.’ was followed by just ‘. . . pizza . . .’).

Test 5. Generation of a sentence from a single picture

A.N.G. was presented pictures of common objects (e.g. a man or a dog) and asked to produce a whole sentence incorporating the picture. Despite the instruction not to simply name the picture but to generate a sentence, she was only able to retrieve, after long pauses (mean response time $\pm$ SD $=$ 15 $\pm$ 6 s), the picture names (e.g. ‘. . . it’s a dog . . . all I can think . . .’; see Table 3). Her performance in this task was gravely impaired as was her performance in Test 3 requiring her to generate sentences from single common words.

Test 6. Generation of a sentence given a pictorial scene

In this task, A.N.G. was asked to produce a sentence to describe simple pictorial scenes selected from the Psycholinguistic Assessment of Language Processing in Aphasia (Kay *et al*., 1992) and the Test for the Reception Of Grammar (Bishop, 1989). She generated meaningful and grammatically correct sentences for all the pictures (‘. . . a boy and a girl are riding an elephant . . .’; see Table 3). In contrast to her severe impairment in generating sentences from single words, single pictures and sentences she was remarkably unimpaired generating sentences from pictorial scene stimuli.

Test 7. Generation of sentences from a pictorial scene: ‘what might happen next?’

In this task, A.N.G. was presented with simple pictures and asked to generate a sentence describing what might happen

Fig. 2 An example of the pictorial scenes used in Test 7.

Fig. 3 Another example of the pictorial scenes used in Test 7.

next. She could only generate sentences for three out of 20 pictures (e.g. for Fig. 2 she correctly produced '. . . he will shoot a goal . . .'). For the remaining pictures she was completely unable to generate a sentence concerning what might happen next, although she was able to describe them (e.g. for Fig. 3 'She is skating on the ice and she is enjoying it.').

Test 8. Story generation from a pictorial context

A.N.G. was presented with simple picture stimuli (e.g. a doctor giving an injection to a young girl) and asked to produce a short story which would include the content of the picture. She was severely impaired in this task and despite instruction she only ever described the pictures (e.g. 'She is having an injection . . . I can't think of anything else.'; see Table 3).

Test 9. Sentence construction task

A.N.G. was required to rearrange single words, printed on separate pieces of paper, to construct meaningful 3, 4, 5 or 7 word sentences. The single words were placed on the table in an order that did not form a grammatically correct sentence (e.g. the sequence 'walking a fine for was evening it'). A.N.G.'s performance was almost flawless (see Table 3). Her only error consisted in reordering 'didn't she mind said she' as 'she didn't said she mind' instead of the target 'she said she didn't mind'. Her responses in this task were prompt.

Summary and conclusions from Experimental Series 1

Following Experimental Series 1, it was clear that our patient had great difficulty in generating words, phrases and sentences. However, this could not be explained in terms of an impairment in the ability to generate a plan of action for constructing a sentence. A.N.G. was in fact unimpaired in a sentence construction task (see Test 9). It should be noted that A.N.G. was able to generate words and sentences under certain test conditions. For example, A.N.G. was able to generate words when naming pictures and when completing sentences with few alternative verbal response options (see Test 1). Also, A.N.G. could generate sentences when these were descriptions of pictorial scenes (see Test 6 and 7) or complex actions as in the Reporter's Test.

We suggest that A.N.G.'s impairment was due to an inability to select a verbal response in situations where the stimulus activated many competing response options. In a situation where a stimulus activates a single 'prepotent' response option or when, among competitors, one verbal response option is considerably more activated, A.N.G. should show no impairment. This predicts the following. First, that A.N.G.'s ability to generate sentences from a proper noun should be superior to her ability to generate sentences from a common word. A proper noun stimulus should strongly activate a single prepotent response. Common words should activate many verbal response options. Secondly, that generation of sentences from phrases with high response predictability should be superior to generation of sentences from phrases with low response predictability, as more verbal response options are activated by the latter with no clear prepotent response identified. Thirdly, that sentence generation from word pairs with high inter-word associations should be superior to sentence generation from word pairs with low inter-word associations. Word pairs with high inter-word associations should strongly activate a prepotent response in addition to weakly activating other response options. Word pairs with low inter-word associations should activate competing verbal response options to a comparable degree. These predictions were tested in our second series of experiments.

Experimental Series 2

Test 10. Generation of a sentence from single proper nouns and single common words

In this task, A.N.G. was randomly presented with single proper nouns (e.g. 'AIDS' and 'Gandhi') and single common words (e.g. 'table' and 'fork') and asked to produce whole sentences incorporating them (see Appendix 1). A highly significant difference was found between A.N.G.'s almost intact ability to generate grammatically complete sentences for proper nouns (e.g. 'Hitler' was followed by 'Hitler is one of those wicked people that should never have been born.') and her very impaired performance for common words [see

Table 4 *Experimental Series 2: summary of correct response and mean reaction times on sentence and phrase generation tasks*

	A.N.G. 1st assessment	A.N.G. re-assessment	Control subjects	J.T.
Test 10				
Proper nouns	26/28	28/28*	28/28	20/23
Reaction time (s)	3.1 ± 1.6		2.18 ± 1.9	
Common words	11/28	27/28*	28/28	19/23
Reaction time (s)	7.8 ± 2.2		2.3 ± 1.7	
Test 11				
Phrases (high predictability)	9/12	12/12*	12/12	8/10
Reaction time (s)	4.3 ± 3.2		1.9 ± 1.6	
Phrases (low predictability)	3/12	12/12*	12/12	8/10
Reaction time (s)	5.7 ± 4.7		2.2 ± 3.0	
Test 12				
Word pairs (high association)	22/30	30/30*	30/30	NT
Reaction time (s)	4.4 ± 3.3		2.6 ± 3.2	
Word pairs (low association)	4/30	27/30*	30/30	NT
Reaction time (s)	4.6 ± 1.9		2.8 ± 4.6	

NT = not tested. Reaction time given as mean ± SD. *All responses were given in <2 s.

Table 4; $\chi^2(1) = 7.26$, $P < 0.0007$]. For two of the 28 proper nouns she failed to generate a sentence; she simply did not respond. She made no response for 14 of the 28 common words, even after long pauses of >15 s (e.g. 'sea' was eventually followed by '. . . No . . . I can't . . . no idea . . .'). For a further three common words she started a sentence that she was unable to complete (e.g. 'short' prompted 'We have short . . .', then after an 18-s pause 'No . . . I can't do it . . .'). Her mean response latencies for her correct answers for the common and proper nouns are reported in Table 4. Five female, age-and educationally matched, controls (who had given informed consent to participate) had no difficulty with this task (see Table 4). Using a 4-s criterion (1 SD above the control mean), eight of A.N.G.'s correct responses for common words were slow. In contrast, her response times in generating sentences for proper nouns were within the range of control values.

Her performance on this task for the common words was slightly better than her performance in Test 3 which required her to generate a sentence from a single common word. This appeared to be due to the fact that the common words that she generated sentences for were names of objects that were present in the examination room or names of items which she was wearing. A.N.G. adopted an heuristic approach which enabled her to generate sentences by describing the location of an object (e.g. 'glass' prompted '. . . There is a glass and a jug on that table . . .' and bracelet prompted '. . . I am wearing a bracelet . . .').

A subset of the stimuli used in Test 10 was administered to a second patient (J.T.) with a severe frontal dysexecutive syndrome (see Appendix 2). J.T. had an almost intact ability to generate grammatically correct sentences for both types of stimuli (see Table 4). However, the content of the sentences generated was often bizarre. For example, for the proper noun 'London', she produced '. . . My teeth need cleaning when I am in London . . .'.

Test 11. Generation of a phrase to complete a sentence with high and low response predictability

This task consisted of 12 sentences which had few verbal response options for their completion (e.g. 'The man walked into the cinema.') and 12 sentences which had many response options (e.g. 'The man walked into the house.'; see Appendix 1). The sentences were randomly presented to A.N.G. who was required to complete them with a second phrase; she produced appropriate responses for almost all the sentences with high response predictability (e.g. 'The man sat in the dentist's chair.' prompted 'and tried on his false teeth'; see Table 4). In contrast, her performance was significantly impaired for low response predictability sentences (e.g. 'The man sat in his chair . . . .' was followed after a 20-s pause 'No I can't . . .') [$\chi^2(1) = 4.19$, $P < 0.04$]. Her mean response time for correct responses for the sentences with high response predictability was within the range of the controls, who had no difficulty with this task (see Table 4).

A subset of the stimuli was administered to J.T. She could generate phrases for almost all the sentences with high and low response predictability (see Table 4) but her responses were bizarre (e.g. 'She took her hairdryer' prompted '. . . and ran like hell . . .'.

Test 12. Generation of a sentence from word pairs with high and low association

The stimuli used in this task consisted of highly associated word pairs (e.g. 'butter–bread') and less associated word pairs (e.g. 'butter–salad'; see Appendix 1). These words had an imagery rating of >450 (Oxford Psycholinguistic Database of Quinlan, 1992) which has been used to classify them as imageable (e.g. Fletcher *et al.*, 1996). The word pairs with high and low associations did not statistically differ in terms of their imageability (Mann–Whitney $U = 1319$, $P < 0.49$). A.N.G. was given a word pair and instructed to produce a complete sentence incorporating both words. A highly significant difference was found between A.N.G.'s well-preserved ability to generate grammatically complete sentences for word pairs with a high association (e.g. 'giraffe–neck' prompted '. . . the giraffes have very long necks . . .') and her poor ability to generate sentences for word pairs with a low association (e.g. 'cat–neck' prompted 'The cat . . .', and then after a 14-s pause, '. . . I can't . . .') [$\chi^2(1) = 13.07$, $P < 0.0003$; see Table 4]. Her errors involved either no response or starting a sentence that she was unable to complete. The mean response latency for her correct answers is given in Table 4. Control subjects had no difficulty with this task (see Table 4).

Summary and conclusions from Experimental Series 2

The performance of A.N.G. on the above tests confirmed our predictions. She was impaired in the generation of sentences and phrases when the target stimulus activated many competing verbal response options. In sharp contrast her performance was unimpaired when she was requested to generate sentences and phrases where there was a prepotent response option or where, among competitors, one verbal response option is considerably more activated. This pattern of performance was not present in patient J.T. despite her severe frontal dysexecutive syndrome. In particular, J.T. typically succeeded in generating phrases and sentences to both constraining and unconstraining stimuli, although her responses were frequently bizarre in content.

Re-assessment

At the end of the above experimental investigation, the patient was transferred to the Neurorehabilitation Department of the National Hospital. After two weeks, she was reassessed on only a subset of the experimental tests. The clinical impression was that a striking recovery in her language skills had been made. In particular, her propositional speech was no longer sparse and reduced. Her fluency was indeed entirely normal: the patient was able to hold a normal conversation describing in detail her physical and language improvement and her rehabilitation programme. Her verbal fluency had also improved. For example, she was able to produce 10 animal names in 60 s (previously five).

Test 10. Generation of a sentence from single proper nouns and single common words

A.N.G. was able to generate promptly and effortlessly grammatically correct sentences for almost all the stimuli (e.g. 'high' prompted 'Cocaine is famous for giving one a high'; see Table 4).

Test 11. Generation of a phrase to complete a sentence with high and low response predictability

Her performance was flawless for both types of sentences (e.g. 'The man walked into the cinema' prompted '. . . where his favourite film was shown.' and 'The man walked into his house' prompted '. . . and found it had been burgled.'; see Table 4).

Test 12. Generation of a sentence from word pairs with high and low association

A.N.G.'s performance was almost flawless for both high and low associated word pairs (e.g. the word pair 'baby–boy' prompted 'He was a baby boy called Andrew.' and 'baby–sweet' prompted 'Babies have sweet teeth.'; see Table 4).

Summary and conclusions from the re-assessment

These findings indicate that simultaneous with A.N.G.'s propositional language improvement there had also been a striking improvement in her performance on sentence and phrase generation tasks.

General discussion

Following a left frontoparietal parafalcine malignant meningioma, A.N.G. presented with a language impairment which can be best described as dynamic aphasia (Luria and Tsvetkova, 1968; Luria 1970, 1973). Her spontaneous speech was markedly reduced, characterized by a near complete lack of general conversation; direct questions only elicited single word or short sentence responses. However, the little spontaneous speech she did produce was well articulated with normal prosody and correct syntactic structure. No morphological, phonological or semantic errors were present. As in the classic dynamic aphasia cases, her profound propositional speech impairment could not be accounted for in terms of nominal language impairment or more general speech production difficulties. Indeed, A.N.G.'s word retrieval, repetition and production were entirely normal. Thus, A.N.G.'s dynamic aphasia can be considered to be a pure propositional language impairment uncomplicated by syntactic difficulties.

The results of Experimental Series 1 showed clear similarities between the performance of A.N.G. and previous patients with dynamic aphasia (e.g. Costello and Warrington, 1989; Esmonde *et al*., 1996) but there were also differences from the patient described by Snowden *et al*., 1996). A.N.G. had gravely impaired verbal generative skills. Given a single common word or picture depicting a common object, she had profound difficulty in generating a sentence which incorporated them. Similarly, she showed a severe impairment in generating phrases to complete sentences. In addition, she was impaired in generating sentences, given a sentence context. In contrast to R.O.H. (Costello and Warrington, 1989) and K.C. (Snowden *et al*., 1996), she was also impaired in a task simply requiring her to generate single words in order to complete a sentence. In these tasks, she exhibited prolonged response latencies and frequently a complete inability to produce a response. However, it should be noted that when she did produce a response it was entirely normal in form and content.

In these first generation tasks there was a notable stimulus feature which predicted A.N.G.'s performance. Her generative abilities were gravely impaired in situations with many verbal response options. However, they were significantly improved in situations where the number of response options was constrained. For example, she could not generate sentences from a single word or from a picture (e.g. a woman). However, in stark contrast, she had no difficulty in generating sentences, or even series of sentences, to describe a pictorial scene. The potential number of response options also predicted A.N.G.'s performance in generating single words to complete a sentence. She had difficulty when there were many potential response options (e.g. 'They went to see the famous . . .'). However, if there were relatively few potential response options her performance improved (e.g. 'The boat passed easily under the . . .'). This contrast, between her impaired generative abilities in tasks with many verbal response options and her relatively preserved generative abilities in tasks where the number of response options was constrained, was also present in her performance on word fluency tasks. She had profound difficulty in generating words from phonological and open semantic categories but she had reasonable skill in generating words from restricted semantic categories (e.g. books of the Bible). This pattern is opposite to that observed in Alzheimer's disease and semantic dementia (Hodges *et al*., 1992, 1995).

Results from Experimental Series 2 confirmed our impression that it was the potential number of response options which predicted A.N.G.'s performance. Her performance was good in tasks where there was a single prepotent response associated with a stimulus. Specifically, while she could generate sentences from single proper nouns, she had grave difficulty generating sentences from single common nouns. Proper nouns have singular or few referents. For example, 'Mona Lisa' is a famous painting. In contrast, common nouns have multiple referents. For example, 'Table' could prompt e.g. 'We inherited an antique table'; 'I have a wooden side table by my bed.'

On phrase-generation tasks A.N.G.'s performance could also be determined by manipulating the number of potential response options associated with the stimulus. Her performance was adequate when she was presented with phrase stimuli where the number of response options was constrained (e.g. 'The man walked into the cinema . . .'). Her performance was very poor when presented with phrase stimuli with many response options (e.g. 'The man walked into the house . . .').

A similar contrast was present in tasks requiring her to generate sentences from word pairs. She showed little difficulty in generating sentences from word pairs which were more likely to activate one prepotent response option more than its competitors (e.g. 'giraffe–neck'). However, she was gravely impaired in generating sentences for word pairs activating many response options (e.g. 'cat–neck'). Both 'giraffe–neck' and 'cat–neck' will activate response options associated with their individual words. However, only in the 'giraffe–neck' stimulus do both individual words strongly activate the same prepotent response option 'Giraffes have long necks.'.

A.N.G.'s pattern of impairment in verbal generation was related to her dynamic aphasia symptoms. Indeed, upon re-assessment and the finding that her propositional language had returned to normal, her performance on verbal generation tasks was satisfactory. In particular, the notable difference between her generative ability to constraining and unconstraining stimuli was no longer present. Moreover, as demonstrated by J.T., patients with a grave frontal dysexecutive syndrome without dynamic aphasia perform equally well with these two qualitatively different forms of stimuli.

Alternative explanations for A.N.G.'s dynamic aphasia

A.N.G.'s pattern of performance cannot be easily explained within the existing accounts of dynamic aphasia. For example, Costello and Warrington (1989) interpreted R.O.H.'s performance in terms of an impairment in verbal planning, at a stage prior to sentence construction. One of their major reasons for reaching this conclusion was R.O.H.'s exceedingly impaired ability to order even as few as three constituent words into a meaningful sentence. In contrast, A.N.G. had no difficulty with this task, even with seven words to arrange. Clearly A.N.G. was able to generate a verbal hypothesis or plan of action to construct a sentence. Furthermore, a failure in an initial higher order verbal plan could not easily account for, or predict, the effect of constraining the number of potential response options on A.N.G.'s performance.

Luria (1970) suggested that generative language impairments arise from a disturbance in the transcoding stage of a plan into the linear scheme of the sentence (see also Snowden *et al*., 1996). If A.N.G.'s impairment was due to a disturbance at the level of the translation of a plan into a linear scheme of a sentence then she should have been generally impaired in any task requiring the generation of sentences. However, she was not. For example, the Reporter's Test requires the understanding of the relationships between two or more concepts, the formulation of a plan and the translation of this plan into a linear scheme of a sentence (e.g. 'you have selected four squares and four circles, you have then tapped the circles harder than the squares . . .'). In addition, a disturbance in the ability to form the linear scheme of a sentence should also predict word order errors in A.N.G.'s sentence structure. However, such errors were completely absent.

An explanation might be offered in terms of an inability to deal with novelty. Clearly, generative tasks require responses to novel stimuli. The Supervisory Attentional System model of Norman and Shallice (1986; see also Shallice, 1988) predicts that damage to the supervisory attentional component will result in impairments when the subject responds to novel stimuli. However, such an account predicts results that are contrary to those shown by A.N.G. For example, Test 11 required the generation of phrases to complete sentences with either high or low response predictability. The phrases with low response predictability detailed habitual events (e.g. 'The man sat in his chair . . .') while the phrases with high response predictability detailed less habitual events (e.g. 'The man sat in the dentist's chair . . .'). A.N.G.'s generative performance was worse on a sentence detailing a habitual event than on a sentence detailing a less habitual event.

Alternatively, an explanation might be offered in terms of an inability to perform abstraction. For example Fletcher *et al*. (1996) proposed that an inability to employ an 'abstract semantic link' might underlie the processes impaired in dynamic aphasia. They suggest that under concrete testing conditions (e.g. naming or describing a concrete action), individuals can use imagery which then allows the 'output word form to be accessed through a relatively automatic naming procedure' (p. 1593). Under conditions where imagery cannot be used, an abstract semantic link must be employed. However, this position cannot account for A.N.G.'s performance. For example, Test 12 involved generating sentences from word pairs. All these pairs consisted of imageable words according to the Fletcher *et al.* (1996) criteria. There was no significant difference in imageability between word pairs with high and low associations.

Patients with frontal lobe lesions have frequently been considered to show failures in the use of appropriate strategies (e.g. Shallice and Evans, 1978; Milner, *et al*., 1985). Indeed, Burgess and Shallice (1996) have recently argued that patients with frontal lobe lesions show poor performance on a task requiring verbal initiation and inhibition, because of 'an inability to acquire or realise an appropriate strategy' (p. 271). Perhaps, it could be argued that A.N.G.'s performance was determined by the ease with which she could generate strategies. However, this explanation cannot easily account for A.N.G.'s performance on the phrase generation task (Test 11). Why should it be easier to generate a strategy to complete the sentence 'The man walked into the cinema . . .' than the sentence 'The man walked into the house . . .'? It is difficult to argue that the generation of a strategy such as 'Consider what people do in these contexts' is easier for the 'cinema' than for the 'house' context. The critical feature here is not the ease of strategy generation 'Consider what people do in these contexts' but the number of response options associated with these contexts (e.g. 'cinema'–seeing a movie; 'house'–cooking a meal, watching the television, going to bed, etc.).

A new account of dynamic aphasia

So how can one explain A.N.G.'s performance? The essential feature of A.N.G.'s generative skills, and the reason for the development of some of the tests used with her, was her grave difficulty on tasks where the number of verbal response options was relatively unconstrained. The suggestion here is that verbal response options compete against one another through mutual inhibition. The greater the number of competing verbal response options activated by a stimulus, the greater the amount of inhibition any individual verbal response option would receive from its competitors. When individual verbal response options are being inhibited by multiple competing verbal response options, there is less probability of one becoming dominant. However, an executive controlling system might be able to resolve the conflict by allowing one verbal response option to become dominant. It is proposed that A.N.G. had suffered disruption to such an executive controlling system.

The idea that selection from competing response options is controlled by an executive system has been proposed for explaining performance on the Stroop Test (Cohen and Servan-Schriber, 1992; Cohen *et al*., 1996). [This is not to claim, however, that the same executive system that mediates performance on the Stroop Test also underlies appropriate performance on the tests used with A.N.G. This is just to suggest that a system involved in the selection of competing verbal response options might show architectural similarities to a dissociable system involved in selecting between input features (i.e. the word or ink colour in the Stroop Test).] In the Cohen *et al*. (1996) computational model, verbal responses compete against each other through lateral inhibitory connections. The executive feature of this model involves a context module which contains units that become active according to the task demands. Under conditions of response competition (i.e. ink colour naming), the context module resolves the conflict by 'supporting the processing of task relevant information, which can then compete more effectively with irrelevant information' (Cohen *et al*., 1996, p. 1517). Lesions to the context module significantly affect the conflict condition, ink colour naming, because this condition relies on response selection. However, lesions to the context module affect word reading less, because this involves a more 'automatic', i.e. 'prepotent', response.

In terms of verbal generation, some stimuli activate only single, or small numbers of, verbal response option units. Under these conditions, the activated response option will be prepotent, receiving minimal inhibition from its competitors. Thus, additional activation from the context module is unnecessary for conflict resolution. In contrast, when verbal stimuli activate many verbal response options, there is no automatic activation of a verbal response. In this case, the context module must preferentially activate one of the competing verbal response options. We suggest that A.N.G. has suffered impairment to the units of the context module. Therefore, under conditions when there are many competing verbal response options and a greater amount of mutual inhibition, she is left in a conflict condition and cannot generate a verbal response. Thus, a failure in the units of the context module would lead directly to a failure in generation tasks where the stimuli are associated with many potential verbal responses.

Anatomical implications

Finally, to consider the anatomical structures that may be implicated in verbal generative skills. Milner (1982) emphasizes that the left frontal lobe is more implicated in the organization of verbal output. The classic literature on dynamic aphasia implicates a region anterior to Broca's area, more inferior than superior (Luria and Tsvetkova, 1968; Luria, 1970, 1973; Costello and Warrington, 1989).

PET studies have also shown activation of left prefrontal cortex during tasks requiring the organization and generation of verbal output. Thus, Nathaniel-James *et al*. (1997), in a PET analysis of the Hayling Sentence Completion Test, report that verbal response generation results in the activation of the middle temporal gyrus and the left inferior frontal gyrus. Similarly, Warburton *et al.* (1996), analysing a task requiring the verbal retrieval of appropriate verbs to given concrete nouns, found activation of the left middle temporal gyrus, left inferior frontal gyrus and left prefrontal cortex. Fletcher *et al.* (1996) reported that recall of non-imageable words, when compared with imageable words, was associated with the activation of the left lateral prefrontal cortex. In particular, the peak of activation was in Brodmann area 45 (C. D. Frith, personal communication).

Interestingly, our patient had a frontal meningioma that impinged upon the anterior part of the left inferior frontal gyrus (Brodmann area 45). This evidence, in the context of the previous findings, provides support for the idea of functional specialization within the prefrontal cortex. Specifically, it supports the notion that the left prefrontal region, in particular Brodmann area 45, is critically involved in verbal generation skills. In particular, we have speculated that this area is involved in the selection of competing verbal responses. Thus, this study allows a provisional insight into the role of Brodmann area 45 in verbal generation and its impairment in dynamic aphasia.

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Appendix 1

Stimuli used in Test 10

Proper nouns			
Mona Lisa	Hitler	London	John Major
AIDS	Bosnia	Oliver Sacks	Margaret Thatcher
Bruce Forsythe	Paris	Churchill	Eiffel Tower
Scotland	Gandhi	Amsterdam	Rolls Royce
Brighton	Cilla Black	IRA	Beatles
Sean Connery	Liz Taylor	Tony Blair	Colgate
Tesco	Saddam Hussein	Sheraton	Hobnobs
Common words			
Sea	Short	Table	Glass
Bracelet	High	Green	Jumper
Fork	Bag	Sure	Door
Watch	Grass	Teeth	Shake
Believe	Prove	Spend	Sort
Fresh	Move	Build	Shave
Cool	Walk	Blue	Red

Stimuli used in Test 11

Sentences with high response predictability

The man walked into the cinema . . .
The man sat in the dentist's chair . . .
The man bought a sandwich and . . .
The pregnant woman entered the delivery room and . . .
The hairdresser moved next to the lady with her scissors and . . .
She walked in the bar and . . .
The waiter gave him his bill and . . .
He turned on the TV and . . .
The bad child was sent to the head teacher and . . .
He went to the post office and . . .
They went to the park with a ball and . . .
She took the hair dryer and . . .

Sentences with low response predictability

The man walked into his house . . .
The man sat in his chair . . .
The man ate a sandwich and . . .
The pregnant woman entered the front room and . . .
The hairdresser moved next to the lady with her pen and . . .
She walked in the garden and . . .
The waiter gave him his hat and . . .
He turned on the light and . . .
The bad child was sent to his mother and . . .
He went to his friend's house and . . .
They went to the park with friends and . . .
She took the wallet and . . .

Stimuli used in Test 12		Imagery ratings (Quinlan, 1992)	
Word pairs with high association			
butter	bread	603	619
giraffe	neck	NF	622
baby	boy	608	618
doctor	hospital	600	602
road	car	609	638
school	children	599	597
court	lawyer	552	557
captain	boat	497	631
water	bridge	632	608
journalist	paper	NF	590
letter	post office	595	NF
dog	cat	636	617
baby	mother	608	638
secretary	typewriter	563	615
conductor	orchestra	NF	619
garden	plants	635	605
actor	movie	NF	571
blossom	flower	618	618
bath	clean	601	454
porter	door	536	599
carpet	floor	538	544
chair	table	610	582
city	town	605	553
doctor	nurse	600	617
dream	sleep	485	530
shoe	foot	601	597
hammer	nail	618	588
stairs	step	551	483
beach	sea	667	606
shark	shore	602	624
Mean imagery ratings		591.11 ± 42.66	
Word pairs with low association			
porter	taxi	536	NF
butter	salad	603	623
cat	neck	617	622
baby	sweet	608	493
doctor	play	600	498
road	rubbish	609	NF
children	theatre	597	NF
lawyer	restaurant	557	611
captain	car	497	638
water	tower	632	596
journalist	chair	NF	610
letter	bank	595	560
dog	pig	636	635
baby	uncle	608	574
secretary	paperclip	533	NF
conductor	singer	NF	575
garden	pond	635	599
actor	camera	NF	576
blossom	leaf	618	608
carpet	hole	538	527
chair	room	610	545
city	smoke	605	615
doctor	bag	600	570
dream	fantasy	485	455
foot	head	597	593
hammer	heavy	618	495
bath	England	601	NF
beach	holiday	667	629
shark	island	602	643
stair	carpet	551	538
Mean imagery ratings		584.29 ± 47.38	

NF = not found.

Appendix 2: Case report

J.T., a 63 year old right-handed woman, was admitted to the National Hospital in May 1997 following a collapse. On examination, she was found to have ataxia, poor memory and profoundly disturbed behaviour. MRI revealed a large falx meningioma based on the anterior cranial fossa. There was associated peripheral vasogenic oedema and mass effect on the adjacent brain, especially on the corpus callosum, on both anterior cerebral arteries and the frontal horns of both lateral ventricles. Following resection of her tumour, the patient died of postoperative complications.

Neuropsychological assessment

J.T. was tested on the shortened version of the WAIS-R and obtained a verbal IQ of 81 and a performance IQ of 74. On Raven's Colour Progressive Matrices, she obtained a poor score of 12/36, her performance being marred by perseverative errors. On the Short Recognition Memory Test (Warrington, 1996), she scored 17/25 for words and 14/25 for faces which are both below the 5th percentile. Again perseverative errors were noted in her response profile. Early visual processing and visual perceptual skills, as assessed by the Shape Detection and Incomplete Letters Tests from the Visual Object and Space Perception Battery, were entirely within normal limits.

Frontal executive functions

J.T. presented with markedly disturbed behaviour. Her mood was euphoric and disinhibited, e.g. she often interrupted conversation by starting to sing loudly. She also presented with spontaneous confabulation. Her performance was extremely impaired on a series of tests considered to be sensitive to frontal lobe functioning. She was able to give only one of the two solutions on the Weigl Colour Form Sorting Test. Her responses on the Cognitive Estimates Test were markedly bizarre (e.g. 'The average length of a man's spine' was given as '25 feet and 11.5 inches'). On the Stroop Test, she was unable to name the colours of the printed words. On the Hayling Sentence Completion Test she performed flawlessly on the response initiation section. However, on the response suppression section all her answers were related to the sentence (e.g. 'Most cats see very well at . . .' prompted 'night'). Her verbal fluency was markedly impaired. In 1-min, she was only able to produce two words starting with the letter 'S', two with 'F', none with 'A' and one animal name.

Language assessment

Speech production

J.T.'s spontaneous speech was fluent, well articulated, with normal prosody and syntax. No paraphasic errors were noted. However, there were indications of disinhibition. For example, when invited to describe her house, she replied: 'It's a three-bedroom house. I like it very much. I'm just trying to think of an adjective to make it sound attractive . . . Well, I suppose it is a pleasant house because its got nice big windows . . . By the way, I can't think of any reason at all why someone would say I like this room.'.

Word retrieval

Although in her spontaneous speech there was no evidence of nominal difficulties, she obtained a borderline score on the Graded Difficulty Naming Test (McKenna and Warrington, 1980). Some of her responses on this task were bizarre (e.g. when requested to name a sporran, she replied: 'It makes me think of a squirrel.').