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A FAILURE OF HIGH LEVEL VERBAL RESPONSE SELECTION IN PROGRESSIVE DYNAMIC APHASIA

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Different theoretical interpretations have been offered in order to account for a specific language impairment termed dynamic aphasia. We report a patient (CH) who presented with a dynamic aphasia in the context of nonfluent progressive aphasia. CH had the hallmark of reduced spontaneous speech in the context of preserved naming, reading, and single word repetition and comprehension. Articulatory and grammatical difficulties were also present. CH had a very severe verbal generation impairment despite being able to describe pictorial scenes and action sequences well. In the experimental investigations CH was severely impaired in word, phrase, and sentence generation tasks when many competing responses were activated by a stimulus. By contrast, he could generate verbal responses satisfactorily when a dominant response was activated by a stimulus. For the first time, we demonstrated that the verbal generation impairment was specific to the production of language. Strikingly, our patient was unimpaired on a number of nonverbal generation tasks (e.g., design fluency, gesture fluency, and motor movement generation). MRI revealed focal left frontal atrophy that predominantly affected Brodmann's Areas 44 and 45. Our findings are discussed with reference to alternative accounts of dynamic aphasia and models of speech production. We interpret our patient's impairment as being underpinned by an inability to select between competing verbal response options. This interpretation converges with evidence from the neuroimaging literature, which implicates the left inferior frontal gyrus in the selection of a response among competing information. We conclude that the left posterior inferior frontal gyrus is involved in the generation of verbal output, and specifically in the selection between competing verbal responses.

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Dynamic aphasia, a severe impairment in propositional language skills despite well-preserved nominal language skills, has been increasingly recognised as a distinct language output disorder in its own right. Luria (1970) coined the term *frontal dynamic aphasia*. The core feature of *dynamic aphasia* is severely reduced spontaneous speech, with a key being an inability to "use speech for generalising or for the expression of thoughts and desires" (p. 199). These patients answered questions easily but were completely incapable of spontaneous expression and storytelling. In the last few decades, there have been several important investigations of the role of the left frontal lobe in dynamic aphasia (e.g., Costello & Warrington, 1989; Luria, 1970, 1973; Robinson, Blair, & Cipolotti, 1998). As a result, there are currently several alternative accounts that attempt to explain dynamic aphasia. Most of these accounts interpret dynamic aphasia broadly within the domain of language; however, some accounts extend beyond this domain. In addition, a parallel line of investigation is the recent focus in neuroimaging on the language functions of the inferior left frontal region (for reviews, see Cabeza & Nyberg, 2000; Price, 1998). Within the functional imaging literature, there is now much debate over the role of the left prefrontal cortex in language and other nonverbal functions. However, as yet there has been no attempt to integrate the neuropsychological studies on the role of the left frontal lobe and dynamic aphasia with neuroimaging data.

In 1948, Goldstein identified a defect in the impulse to speak (i.e., spontaneous speech) as one of the two main types of transcortical motor aphasia. The second type involved partial damage to the motor speech area resulting in defects to the motor act of speaking. Luria investigated the underlying mechanism of the first type and initially referred to it as a gross disturbance to the "dynamics of verbal thinking" (1966, p. 358–360). Thus, the syndrome of dynamic aphasia is characterised by severely reduced spontaneous speech despite relatively intact repetition, naming, single word comprehension, and reading (Luria, 1966, 1970, 1973). However, Luria's descriptions clearly demonstrate that some cases of dynamic aphasia presented with additional articulatory, linguistic, or frontal impairments. For example, Luria (1970) provided qualitative descriptions of 12 patients with decreased spontaneous speech (see Table 1). Case 7 was described to have effortful articulation and errors when repeating more than one word (p. 203), whereas Case 8 produced disconnected grammatically disordered word sequences when telling a story (p. 207). From his descriptions, it is clear that heterogeneity exists and that dynamic aphasia in a pure form was present in only a few of Luria's series. Indeed, most patients presented with impairments in either speech production, repetition, naming, or comprehension ability. However, in all cases the central feature was a disturbance to spontaneous speech that was *disproportionate* to any other language impairment.

Luria's (1966, 1970, 1973) account of dynamic aphasia focused on an inability to form a *linear scheme of a sentence*. This was explained as a breakdown in the transitional stage of inner speech, which translates the general plan into a linear scheme of a sentence. According to Luria, propositional speech is initiated by a plan. This account of dynamic aphasia assumed that the original plan or intention was present. However, a subsequent breakdown in internal speech resulted in a failure to form the linear scheme and, thus, reduced propositional speech.

The literature suggests that dynamic aphasia can present in either a *pure* or *mixed* form. Luria (1966, 1970) hinted that the more pure form of dynamic aphasia might not involve the posterior parts of the left frontal lobe and that if the premotor system was involved anteriorly, dynamic aphasia may be accompanied by additional impairments (e.g., a disturbance to the motor aspects of speech). In both the pure and mixed form, the hallmark of dynamic aphasia is severely reduced propositional speech. However, the pure variant consists of this hallmark in the absence of any grammatical, articulatory, or lexical impairment. Pure dynamic aphasic patients have intact naming, repetition, and comprehension skills (for examples, see Costello & Warrington, 1989; Gold, Nadeau, Jacobs, Adair, Rothi, & Heilman, 1997; Robinson et al., 1998; Table 1). Examples of the mixed variant of dynamic aphasia are Cases 7 and 8 described by Luria (1970), who

Table 1. *Summary of language functions in dynamic aphasic cases*

	Luria[a] *(n = 12)*	*ROH*[b]	*CO*[c]	*ANG*[d]	*MP*[e]	*PSP*[f] *(n = 3)*	*KC*[g]	*CH*
Spontaneous speech	x	x	x	x	x	x	x	x
Speech production								
Articulation	x (4)	√	√	√	√	x mild (1)	√	x mild
Grammatical sentences	x (6)	√	√	√	√	x mild (1)	x mild	x mild
Repetition								
Words	√ (2)	√	√	√	√	nt	√	√
Sentences	x (2)	√	√	√	√	nt	√	x
Oral naming (pictures)	√ (4) x (7*)	√	√	√	x mild	√	√	√
Comprehension								
Words	√ (3)	√	√	√	√	x (1)	√	√
Sentences	√ (5) x (2)	x mild	√	nt	√	x mild (2)	x mild	x mild
Reading	√ (4) x (1)	√	nt	√	√	nt	nt	√

√ = intact; x = impaired; nt = not tested; ( ) = number of patients with this function reported; * = naming difficulties in spontaneous speech.
[a] Luria (1970); [b] Costello and Warrington (1989); [c] Gold et al. (1997); [d] Robinson et al. (1998); [e] Raymer et al. (2002); [f] Esmonde et al. (1996); [g] Snowden et al. (1996).

presented with additional grammatical and articulatory difficulties (for other examples, see Esmonde, Giles, Xuereb, & Hodges, 1996; Snowden, Griffiths, & Neary, 1996; Table 1). Crucially, the core impairment of both the pure and mixed form of dynamic aphasia remains the same; namely, severely reduced language output skills in the context of relatively well-preserved nominal, repetition, and word comprehension skills.

Dynamic aphasic patients have been documented in the context of both neurodegenerative conditions and focal lesions. Esmonde et al. (1996) described three patients with the neurodegenerative condition progressive supranuclear palsy (PSP). These PSP patients initially presented with a mixed dynamic aphasia (see Table 1). Spoken language production was impaired despite mostly intact naming and word comprehension skills. Repetition was said to be intact, although it was not formally tested. However, when speech was produced, some grammatical errors were evident. All three patients performed poorly on standard verbal fluency tests, with phonemic tests more impaired than semantic tests. In narrative and picture description tasks, these patients' verbal output was impoverished, indicating that the verbal generation impairment was present for both verbal and pictorial input. Two of the patients were given sentence completion tests. They either did not respond or produced bizarre responses. The authors concluded that the PSP patients' language disorder most closely resembled Luria's designation of dynamic aphasia. Snowden et al. (1996) reported a mixed dynamic aphasic patient (KC) with frontal lobe degeneration and a progressive language disorder (see Table 1). KC's ability to produce verbal responses in general conversation and storytelling tasks was impaired. This was documented in the context of preserved naming, single word comprehension, and repetition skills. Similar to the PSP patients, KC presented with additional grammatical difficulties when producing sentences. KC's dynamic aphasia was accounted for by a failure in the temporal integration of propositional language. Snowden et al. view this failure as having many similarities to Luria's transitional stage of transcoding a plan or intention into the linear scheme of the sentence. In terms of the anatomical areas involved, two of the three PSP patients were reported to have frontal lobe atrophy, and SPECT showed that KC had reduced uptake of tracer in the frontal region.

A few cases of dynamic aphasia in focal lesions have been put on record. For example, Luria's account was investigated in a pure dynamic aphasic patient ROH (Costello & Warrington, 1989; see Table 1). ROH had a malignant astrocytoma affecting the left posterior frontal lobe. Despite relatively preserved naming, reading, and repetition skills, ROH had some difficulties on phrase and sentence generation tasks. No formal investigation of syntactic processing skills was reported. However, it was noted that his performance was impaired on a sentence construction task. This task involved rearranging individual words of sentences into an order that formed a grammatically correct sentence. His impaired performance led the authors to hypothesise the underlying deficit to be a selective impairment in verbal planning in the context of his average performance on the Picture Arrangement subtest of the WAIS. This deficit is thought to be prior to the implementation of narrative expressive speech.

Robinson et al. (1998) documented a pure dynamic aphasic patient ANG who had a malignant left frontal meningioma particularly impinging on Brodmann's Area (BA) 45 (see Table 1). ANG's propositional language skills were extremely reduced in the context of normal naming, repetition, and reading skills. ANG's performance was severely impaired on word, phrase, and sentence generation tasks. However, when she was simply describing pictorial scenes or complex actions, she produced normal speech. In addition, ANG was able to order individual words in a sentence construction task. This suggested that her verbal planning skills were intact, unlike ROH. A series of experimental investigations found that ANG's verbal generative impairment was only present for tasks involving stimuli that activated many competing response options. For example, while she was unable to generate sentences from common words (e.g., table), she had no difficulty generating sentences from proper nouns (e.g., Gandhi). Thus, ANG did not present with a verbal generation impairment when stimuli activated a prepotent or dominant response. This dissociation was present for the generation of phrases and sentences. However, no formal investigation of single word generation was undertaken. ANG's dynamic aphasia was accounted for by an impairment in the ability to select a verbal response option whenever a stimulus activated many competing verbal responses. However, the question of whether this deficit was or was not specific to the language domain remains open.

In the accounts discussed so far, dynamic aphasia is seen broadly within the domain of language. In two other studies, the explanations extend beyond the domain of language. Gold et al. (1997) described a patient (CO) who presented with a pure dynamic aphasia following bilateral striatocapsular infarctions (see Table 1). Dynamic aphasia was only observed after the second infarct, which involved the right hemisphere and was also associated with impaired design fluency performance. It was tentatively suggested that dynamic aphasia may not be restricted to the verbal domain or to language, and may be related to associated executive dysfunction. The dynamic aphasia in their patient was attributed to a specific impairment in the development of a "strategy to search the lexical/semantic network and difficulty in endogenous concept formation" (p. 390).

There has been a recent treatment study of a patient (MP) who presented with mixed dynamic aphasia following a left hemisphere stroke, involving the left frontal subcortical region and part of the anterior insula (Raymer, Rowland, Haley, & Crosson, 2002; see Table 1). MP's sentence generation abilities were reduced in response to single words that activated a number of competing response options. This pattern is in keeping with the performance of the previously reported pure dynamic aphasic patient ANG (Robinson et al., 1998). Treatment of reduced verbal initiation involved a technique that paired nonsymbolic limb movements with cued sentence production. This technique has predominantly been used to facilitate single word production. After treatment, MP's ability to generate semantically and grammatically correct sentences in response to trained and untrained words improved, more so for the trained words. Raymer et al. hypothesised that initiating movement sequences may activate the intact right prefrontal cortex. This activation may subsequently engage the left prefrontal cortex, which is involved in language initiation. Facilitation of verbal initiation was thought to involve complex movements, not simple repetitive movements, as only the former has been associated with activation of the prefrontal cortex (Pickard & Strick, 1996). The extent to which impaired verbal generation is specific to the verbal domain is of interest, particularly given this treatment involving the use of a nonverbal strategy. In the context of dynamic aphasia, the relationship between verbal and nonverbal generation has not been directly investigated.

In this paper we will consider the five main positions which have been put forward to account for dynamic aphasia. Three positions attempt to account for dynamic aphasia within the domain of language.

1. Luria (1970, 1973) first proposed that the critical deficit is in the transitional stage of forming a linear scheme of a sentence. More specifically, Luria argued that there is a breakdown in the translation of internal speech into a plan that subsequently initiates propositional speech.
2. Costello and Warrington (1989) suggested that dynamic aphasia is due to a selective impairment in verbal planning. This stage was thought to be prior to the implementation of narrative expressive speech.
3. Robinson et al. (1998) hypothesised that dynamic aphasia is underpinned by an inability to select between competing verbal responses. This is when many competing response options are activated by a stimulus with no prepotent or dominant response available.

Two positions attempt to account for dynamic aphasia in terms of a deficit extending beyond the domain of language.

4. Gold et al. (1997) suggested that dynamic aphasia is attributable to an impairment in forming an efficient strategy to search within the lexical/semantic network. This impairment was speculated to be associated with executive dysfunction.
5. Raymer et al. (2002) hinted that the deficit underpinning dynamic aphasia may not be selective for verbal generation but may involve, more generally, the ability to generate verbal and nonverbal responses.

We report the case of CH, who presented with a mixed form of dynamic aphasia. This was in association with frontotemporal degeneration and nonfluent progressive aphasia. CH had a marked reduction in spontaneous speech in the context of relatively intact naming, reading, and single word repetition and comprehension skills. In addition to a slight dysarthria, there were additional articulatory and grammatical difficulties in spoken language. Our aim was to investigate the underlying mechanism responsible for the core impairment of reduced propositional language in dynamic aphasia. A further aim was to investigate the extent to which this verbal generation impairment was specific to the verbal domain.

CASE REPORT

CH is a 60-year-old, right-handed, retired electronics lecturer who subsequently worked as a quality control manager for an electronics company. In September 1998, following a 4-year history of progressive nonfluent speech difficulties, CH was referred by Dr Pearce to the Department of Neuropsychology. CH was subsequently followed up in the Cognitive Disorders Clinic under the care of Professor Rossor. Neurological examination was normal apart from the cognitive impairments described below.

A MRI brain scan in December 1998 revealed focal atrophy in the left frontal lobe, especially involving the superior and inferior frontal gyri (see Figure 1). The insula is involved in the left with some atrophy of the inferior part of the left superior temporal gyrus. The areas involved with maximal atrophy include BA 44 and 22. Closer examination of the MRI scan was undertaken in order to ascertain which areas were unequivocally involved. Thus, left and right frontal and temporal areas were investigated. In the left frontal lobe, BA 44 was moderately atrophic and BA 43, 45, and 46 were mildly atrophic. BA 47 was normal bilaterally. In the right

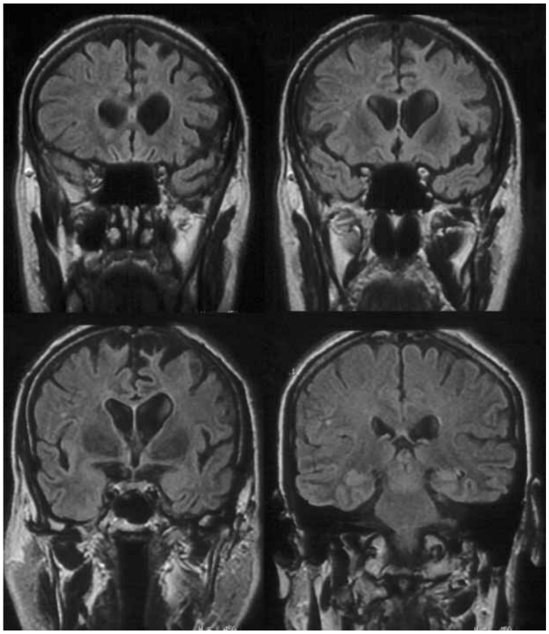

Figure 1. *Coronal T_1 weighted MRI of frontal and temporal regions showing focal atrophy in the left frontal lobe, particularly in the inferior and superior frontal gyri, and the inferior part of the left superior temporal gyrus (see text).*

frontal lobe, BA 43, 44, 45, and 46 were normal. In the temporal lobe, BA 22 was moderately atrophic on the left and only mildly atrophic on the right. BA 21 and 38 were only mildly atrophic on the left and normal on the right. BA 37 was normal bilaterally. In addition, BA 41 and 42 (primary auditory cortex) were only indicative of probable atrophy on the left and were normal on the right. A clinical diagnosis of frontotemporal dementia was made.

Initial assessment of cognitive functioning was undertaken in October 1998. CH was assessed on two further occasions in June 1999 and August 2000. Only the first two assessments will be reported as these were carried out at the same time as the experimental investigations. Importantly, CH's condition was relatively stable between these two assessments as no significant decline was observed in the cognitive baseline.

Cognitive baseline

CH was assessed on a shortened form of the Wechsler Adult Intelligence Scale-Revised (WAIS-R; Wechsler, 1981; see Table 2). On both assessments, he obtained low average Verbal IQs. On the first assessment he obtained a superior Performance IQ and on the second assessment he obtained a high average Performance IQ. On an untimed test of nonverbal general intelligence, the Advanced Progressive Matrices Set 1 (Raven, 1958), he performed in the high average range on the first assessment and the average range on the second assessment. As his premorbid level of optimal functioning was estimated to be superior on the basis of occupational and educational background, these results indicate a moderate degree of intellectual decline, particularly in the verbal domain. Verbal and visual memory functions were normal on both assessments. His performance was in the good average range or above on recognition memory tests (Warrington, 1984, 1996). Visual perceptual and visuospatial skills remained normal as assessed by two subtests from the Visual Object and Space Perception Battery (Warrington & James, 1991). Oral calculation skills were mildly impaired as he performed in the low average range on the Oral Graded-Difficulty Calculation Test (Jackson & Warrington, 1986). Psychomotor speed was somewhat slowed on the Symbol Digit Modalities Test (Smith, 1982). On the first assessment, a severe orofacial apraxia was evident. Similarly, on the first assessment a mild limb dyspraxia was observed, as his copy of meaningless gestures with both hands was slightly weak.

Frontal executive functions. CH's performance on a series of tests considered to be sensitive to frontal lobe damage was only impaired on verbal fluency tasks and the Brixton Spatial Anticipation Test (Burgess & Shallice, 1996; see Table 2). On verbal fluency tasks his performance was severely impaired for phonemic tasks. Verbal fluency for semantic categories was considerably better, although impaired. In contrast, his performance was normal on a modified version of the Wisconsin Card

Table 2. *Cognitive scores for CH*

	October 1998	*June 1999*
	General cognitive scores	
Verbal IQ	81	82
Digit span*	4	6
Vocabulary*	6	4
Arithmetic*	8	8
Similarities*	9	9
Performance IQ	120	111
Picture completion*	13	12
Picture arrangement*	10	12
Block design*	14	12
Advanced Progressive Matrices	8/12 (75–90th %ile)	6/12 (50–75th %ile)
Recognition Memory Test		
Words	44/50 (50–75th %ile)	47/50 (75–90th %ile)
Faces	48/50 (> 95th %ile)	44/50 (50–75th %ile)
Topographical	—	23/30 (50th %ile)
Object decision	17/20	19/20
Cube analysis	10/10	10/10
Oral calculation	8/24 (25th %ile)	—
Symbol Digit Modalities Test	35 ($M = 41.5 \pm 8.6$)	25 ($M = 41.5 \pm 8.6$)
Limb praxis	left = 7/10, right = 8/10	
	Frontal executive functions	
Verbal fluency		
F	2	7
A	1	1
S	5	7
FAS total ($M = 42$, $SD = 12.1$)[a]	8 (<1st %ile)	15 (<1st %ile)
Animals ($M = 18.2$, $SD = 4.2$)[a]	11 (< 10th %ile)	9 (< 5th %ile)
Food	12	10
Tools	11	—
Politicians	—	8
Farm animals	—	5
Countries	—	6
Brixton Spatial Anticipation Test[b]	Impaired (SS = 1)	—
Wisconsin Card Sorting Test	6/6 categories	6/6 categories
Trail Making Test		
A	56" (25–50th %ile)	52" (25–50th %ile)
B	130" (25–50th %ile)	152" (10–25th %ile)
Hayling Sentence Completion Test[b]	Low average (SS = 4)	—
Section 1 (sensible completion)	Impaired (SS = 1)	—
Section 2 (unrelated completion)	Average (SS = 6)	—
Section 2 (errors)	Average (SS = 6)	—

[a] Spreen and Strauss (1998). [b] SS = scaled score; from 1–10 with 6 being average.
* = age-scaled score.

Sorting Test (H. E. Nelson, 1976) and the Trail Making Test (Army Individual Test Battery, 1944), although mildly slowed on the second assessment. The Hayling Sentence Completion Test (Burgess & Shallice, 1996) was only administered in the first assessment. His performance was impaired on Section 1 (response initiation) as he was unable to complete 5/15 sentences and responded with "*yeah*" to a further sentence. However, on Section 2 (response suppression) he was able to complete all sentences with unrelated responses and performed in the average range for both time and errors.

In sum, CH presented with a severe degree of decline in his performance on the verbal scale of the WAIS-R and a severe orofacial apraxia. In addition, mild dysexecutive impairment and a mild limb apraxia were evident. In contrast, his nonverbal intellectual functions were in keeping with his premorbid optimal level of function. Similarly, memory and visual perceptual functions remained intact across assessments.

Language baseline

The language baseline was completed between October and November 1998. A second assessment of a select number of language functions was completed at the same time as the second cognitive assessment (June 1999).

Speech production. Spontaneous speech was extremely sparse, effortful, somewhat dysprosodic, and slightly dysarthric. Initiation of conversation was rare, and he was only able to produce phrases of no more than four to five words, often responding to questions with a single word. No phonological, semantic, or word order errors were made. Although the content was appropriate, there was some evidence for initiation of articulation difficulties that resulted in false starts (e.g., wiping → wip-wiping). His descriptions of complex scenes (Beach, Cookie Theft) were reduced, nonfluent, and agrammatical in that there were relatively few function words (e.g., "boy jump, make a sand castle, tip-pee over boat . . ."). The sparseness of speech precluded formal analysis of one speech sample elicited from a story (e.g., Quantitative Production Analysis [QPA]; Berndt, Wayland, Rochon, Saffran, & Schwartz, 2000). However, we analysed CH's responses from three other tasks that elicited speech from pictorial stimuli. The three tasks were: (1) descriptions of complex scenes (Beach, Cookie Theft); (2) descriptions of simple scenes from the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA; Kay, Lesser, & Coltheart, 1992; Test 3 below); and (3) story generation from pictorial scenes (Test 5 below). The three tasks provided a speech sample of 151 words (of these, 69 nouns and 35 verbs) that formed the basis for calculating some QPA measures. A broad comparison was possible between CH's speech production and the descriptive statistics reported in the QPA training manual for a sample of nonfluent aphasic patients and normal control subjects by Berndt et al. (2000). The most striking measure was CH's markedly reduced speech rate of 11 words/minute, calculated from Task 1 (nonfluent aphasic patients = 39.01, normal control subjects = 160.82). The overall proportion of verbs CH produced was 0.34 (Berndt et al., 2000; nonfluent aphasic patients = 0.37, *SD* = 0.10, normal controls = 0.48, *SD* = 0.06). Of note, the proportion of verbs CH produced on Task 1 and 3 involving more complex scenes was just within the range of normal controls (Task 1 = 0.44, Task 3 = 0.43). By contrast, CH produced an extremely low proportion of closed-class words (0.24, nonfluent aphasic patients = 0.41, *SD* = 0.11, normal control subjects = 0.54, *SD* = 0.04).

In contrast to his severely reduced spontaneous speech, the Reporter Test was performed virtually at ceiling (De Renzi & Ferrari, 1978; see Table 3a). This test requires the production of a sentence to describe a sequence of actions executed by the examiner. It taps the ability to observe a series of actions, comprehend the actions, formulate a narrative that describes the actions, and produce a narrative of speech that explains the action sequence accurately so that it can be executed by a third party. CH could explain the sequence of actions executed by the examiner, although his descriptions were agrammatic in that some function words were omitted (e.g., to the action: "Touch the green circle, then take the green square" CH said " . . . *touch green circle, take that one, green square* . . . "). Only two errors were recorded: a response that included gestures of the action and an incomplete description of the entire action sequence (i.e., to the action: "Put the red circle on the green triangle" CH said " . . . *circle on top* . . . "). His agrammatism suggests that he had difficulties in the formulation of a sentence structure. However, his preserved ability to describe the

Table 3a. *Spoken language scores for CH*

Task	*Oct/Nov 1998*	*June 1999*
Production		
Reporter Test		13/15
Repetition		
Phonemes		
Single	5/6	
Sequence	3/10	
Single digits	9/9	
Letter names	21/24	
Words		
High frequency		
1-syllable	30/30	
2-syllable	27/30	
3-syllable	28/30	
Low frequency		
1-syllable	30/30	
2-syllable	28/30	
3-syllable	24/30	
Nonwords		
1-syllable	7/10	
2-syllable	10/10	
3-syllable	7/10	
Sentences		
Cliché	4/15	
Non-cliché	7/15	
Word retrieval		
GNT	24/30	26/30
Nouns	71/75	
Verbs	58/75	
Word comprehension		
Synonym Test	46/50 (75–90th %ile)	44/50 (50–75th %ile)
BPVS	145/150	
Phoneme discrimination	72/72	
Sentence comprehension		
TROG	73/80	67/80
Token Test	11/15	

GNT = Graded Naming Test; TROG = Test for the Reception of Grammar; BPVS = British Picture Vocabulary Scale.

executed actions clearly indicated that he did not have a problem in verbal planning in the sense of Costello and Warrington (1989) on this particular task.

Repetition. CH's repetition skills were predominantly intact (see Table 3a). Repetition of single phonemes (e.g., ba) was largely intact, although repetition of sequences of phonemes was poor (e.g., ba-ta-ka). Repetition of single digits was flawless. Single letter repetition was almost flawless except for the addition of "e" to three letters (i.e., s, n, and f → *esse, enne,* and *effe*). Word repetition skills were slightly weak (93% correct; 167/180). A very slight dysarthria was present. In addition, words repeated with some articulatory distortion but *without* phonemic errors were scored correct if the target was clearly identifiable (21/167 correct words). Word length and frequency effects were absent. The errors were mainly phoneme and morpheme omissions (e.g., wilderness→*wildness*, wonderful → *wonder*) and false starts (e.g., gigantic → *gi-gi-gi-gigantic*). Nonword repetition was weak (80%). The distribution of errors was similar to word repetition (e.g., false starts, inima → *in-inima*; phoneme omissions, crealth → *creal*) except for two real-word substitutions (i.e., ampty → *empty*, plonth → *plonk*). Repetition of cliche and noncliche three- to seven-word sentences was impaired (36.7% correct). Similar to spontaneous speech, the errors CH made in sentence repetition mainly consisted of omission of functors (73.7% errors; e.g., "Give him a hand" → "*Give him hand*"). However, there were a few errors involving the repetition of functors (21.1%; e.g., "He shut the door" → "*He shut the the door*") and there was only one instance of a content word omission.

It seems unlikely that CH's orofacial dyspraxia can be a confound for his verbal generation impairment. A double dissociation has been documented where patients have been described with a relative preservation of repetition and/or speech production despite a severe orofacial apraxia (De Renzi, Piezcuro, & Vignolo, 1966; Tyrrell, Kartsounis, Frackowiak, Findley, & Rossor, 1991). Conversely, patients with impaired sentence generation but no orofacial apraxia are also on record (e.g., Gold et al., 1997).

Word retrieval. Picture naming skills were well preserved. CH's responses on the picture naming tasks were scored correct if they were clearly identifiable and contained no more than one phonological error. Using this slightly lenient criteria, on the Graded Naming Test (McKenna & Warrington, 1980) he performed in the high average range on the first assessment and in the superior range on the second assessment (see Table 3a). Across the two assessments there were three semantic errors (e.g., cowl → *shroud*), two phonological errors (e.g., yashmak → *ashmak*, tutu → *petu*), four no responses, and one instance of a phonological fragment (corkscrew → *c*). CH was given an oral naming task using a set of verbs and nouns matched for frequency (Kucera & Francis, 1982). In response to each picture, CH was asked to name the action or object depicted. He performed this task well, with oral naming of objects being significantly better than oral naming of actions, $\chi^2(1) = 7.99$, $p < .005$, with Yates correction applied (see Table 3a).

Word comprehension. Word comprehension skills were well preserved. CH's performance on the Synonym Test (Warrington, McKenna, & Orpwood, 1998) was in the high average range on the first assessment and at the upper end of the average range on the second assessment (see Table 3a). Similarly, his performance on the British Picture Vocabulary Scale (Dunn, Dunn, Whetton, & Pintilie, 1982) was almost at ceiling.

Word–sound processing skills were investigated using a phoneme discrimination task. CH was asked to judge whether two similar sounds (e.g., choke–joke, heef–haff) were the same or different. His performance on this task was flawless (see Table 3a). This indicates that his speech perception skills were intact and not contributing to repetition or production difficulties. In sum, his ability to understand word meanings and sounds was well preserved as his performance on word and word–sound comprehension tasks was intact.

Sentence comprehension. Sentence comprehension skills were mildly impaired (see Table 3a). His performance on the Test for the Reception of Grammar (Bishop, 1983) was weak on the first assessment and mildly impaired on the second assessment. His errors were restricted to the syntactically complex sentences and not those indicative of semantic or vocabulary problems as detailed in the manual. On a shortened version of the Token Test (De Renzi & Faglioni, 1978), his performance was weak.

Reading. CH's reading ability was weaker than expected. Reading aloud Arabic numerals and letter names was almost flawless (see Table 3b). On the National Adult Reading Test (NART; H.E. Nelson & Willison, 1991) he performed within the average range on the first assessment and the low average range on the second assessment. The effect of frequency, regularity, imageability, and lexicality on his ability to read aloud was further investigated using stimuli from the PALPA (Kay et al., 1992) and a revised version of Patterson and Hodges (1992; stimuli provided by Patterson). Word frequency was found to have a significant effect on CH's reading ability, $\chi^2(1) = 11.12$, $p < .005$, with Yates correction applied. However, there was no effect of regularity or imageability (see Table 3b). Further, nonword reading was relatively good. Speed of reading a passage was significantly slower than controls. Numerous omission errors were noted, with omission of "*the*" representing the greatest proportion of these errors.

Table 3b. *Written language scores for CH*

Task	*Oct/Nov 1998*	*June 1999*
Reading		
Arabic numerals	9/9	—
Letter names	38/40	—
NART	20/50 (25–50th %ile)	13/50 (10–25th %ile)
Words		
Regular	30/30	41/50 (HF); 33/48 (LF)
Exception	29/30	43/48 (HF); 27/46 (LF)
High imageability	35/40	—
Low imageability	35/40	—
Nonwords	20/24	—
Passage	108 s ($M = 30$, $SD = 8$)	129 s ($M = 30$, $SD = 8$)
Spelling		
GDST (written)	20/30	19/30
Words		
Regular	50/50	28/28
Exception	39/50	25/32

NART = National Adult Reading Test; HF = high frequency; LF = low frequency; GDST = Graded Difficulty Spelling Test.

Spelling. Spelling skills were slightly weak as assessed by writing-to-dictation tasks. On a graded-difficulty spelling test (Baxter & Warrington, 1994) CH performed at an average level (see Table 3b). Upon further investigation, a regularity effect was found for Assessment 1, $\chi^2(1) = 10.21$, $p < .005$, and Assessment 2, $\chi^2(1) = 5.1$, $p < .025$, with Yates correction applied (stimuli partly from the PALPA, Kay et al., 1992).

Summary and diagnosis

In summary, the most remarkable feature of CH's nonfluent dysphasia consisted of a severe reduction of propositional speech in the context of relatively well-preserved nominal, comprehension, repetition, and reading skills. By comparison, written language was less affected.

CH could be classed as fulfilling previously proposed criteria for nonfluent progressive aphasia (e.g., Chawluk et al., 1986; Hodges & Patterson, 1996; Kirschner, Tanridag, Thurman, & Whetsall, 1987; Mesulam, 1982; Mesulam & Weintraub, 1992; Snowden, Goulding, & Neary, 1989). Within the domain of nonfluent progressive aphasia, CH's dysphasic impairment is best classified as a dynamic aphasia (Luria, 1966, 1970, 1973; Luria & Tsvetkova, 1968). His severe propositional language impairment is with a relative preservation of repetition and naming. This would make it unlikely that his language impairment can be clinically classed as Broca's aphasia.

CH presented with a mixed form of dynamic aphasia in that the core feature of reduced propositional language skills was present in association with additional articulatory and grammatical difficulties. In the following series of experimental investigations, the nature and basis of CH's verbal generation impairment was explored.

EXPERIMENTAL SERIES 1: VERBAL GENERATION INVESTIGATION

The experimental investigations were undertaken and completed in a 6-month period between the first two cognitive assessments. CH's condition was relatively stable during the time of the experimental investigations as no significant decline was observed in the cognitive baseline. For all tests, the examiner recorded the number correct and response time with the use of a stopwatch. For all verbal generation tests, response time (RT) was defined as the time from the end of stimuli presentation to the time the patient started to generate a response. For two tasks (Tests 6 and 10), RT was defined as the time taken from stimuli presentation to the time of task completion. Mean RT was calculated for correct responses only.

The first series of tests are designed to investigate the extent of CH's dynamic aphasia. The tasks are based on those used by Robinson et al. (1998). A summary of scores obtained by CH is presented in Table 4. For comparison purposes the scores previously reported for the pure dynamic aphasic patient ANG (Robinson et al., 1998) are included in Table 4. ANG's RTs are not reported, as all correct responses were produced in less than 2 seconds for Tests 1–5.

Table 4. *Verbal generation scores: Number correct and mean RTs (Experimental Series 1)*

	CH		*ANG*
	No. correct	*Mean RT*[a]	*No. correct*
Test 1. Generation of a phrase to complete a sentence	6/10	6.0 (2.5)	3/20
Test 2. Generation of a sentence from a single common word	11/20	11.1 (4.7)	2/15
Test 3. Generation of a sentence given a pictorial scene	20/20	12.9 (8.4)	34/34
Test 4. Generation of sentences from a given pictorial scene	3/20	13.3 (3.8)	3/20
Test 5. Story generation from a pictorial context	0/10	—	0/5
Test 6. Sentence construction task	9/10	16.4 (11.4)	14/15

[a]RT = response time in seconds with standard deviation in parentheses.

Test 1. Generation of a phrase to complete a sentence

CH was read aloud phrases and required to complete each with a second phrase to form a meaningful sentence (e.g., "The children were . . ."). His performance was poor and very slow. He was unable to produce any response for four phrases and only produced responses for the remaining phrases after a long pause (e.g., "The children were . . . *playing together*" after 8 seconds).

Test 2. Generation of a sentence from a single common word

CH was presented with single common words and asked to produce a whole sentence incorporating the target word. His performance was poor and slow. CH was only able to generate sentences containing at least three words for only 55% of the target stimuli (e.g., drove → "*I drove a car*"). Three of the responses generated were grammatically incorrect (e.g., old → "*He's old man*"); however, for the purpose of this task these were counted as correct. Errors consisted of five no responses and four repetitions of the target word.

Test 3. Generation of a sentence describing a pictorial scene

CH was presented with simple pictorial scenes selected from the PALPA (Kay et al., 1992) and asked to produce a sentence to describe each one. His performance was flawless, although responses were produced after a long pause. He was able to generate meaningful sentences for all of the pictures (e.g., *A girl* [is] *washing the horse*"*)*, although most contained at least one grammatical error.

Test 4. Generation of sentences from a pictorial scene: "What might happen next?"

CH was presented with simple pictorial scenes from the PALPA that were not used in the previous task. He was asked to generate a sentence describing what might happen next. His performance was extremely impaired and slow. It was noticeable that although CH was almost completely unable to generate sentences concerning "what might happen next," he was able to describe the contents of presented scenes (as in Test 3).

Test 5. Story generation from a pictorial context

CH was presented with five simple picture stimuli, such as a man sawing a log. The stimuli were presented on two separate occasions. He was asked to produce a short story that would include the content of the picture. His performance was severely impaired. He was only able to describe the pictures (e.g., "*Sawing it . . . yeah. . . . log . . . trestle*").

Test 6. Sentence construction task

The sentence construction task has been considered to be a test of verbal thought or planning (Costello & Warrington, 1989). In this task, single words are printed on separate pieces of paper and presented in a grammatically incorrect order. Each group of words has to be arranged to construct a meaningful sentence. Their dynamic aphasic patient (ROH) failed this task as he was only able to correctly arrange 5/27 sentences. However, the dynamic aphasic patient ANG showed no difficulty with the task (Robinson et al., 1998). The dynamic aphasic patient KC also performed normally in the oral modality and failed only when asked to manually move the cards (Snowden et al., 1996). In order to compare CH's performance with that of other dynamic aphasics, we gave him 10 sentences to rearrange (3–7 words in length). He performed almost flawlessly. There was no significant difference from five age-, education-, gender-, and occupation-matched controls ($M = 9.8/10$, range 9–10). The only error CH made involved the 5-word sentence "The suitcase was too heavy" → "*The was too suitcase heavy*". Similar to ANG and, to an extent, KC, CH passed this task, which represents a difference from ROH. For the previous dynamic aphasic patients no information regarding the time taken to complete this task is available. We timed CH's responses and found he was slower than controls. However, it should be noted that his performance was generally slow on all tasks involving language (see, for example, his RTs when asked to generate a sentence to describe pictorial scenes as in Test 3). Thus, the significance of his slow performance on this task is unclear. Moreover, it is unclear whether a sentence construction task should really be regarded as a more general problem-solving task rather than an online language planning task.

Summary

Experimental Series 1 clearly demonstrates that CH had a severe verbal generation impairment only in conditions where a response to words, phrases, and pictorial stimuli required him to generate sentences that were not constrained by the stimulus. In contrast, CH had no difficulty generating sentences when these were constrained by the stimulus; that is, when describing pictorial scenes or action sequences (i.e., Reporter Test). CH was also unimpaired in the sentence construction task.

CH's performance on verbal generation tasks is directly comparable to that of ANG, who had a severe verbal generation impairment in response to words, phrases, and sentences. However, like CH, she was able to generate sentences without difficulty to describe pictorial scenes and action sequences. ANG's verbal generation deficit was accounted for in that she was unable to select a verbal response in situations where the stimulus activated many competing response options (i.e., the stimulus is unconstrained). In a situation where a stimulus activated a single prepotent response option, or when one verbal response option among competitors is considerably more activated (i.e., the stimulus is constrained), ANG showed no impairment.

EXPERIMENTAL SERIES 2: THE EFFECT OF COMPETING RESPONSE OPTIONS ON SENTENCE GENERATION

In this series, the hypothesis that impaired verbal generation is underpinned by an inability to select a verbal response when the stimulus activates many response options was investigated in CH. The tasks and stimuli are based on Robinson et al. (1998). A summary of scores is given in Table 5. For comparison purposes the scores previously reported for the pure dynamic aphasic patient ANG and 5 matched controls (Robinson et al., 1998) are included in Table 5. CH's response times were compared to controls using the modified *t*-test, which was specifically developed to compare an individual's score with a small control sample (see Crawford & Garthwaite, 2002).

Test 7. Generation of a sentence from a single proper noun and a single common word

CH was randomly presented with single proper nouns (e.g., Bosnia, Sean Connery) and single common words (e.g., glass, red) and asked to

Table 5. *The effect of competing response options on sentence generation: Number correct and mean RTs*[a] *(Experimental Series 2)*

	CH		*ANG*		*Controls*	
	No. correct	*Mean RT*	*No. correct*	*Mean RT*	*No. correct*	*Mean RT*
Nouns (Test 7)						
Proper	22/30	13.1 (5.9)	26/28	3.1 (1.6)	28/28	2.2 (1.9)
Common	10/30	11.8 (8.2)	11/28	7.8 (2.2)	28/28	2.3 (1.7)
Phrases (Test 8)						
High predictability	19/22	6.1 (3.9)	9/12	4.3 (3.2)	12/12	1.9 (1.6)
Low predictability	11/22	8.3 (3.7)	3/12	5.7 (4.7)	12/12	2.2 (3.0)

[a] RT = response time in seconds with standard deviation in parentheses.

produce a whole sentence incorporating the target. A highly significant difference was found between CH's good ability to generate meaningful sentences for proper nouns (e.g., Tony Blair → *Tony Blair is the prime minister*) and his very impaired performance for common words, $\chi^2(1) = 8.10$, $p < .005$, Yates correction applied. Of the sentences CH generated, 17 contained at least one grammatical error or were only partial sentences (e.g., door → *Opened the front door*). Responses were produced after a long pause and were significantly slower than controls for both proper nouns, $t(4) = 5.24$, $p < .05$, and common words, $t(4) = 5.10$, $p < .01$. Errors were all no responses, except on one occasion in which only a single word was generated (red → *dread*).

Test 8. Generation of a phrase to complete a sentence with high and low response predictability

CH was presented with 22 sentences that had few verbal response options for their completion (e.g., The man walked into the cinema . . .) and 22 sentences that had many (e.g., The man walked into the house . . .). He was required to complete each phrase with a second phrase (i.e., more than one word) to form a meaningful sentence. CH produced appropriate responses for almost all the high response predictability (HRP) phrases, such as "She opened her purse . . . *bought an item.*" In contrast, his performance was significantly impaired for low response predictability (LRP) phrases (e.g., "She took the bag and . . . *no response*"), $\chi^2(1) = 5.13$, $p < .025$, Yates correction applied. Of the phrases completed with a phrase, 15 of the HRP and 10 of the LRP sentences contained at least one grammatical error (e.g., "She walked into the bar . . . *[to] buy a drink*"). Responses were generated after a considerable pause and were significantly slower than controls for HRP phrases, $t(1) = 2.40$, $p < .05$; and approached significance for LRP phrases, $t(1) = 1.86$, $p < .10$. Errors consisted of no response for 1 HRP and 8 LRP phrases and a single word response for 2 HRP and 3 LRP phrases.

Summary

CH's ability to generate a sentence from a proper noun, which should activate a single prepotent response, was superior to his ability to generate a sentence from a common word, which should activate many verbal response options. In addition, his ability to generate phrases to complete phrases high in response predictability, which should strongly activate a single prepotent response, was superior to his ability to generate phrases to complete phrases low in response predictability, which should activate many verbal response options. Thus, his ability to generate a verbal response was significantly better when stimuli activate a prepotent response.

This performance of CH replicates the findings of ANG, the pure dynamic aphasic patient. This suggests that CH's verbal generation impairment was underpinned by an inability to select a verbal response where a stimulus activates many competing alternative response options with no prepotent response available.

EXPERIMENTAL SERIES 3: THE EFFECT OF COMPETING RESPONSE OPTIONS ON SINGLE WORD GENERATION

As the tests in Experimental Series 2 required the generation of phrases and sentences, it is uncertain whether the same process operates at the level of single words.

Test 9. Generation of a single word to complete a sentence

This test was designed to investigate whether CH's ability to generate a single word is affected by the number of possible response options activated by a stimulus. Thus, a sentence completion task was devised that systematically varied the number of alternative completion words (i.e., level of constraint) and the probability for a dominant response. This task was based on the Hayling Sentence Completion Test (Burgess & Shallice, 1996).

Hypotheses. It was noted in the cognitive baseline that CH's performance on the Hayling was unusual, as he was more impaired at generating a word to complete a sentence on the initiation part (Section 1) than the suppression part (Section 2). The reverse performance is usually observed in that Section 2 is typically performed more poorly than Section 1. Upon closer scrutiny of the sentences in Section 1, it was noted that the sentences vary in level of constraint. Each sentence has a probability for a dominant response based on the Bloom and Fischler (1980) completion norms, which range from .99–.68. Interestingly, three of the five sentences for which CH did not produce a response were in the lowest ranked probabilities for having a dominant response (i.e., .68, .70, .71). Thus, in Test 9a, the effect of level of constraint on CH's ability to generate a single word to meaningfully complete a sentence was investigated further. The task demands of Section 2 of the Hayling are that a sentence must be completed with an unrelated response (one that is not guided by the sentence frame). This is in contrast to Section 1, which requires the generation of a meaningful completion word (guided by the sentence frame). In Test 9b, CH was asked to complete each sentence with a single word that was unrelated to the meaning of a sentence. The process of generating a single word to complete a sentence remains constant; however, the response generated is no longer connected to, or constrained by, the stimulus. This allows for several hypotheses regarding CH's performance.

1. If CH has a generalised verbal generation impairment, manipulating the task demands will be irrelevant, as he is still required to generate a single word to complete all sentences. Hence, the pattern of performance for Tests 9a and 9b will be the same.
2. If CH's verbal generation impairment is underpinned by an inability to select a verbal response when many competing response options are activated by a stimulus without a clear prepotent response, then his performance will be affected by the level of constraint only in the meaningful completion task in which the response is connected to the stimuli (Test 9a). Furthermore, as the level of constraint and probability for a dominant response becomes lower, and the number of activated completion words increases, his performance on Test 9a will deteriorate. By contrast, on the unrelated completion task (Test 9b) CH's performance will not be affected by level of constraint, as responses are no longer connected to, or constrained by, the sentence frame. In this case there are two possibilities:
   a. CH's performance on Test 9b will be reduced for all levels of constraint as each sentence has multiple competing response options; or
   b. CH's performance on Test 9b will be relatively good for all levels of constraint if another intact cognitive process is used. Why is this proposed? Given CH's ability to complete many sentences from the Hayling, particularly on Section 2, and relatively well-preserved cognitive functioning, it seems plausible that another cognitive process could overcome his verbal generation impairment, such as the formation and use of a strategy.

Materials. A set of sentences with the final word omitted was selected from the Bloom and Fischler norms (1980). The stimuli were selected so that the number of alternative completion words varied such that the probability of a dominant response varied accordingly. The stimuli were grouped to form four different levels of constraint: very high constraint, medium-high constraint, low constraint, and very low constraint (stimuli provided by C. Frith & D. Nathaniel-James). For example, the sentence "Water and sunshine help plants . . ." is high in constraint, with only 1 listed completion word (i.e., grow) that has a probability of .99 for being the dominant response produced. By comparison, the sentence "There was nothing wrong with the . . ." is very low in constraint and has 16 listed alternative completion words, each with a probability no larger than .14 for being the dominant response produced. Formation of the four levels of constraint was achieved by calculating the mean of the highest probability response for each sentence in each level. This resulted in four levels, each containing 32 sentences: very high constraint (VHC) = .93; medium-high constraint (MHC) = .73; low constraint (LC) = .53; very low constraint (VLC) = .20. The stimuli were used in Test 9a and 9b.

Method. CH was given the stem of a sentence and asked to generate an appropriate single word to complete it in two experimental conditions. In the *meaningful completion condition* (Test 9a) he was asked to generate a single word connected to the sentence. In the *unrelated completion condition* (Test 9b) he was asked to generate a single word unrelated to the sentence, such that the completed sentence did not make sense (e.g., London is a very busy . . . *elephant*). Test 9a was based on Section 1 of the Hayling whereas Test 9b was based on Section 2. The sentences were presented in a pseudorandom order. Test 9a was given on three separate occasions over a 6-month period. Test 9b was given on one occasion after the third administration of Test 9a. The number correct and mean RTs are reported in Table 6.

Test 9a: Meaningful completion

CH's performance was almost at ceiling when generating single words to complete the VHC sentences that have a high probability for a dominant response. In contrast, his ability to generate single words to complete the VLC sentences that have a very low probability for a dominant response was severely impaired. As this test was administered on three occasions, CH's performance on each sentence across trials was analysed. Each sentence was given a score between 0 and 3 that represented the frequency with which CH generated a correct response over the three trials (see Appendix A). The basis for comparison between levels of constraint was the frequency with which CH scored 3, indicating a correct response on all three trials. CH's ability to generate a correct response was not independent of the level of constraint, $\chi^2(3) = 18.85$, $p < .005$. Upon closer scrutiny, CH's performance for the two most constrained levels (VHC and MHC) just fell short of significance, $\chi^2(1) = 3.78$, *ns*. p (.05) = 3.84, with Yates correction applied. However, CH performed significantly better for VHC than LC sentences, $\chi^2(1) = 8.38$, $p < .005$, with Yates correction applied, and by implication VLC sentences. Similarly, MHC sentences were performed better than VLC sentences, $\chi^2(1) = 5.15$, $p < .025$, with Yates correction applied. The difference between the lowest two levels of constraint (LC and VLC) did not reach significance. Errors consisted of no responses, responses that were meaningless, responses that were repetitions of words contained in the sentence frame, or responses with more than one word. Analysis of variance was used to examine the effect of mean RTs, with no significant differences found between the four levels of constraint for the three times it was administered, $F(3, 8) = 1.53$, *ns*. However, CH's response times were considerably slower than normal controls on the original Hayling Section 1 ($M = 0.67$ s/sentence; for CH see Table 6).

Test 9b: Unrelated completion

CH's performance was virtually at ceiling for all four levels of constraint in this condition. Remarkably, his performance was equally good for the VHC as well as the VLC sentences, $\chi^2(3) = 0.23$, *ns*. In other words, his ability to generate an unrelated single word to complete "Water and sunshine help plants . . ." was as good as his ability to generate an unrelated single word to complete "There was nothing wrong with the . . ." There was no significant difference between mean RTs for levels of constraint, $F(3) = 1.08$, *ns*. CH's response times were comparable to normal controls on the original Hayling Section 2 ($M = 3.4$ s/sentence; for CH see Table 6).

Summary

CH's ability to generate a single word to complete sentences meaningfully (Test 9a) was influenced by the level of constraint and probability for a dominant response. His ability to generate a single

Table 6. *The effect of competing response options on single word generation to complete a sentence: Number correct and mean RTs*[a] *(Experimental Series 3)*

		Meaningful Completion (Test 9a)		*Unrelated completion (Test 9b)*	
Level of constraint[b]	*Trial*	*No. correct*	*Mean RT*	*No. correct*	*Mean RT*
Very high constraint	T1	29/32	1.80 (1.2)	—	—
(Prob = .93)	T2	29/32	1.85 (1.6)	—	—
	T3	30/32	1.97 (2.1)	31/32	3.26 (2.7)
Medium-high constraint	T1	23/32	3.05 (2.8)	—	—
(Prob = .73)	T2	25/32	2.50 (2.6)	—	—
	T3	28/32	4.08 (4.3)	31/32	4.39 (3.7)
Low constraint	T1	21/32	3.42 (2.5)	—	—
(Prob = .53)	T2	21/32	3.41 (3.9)	—	—
	T3	25/32	4.13 (3.7)	31/32	4.13 (3.4)
Very low constraint	T1	17/32	2.70 (2.9)	—	—
(Prob = .20)	T2	16/32	2.80 (1.8)	—	—
	T3	18/32	7.59 (7.7)	30/32	3.17 (3.6)

[a] RT = response time in seconds with standard deviation in parentheses; [b] Prob level is the probability of the dominant response being generated.

word to complete a sentence was best when the level of constraint and probability for a dominant response was high. In contrast, it was poorest when the level of constraint was low with no dominant response option. Remarkably, CH's ability to complete sentences with single words in the unrelated completion condition (Test 9b) was almost at ceiling and clearly not affected by the level of constraint of a sentence. The fact that CH's pattern of performance ranged from impaired in Test 9a to unimpaired in Test 9b clearly indicates that his verbal generation difficulties are not underpinned by a more generalised verbal generation impairment. That level of constraint only affected performance in the meaningful completion task provides evidence that CH's verbal generation impairment is underpinned by an inability to select a verbal response when many competing response options are activated by a stimulus. CH's virtually intact performance on all four levels of constraint in the unrelated completion condition leads to the conclusion that in certain conditions CH is remarkably able to overcome his verbal generation impairment.

Of particular interest was his intact performance in generating a single word unrelated to the sentence frame. This task has the greatest number of potential responses. We suggest that CH was able to form and use a semantic strategy allowing him to generate unrelated responses. Burgess and Shallice (1996) described two of the most common strategies used by controls on Section 2 of the Hayling that required generation of unrelated words. One strategy consisted of choosing objects from the examiner's office and the other consisted of generating exemplars from a semantic category. These are precisely the strategies that CH used. First, he described objects in the examination room (e.g., computer). Second, he generated items from different semantic categories (i.e., kitchen items, railway objects, colours, electronic items and machinery, household items, tools, musical instruments, furniture, money, body parts, and car parts). These two strategies, resulting in generating approximately 10 items from 12 categories, is consistent with his poor performance on semantic fluency tasks (e.g., animals < 10th percentile, see Table 2). This observation does not support Gold et al.'s (1997) hypothesis that dynamic aphasia may be due to defective semantic strategy formation and/or use.

EXPERIMENTAL SERIES 4: SEMANTIC STRATEGY FORMATION

Test 10. Semantic categorisation task

Materials. A set of 80 words printed on individual cards was selected for this task (based on Gold et al., 1997). The stimuli formed 16 categories, with each containing five highly associated items (e.g., fruit = orange, pineapple, grapefruit, cherries, apple). Pairs of categories were created, with the degree of association being manipulated such that category pairs were *close* or *distant*. Close was defined as being closely related across the two categories. Distant was defined as being distantly related across the two categories. The close category pairs were field animals–African animals, office items–bedroom items, outdoor clothing–beach clothing, and sharks–fish. The distant category pairs were animals–clothing, food–sport equipment, flowers–vehicles, and sea animals–furniture.

A set of 80 coloured pictures depicted on individual cards was selected for this task (based on Gold et al., 1997). The stimuli formed 16 categories, with each containing five highly associated items. Pairs of categories were created with the degree of association being manipulated as outlined above. The four close category pairs were field animals–African animals, office items–bedroom items, kitchen appliances–household appliances, and fruit–vegetables. The four distant category pairs were clothing–animals, food–sport equipment, wheels–furniture, and office items–fish.

Method. CH was given a stack of 10 cards containing a pair of categories and asked to sort the stimuli into two piles under two conditions: cued and uncued. In the cued condition, the names of the two categories were stated prior to sorting. In the uncued condition, the category names were not given at any stage. The number of items correctly sorted and the mean RT taken to complete the sorting were recorded. Five age- and education-matched controls completed these tasks.

Results. CH's performance on this task was virtually at ceiling for sorting closely and distantly related categories in both the cued and uncued conditions (see Table 7). Further, there was no difference in his good performance for word or picture stimuli. For the critical uncued condition when sorting close categories, CH made three errors for word stimuli and two errors for picture stimuli, which was almost identical to controls. Although the number of total errors CH made on this task was less than the average number of errors made by controls, the time taken for CH to complete each sort was consistently longer.

Summary

CH has a severe single word generation impairment only when many competing response options are activated by a stimulus. However, his ability to

Table 7. *Semantic categorisation task: Number correct and mean RTs*[a] *(Experimental Series 4)*

	Words				*Pictures*			
	Close		*Distant*		*Close*		*Distant*	
Condition	*No. correct*	*Mean RT*	*No. correct*	*Mean RT*	*No. correct*	*Mean RT*	*No. correct*	*Mean RT*
Cued								
CH	40/40	18.8	40/40	20	39/40	28.3	40/40	25.5
Controls	39.5/40	11.3 (6.2)	40/40	8.8 (4.2)	38.5/40	11.8 (4.5)	40/40	10.3 (2.0)
Uncued								
CH	37/40	34.8	40/40	19.3	38/40	47	40/40	28.3
Controls	36.3/40	15.6 (6.5)	40/40	8.2 (1.6)	37.3/40	20.9 (5.3)	39.5/40	14.8 (4.7)

[a] RT = response time in seconds with standard deviation for controls in parentheses.

generate an unrelated single word is normal. We attribute this to his intact ability to form and use a semantic strategy when a response is unrelated to the stimulus.

EXPERIMENTAL SERIES 5: RANDOM NUMBER GENERATION

The aim of the next two experimental series was to address CH's ability to generate other nonlinguistic responses. In the fifth series, we investigate CH's ability to generate items from the category of numbers, which are known to dissociate from other lexical categories (e.g., Dehaene & Cohen, 1997). In our task we use random number generation that involved only a restricted number set between 1–9 (e.g., 1–4). In this sense CH was asked to generate numbers from a restricted response set.

For the random number generation tasks we used 10 age-, gender-, and education-matched controls. Of these 10 male controls, 5 were occupation-matched (i.e., engineers; E controls) and 5 were not (NE controls). The E controls were all employed as consultant engineers with the same company. Their mean age was 56.4 years (range 54–60) and the mean level of intellectual functioning was 123.4 (range 122–127) as estimated by their performance on the NART. The NE controls were recruited on the basis that all five had professional jobs, but were not engineers. Their mean age was 53.6 years (range 50–61) and the mean estimated level of intellectual functioning was 119.6 (range 113–123). CH's performance was compared to controls using the modified t-test, $df = 4$ (Crawford & Garthwaite, 2002).

Test 11. Random number generation

Materials and method. CH was asked to generate numbers in a random order for 100 trials in synchrony with a pacing tone that occurred once every 3 seconds (partly based on Jahanshahi, Profice, Brown, Ridding, Dinnberger, & Rothwell, 1998). The hat analogy was used to explain the concept of randomness, as detailed in Jahanshahi et al. The size of the response set was varied so that the task was performed under three conditions: (a) number set 1–9, (b) number set 1–4, and (c) number set 1–2. Responses were recorded and errors were numbers outside of the identified response set. The percentage of responses that were repeats of the previous number (e.g., 1–1), ascending series (e.g., 1–2 would be counted as 1, and 1–2–3 would be counted as 2), or descending series (e.g., 2–1) was calculated. Repetition and seriation have been identified as important factors in human random number generation (Ginsburg & Karpiuk, 1994). A summary of percentages is presented in Table 8.

Results. In task 11a, CH was asked to randomly generate numbers between 1 and 9. The percentage of CH's responses that were repeats and descending series was comparable to all controls. By contrast, the percentage of ascending series given by CH was significantly greater than that of both E and NE controls.

In task 11b, CH was asked to randomly generate numbers between 1 and 4. CH's performance was indistinguishable when compared to E controls in that the percentage of responses that were repeats, ascending series, and descending series was comparable. In comparison to NE controls, the percentage of CH's responses that were ascending and descending series was comparable, although CH did produce significantly more repeats. However, this higher percentage of repeats that CH produced (30% comparing with NE controls 10.4%) is actually the more correct pattern, as the chance level for repeating a digit when one is drawing a digit randomly from a small set is 25%.

In task 11c, CH was asked to randomly generate the numbers 1 and 2. The percentage of CH's responses that were repeats, ascending series, and descending series was not significantly different from that of E and NE controls.

Summary

Overall, CH's ability to generate random numbers is comparable to controls on all measures. In this task CH is behaving in a different fashion from the other generation tasks, where he is unable to produce a verbal response. In this respect, he is able to generate answers, as with the unrelated

Table 8. *Random number generation tests: Percentage of total responses and modified t-test comparison between CH and controls[a] (Experimental Series 5)*

	CH	Engineer controls		Nonengineer controls		Chance
Test	*% responses*	*% responses*	*t(4)*	*% responses*	*t(4)*	*% responses*
		Number Set 1–9 (Test 11a)				
Repeats						
Trial 1	0	3.8 (5.4)	–0.6	3.6 (2.5)	−1.3	11.1
Trial 2	5		–0.2		0.5	
Ascending Series						
Trial 1	24	7.0 (3.5)	4.38**	14.4 (3.5)	2.49*	9.8
Trial 2	24		4.38**		2.49*	
Descending series						
Trial 1	12	13.2 (5.4)	–0.2	11 (5.4)	0.2	9.8
Trial 2	15		–0.3		0.7	
		Number Set 1–4 (Test 11b)				
Repeats	30	16 (7.3)	1.76	10.4 (6.5)	2.74*	25
Ascending series	21	18.8 (2.7)	0.75	17.8 (5.8)	0.5	18.7
Descending series	25	23.6 (6.2)	0.21	24.4 (4.3)	0.13	18.7
		Number Set 1–2 (Test 11c)				
Repeats	48	43.6 (4.8)	0.83	32.8 (24.2)	0.57	48
Ascending series	28	28 (2.4)	0	23.6 (4.5)	0.89	25
Descending series	23	27.2 (2.2)	−1.77	24.2 (2.2)	−0.27	25

[a] Standard deviations for controls in parentheses. $^{*}p < .05$; $^{**}p < .01$.

completion part of the Hayling task (and Test 9b). Again, the type of response that is required is dependent on the specific cognitive requirements induced by the task instruction; responses are not produced by the language mechanism in normal generation mode. There was, however, one condition involving the largest number set between 1–9 where CH, although still able to generate a response, produced a number of responses that were part of an ascending series. This type of response has been documented in the context of TMS studies involving the left dorsolateral prefrontal cortex (Jahanshahi et al., 1998) and therefore raises the possibility of their occurring as an associated deficit. In the next experimental section, we address the extent to which CH's verbal generation impairment was domain specific.

EXPERIMENTAL SERIES 6: NONVERBAL GENERATION TASKS

This experimental series was designed to investigate whether CH's verbal generation impairment was limited to verbal output or was part of a more generalised impairment in the ability to generate a response. Nonverbal generation tasks included design fluency, gesture fluency, and motor movement generation. For the following experimental series, we used the same controls as those described in Experimental Series 5. The E controls completed all nonverbal fluency tests, whereas the NE controls completed all nonverbal fluency tests except for two design fluency tests where standardised data was available (Test 12a and 12b). CH's performance was compared to controls using the modified *t*-test, $df = 4$ (Crawford & Garthwaite, 2002).

Test 12. Design fluency

The design fluency tasks are partly based on Jones-Gotman and Milner (1977) and Regard, Strauss, and Knapp (1991). For all design fluency tasks, CH was provided with a pencil and as many A4 sheets of blank paper as was required, except for Test 12e where sheets with arrays of five dots were provided. The total number of responses generated and errors were recorded for all tasks. Errors included perseverative responses (i.e., a repeat of one previously given) and inappropriate responses (i.e., if it clearly broke the rules given). A summary of scores is given in Table 9.

Test 12a: Free condition

In this task, based on Jones-Gotman and Milner (1977), CH was asked to draw as many designs as possible in 4 minutes. The standard instructions were given. The total number of drawings generated by CH was comparable to both E controls and an age-matched control group reported by Jones-Gotman (1996; cited in Spreen & Strauss, 1998). CH generated no errors. Occasional errors consisting of recognisable drawings (e.g., letter of the alphabet) were produced by E controls.

Test 12b: Fixed condition

In this task, based on Jones-Gotman and Milner (1977), CH was asked to draw as many designs with four straight lines as possible in 4 minutes. The standard instructions were given. The number of designs CH generated was comparable to both E controls and an age-matched control group reported by Jones-Gotman (1996; cited in Spreen & Strauss, 1998). Although the E control mean was slightly higher than both CH and normal controls, there was great variability in their performance (range = 15–38). CH made only one perseverative error. Occasional errors consisting of partial perseverations or recognisable drawings were produced by E controls.

Test 12c: Geometric shapes fluency

CH was asked to draw as many different geometric shapes as possible in 4 minutes. He performed this task well and generated no errors. CH's performance was not significantly different from E or NE controls.

Test 12d: Objects fluency

CH was asked to draw as many recognisable objects as possible in 4 minutes. He was instructed that each drawing must be nameable. CH's

Table 9. *Design and gesture fluency: Total number generated and modified t-test comparison between CH and controls*[a] *(Experimental Series 6)*

	CH	Engineer controls		Nonengineer controls	
	Total no. generated	*Total no. generated*	*t(4)*	*Total no. generated*	*t(4)*
		Design fluency (Test 12)			
12a. Free condition	11	13.8 (3.9)	−0.16	11.8 (4.4)	−0.17
12b. Fixed condition	17	28.0 (9.6)	−0.11	12.6 (4.3)	0.97
12c. Geometric shapes	14	17.8 (4.7)	−0.74	16.6 (3.8)	−0.63
12d. Objects	12	18.6 (5.6)	−0.52	14.6 (11.6)	−0.20
12e. 5-point test	20	39.5 (7.19)	−2.43*	18.8 (9.4)	0.12
		Gesture fluency (Test 13)			
13a. Meaningless movements					
Trial 1	26	22.2 (5.3)	0.65	22.0 (5.8)	0.63
Trial 2	26				
13b. Meaningful movements					
i. Use of objects					
Trial 1	12	18.6 (2.9)	−1.92	16.0 (4.9)	−0.65
Trial 2	13				
ii. Use of tools					
Trial 1	8	11.4 (1.8)	−1.47	11.2 (1.6)	−1.26
Trial 2	10				

[a] Standard deviations for controls in parentheses. * $p < .05$.

performance was not significantly different than controls, although it was somewhat lower. No errors were made.

Test 12e: Five-point test

In this task, based on Regard et al. (1991), CH was presented with the standard record sheet containing an array of five dots and asked to connect the dots in as many different ways as possible. The instructions and 3-minute time limit was based on the version used by Lee, Strauss, Loring, McCloskey, and Haworth (1997). It was noticeable that E controls tended to use a strategy on this task that allowed a much higher number of designs to be produced. Upon closer scrutiny, it seems the E controls produced the same number of unique designs, although many designs were repeated but from a rotated angle (i.e., at 90°, 180°, and 270°). The scoring criteria allow these responses; however, this approach was clearly not adopted by CH and NE controls. CH's performance is indistinguishable from the NE controls and just significantly below the E controls. CH made no errors, whereas one E control made two perseverative errors.

Comment

CH's performance on the design fluency tests was entirely normal when compared to the NE controls. When compared to the E controls, CH's performance was only slightly weaker on one of the five tests. Overall, the results of the design fluency tasks indicate that CH does not present with a clear impairment in the ability to produce meaningful and meaningless designs in a structured or less structured format.

Test 13. Gesture fluency

These tests are based on Jason (1985). CH was asked to generate as many movements as possible with the upper limbs in 2 minutes. A video camera recorded responses to aid scoring. The total number of responses generated, perseverative responses, and inappropriate responses were recorded. CH completed these tasks twice on different days, with the average score used for comparison with the controls, who only completed these tasks once. A summary of scores is given in Table 9.

Test 13a: Meaningless movements

CH was asked to make as many different meaningless positions with the fingers of his hands as possible. Although CH generated slightly more responses than controls, this was not significant. CH made 6 perseverative errors over the two trials, NE controls made an average of 4.6 perseverative errors (range = 2–9), and E controls made no errors.

Test 13b: Meaningful movements

In this task, CH was asked to demonstrate as many different things he could do with his hands in two conditions: (i) use of objects, and (ii) use of tools. For each condition one example was demonstrated (i.e., i. opening a jar, ii. using a saw). CH generated slightly fewer responses than controls in both conditions, although this did not reach significance. CH made no errors in either condition. By contrast, in the first condition two controls made no more than two errors and in the second condition two controls made one error each.

Comment

CH's ability to generate meaningless and meaningful gestures with the hands was comparable to controls. It may be noteworthy that CH's performance was above the mean of controls for meaningless gestures and slightly below controls for meaningful gestures. A PET study by Decety et al. (1997) found that observation of meaningless actions was mainly associated with a right occipitoparietal pathway while observation of meaningful actions strongly engaged left frontotemporal regions. CH's strong performance for meaningless gestures and relatively weaker performance for meaningful gestures would fit with this data and may be due to his left frontotemporal degenerative process. In terms of errors, both CH and NE controls made slightly more perseverative errors than E controls only when generating meaningless movements. Overall, these results suggest that CH does not present with a gesture fluency impairment.

Test 14. Motor movement generation

In this task, based on Deiber et al. (Deiber, Passingham, Colebatch, Friston, Nixon, & Frackowiak, 1991), CH was asked to select motor movements using a joystick that could be moved in four directions: up (U), down (D), left (L), and right (R). CH held the joystick positioned on a table with his right hand. In time with a tone every 3 seconds, CH was asked to select a motor movement that did not correspond to a sequence or pattern. This task was carried out under two conditions that varied the number of possible movement options he could select: (a) two movement options, which comprised either U and D, or L and R; and (b) four movement options, which comprised U, D, L and R. Each condition lasted 4 minutes. To familiarise the patient with the task a baseline condition was administered first, in which CH was asked to move the joystick in only one direction (U) in time with the tone. The baseline condition lasted for 2 minutes. The examiner observed all responses and recorded the position selected. The percentage of total responses that were repeats (e.g., U–U) and opposites (e.g., U–D or L–R) was calculated. This enabled an analysis of fixed or random response patterns, and allowed comparison between CH and controls. A summary of percentages is given in Table 10.

Test 14a: Two-movement options

In the two-movement condition, CH was requested to select between one of the two options and move the joystick accordingly in a manner that did not represent a pattern. CH completed both variations of this task separately (U and D, L and R). The percentage of CH's responses that were repeats and opposite movements for both tasks was comparable to all controls.

Test 14b: Four-movement options

In the four-movement condition, CH was asked to select between one of the four options and move the joystick accordingly in a manner that did not represent a pattern. There was no difference in the percentage of responses that were repeats and opposite movements between CH and all controls.

Comment

CH's performance on the motor movement generation task that required the selection of

Table 10. *Motor movement generation: Percentage of total responses and modified t-test comparison between CH and controls* [a] *(Experimental Series 6)*

	CH	*Engineer controls*		*Nonengineer controls*		*Chance*
	% responses	*% responses*	*t(4)*	*% responses*	*t(4)*	*% responses*
14a. Two options						
U–D						
Repeats	52	50.5 (5.5)	0.25	44.6 (16.1)	0.42	50
Opposites	48	49.5 (5.5)	–0.25	55.4 (16.1)	–0.42	50
L–R						
Repeats	42.9	53.3 (7.1)	–1.34	45.2 (16.2)	–0.13	50
Opposites	57.1	46.6 (7.3)	1.31	54.8 (16.2)	0.13	50
14b. Four options						
U/D/L/R						
Repeats	38.8	26.2 (5.8)	1.98	20.1 (15.2)	1.12	25
Opposites	23.8	27.0 (8.6)	–0.34	31.5 (9.5)	–0.74	25
Other	37.4	46.8 (10.0)	–0.86	48.4 (11.8)	–0.85	50

[a] Standard deviations for controls in parentheses.
None of the t-tests reached significance level of $p < .05$.

movements from a response set that had either two or four options was comparable to controls. The percentage of sequences (repeats or opposite movements) was not different to that generated by controls, suggesting that CH does not have an impairment in the ability to generate and select motor movements.

Summary

CH's performance on design fluency, gesture fluency, and motor movement generation tasks was comparable to both engineer and nonengineer controls on 14 out of 15 measures. Overall, these results suggest that CH does not have a nonverbal generation impairment and that his impaired ability to generate verbal responses is domain specific.

DISCUSSION

Primary progressive aphasias have been divided into fluent and nonfluent subtypes (Grossman, 2002; Hodges & Patterson, 1996). CH's clinical presentation is consistent with nonfluent progressive aphasia. Within this clinical category, CH presented with a central language impairment that is best described as dynamic aphasia (Luria, 1970, 1973; Luria & Tsvetkova, 1968). In addition, CH presented with a mild peripheral speech disorder as his severely reduced spoken language contained some articulatory errors and was somewhat halting. CH rarely initiated conversation or connected speech. The largest sample of connected speech was elicited when he was describing complex scenes. However, his speech was reduced and asyntactic predominantly due to the omission of function words (e.g., *The girl [is] washing the* horse). He responded to most questions with single word answers, although occasionally phrases of no more than five words in length were produced. CH's severely reduced spoken language was not underpinned by a primary deficit in naming, reading, repetition, or comprehension, as these were predominantly preserved. Moreover, other cognitive skills were intact and remained stable over the time of this investigation (e.g., nonverbal intellectual, visual perceptual, and episodic memory functions). Thus, CH presented with the mixed form of dynamic aphasia. That is, the core feature of reduced propositional language was present in association with additional articulatory and grammatical difficulties.

On standard verbal generation tests, CH was severely impaired. In particular, CH's performance on verbal fluency tasks was impaired, more so for phonemic than for semantic tasks. In the cognitive baseline, his performance on the Hayling Sentence Completion Test was impaired only on the initiation section.

Experimental Series 1 demonstrated that CH's severely reduced verbal generation skills were comparable to the pure dynamic aphasic patient ANG (Robinson et al., 1998) and other dynamic aphasic patients (e.g., Costello & Warrington, 1989; Esmonde et al., 1996; Gold et al., 1997). Similar to ANG, CH had profound difficulty in the generation of phrases and sentences when more than a simple description was required from stimuli that included single words, phrases, and pictorial scenes. Experimental Series 2 demonstrated that like ANG, CH's ability to generate sentences and phrases was best from stimuli that strongly activated a dominant response (proper nouns, phrases with a high response predictability). By contrast, CH's ability to generate phrases and sentences was impaired when many competing response options were activated by stimuli (common words, phrases with a low response predictability). This replicated the findings of the pure dynamic aphasic ANG.

This finding was extended to the single word level for the first time in Experimental Series 3. CH's ability to complete sentences with a single word was significantly better when there was a high probability for a dominant response. CH's performance was virtually at ceiling when completing a sentence that had a highly associated dominant single word response (e.g., Water and sunshine help plants . . .). By contrast, his ability to complete sentences with a single word was impaired when many alternative completion words were activated; that is, in a situation where each activated completion word had a low probability for being the dominant response (e.g., There was nothing wrong with the . . .). Interestingly, CH performed at ceiling when he was required to complete sentences with a single word unrelated to the frame (e.g., London is a very busy . . . *elephant*). In this condition, there was no stimulus–response connection and the response was not constrained by the sentence. We speculated that CH's good performance in this condition was attributable to a strategy used, in that he systematically generated a single word to complete each sentence by either choosing objects from the examiner's office (e.g., computer) or generating exemplars from semantic categories (e.g., machinery, colours, musical instruments). These results suggested that CH had an intact ability to generate and apply a semantic strategy. Our formal investigation in Experimental Series 4 confirmed that CH's ability to form and use a semantic strategy was entirely normal.

As discussed earlier, Experimental Series 5 demonstrated that CH did not have a deficit in randomly generating numbers from a restricted set. Further, Experimental Series 6 showed CH's nonverbal response generation skills were normal. CH's ability to generate designs and gestures, and to generate and select motor movements, was comparable to two groups of carefully matched controls on almost all 15 measures. Indeed, he was normal ($p > .05$) or better than normal on 14 out of 15 measures. Thus, CH does not have an impairment in the ability to generate nonverbal responses. CH is the first dynamic aphasic patient in whom the characteristic verbal generation impairment is demonstrated to be specific to the language production domain. It is important to note that language impairments are not always the first cognitive domain to be involved in dementia. For example, De Renzi (1986) reported one case of slowly progressive pure apraxia and two cases of slowly progressive visual agnosia without generalised dementia. Therefore, CH's intact performance on nonverbal generation tasks cannot be explained by a greater sensitivity of verbal than nonverbal responding to the initial stages of a degenerative disorder (anonymous reviewer suggestion).

Dynamic aphasia and other forms of aphasia

Following Luria's (1968, 1970) terminology we have termed our patient's impairment dynamic aphasia. This has been described in the context of a progressive nonfluent language impairment and raises the possibility that dynamic aphasia can be a distinct clinical manifestation within the nonfluent progressive dysphasias (for examples of clinical variations within progressive aphasias, see Croot, Hodges, Xeurub, & Patterson, 2000).

Dynamic aphasia has been reported more often in the context of acquired rather than progressive nonfluent dysphasia. Some authors have adopted Luria's terminology of dynamic aphasia and others refer to this syndrome as transcortical motor aphasia (TCMA; e.g., Gold et al., 1997). Since Goldstein's early pioneering work in 1948, several studies of TCMA have been reported (e.g., Alexander, Naeser, & Palumbo, 1990; Alexander & Schmidt, 1980; Ardila & Lopez, 1984; Benson & Ardila, 1996; Berthier, 1999; Cappa & Vignolo, 1999; Freedman, Alexander, & Naeser, 1984; Goodglass & Kaplan, 1983; Luria, 1970). These studies identified different subclinical types of TCMA. In the majority of studies, at least two broad types of TCMA have been identified: pure and mixed. Pure TCMA has been described as being characterised by sparse speech output with near normal repetition, comprehension, grammar, and articulation. Pure TCMA has also been termed dynamic aphasia subtype (Ardila & Lopez, 1984), 2nd profile (Alexander et al., 1990), and Type I (Benson & Ardila, 1996). Mixed TCMA has been described as being characterised by articulatory and prosodic impairments. Mixed TCMA has also been termed supplementary motor area subtype (Ardila & Lopez, 1984), 1st profile (Alexander et al., 1990), and Type II (Benson & Ardila, 1996). A few studies have proposed that more than two types of TCMA exist. For example, Freedman et al. (1984) suggested the existence of four subtypes: classical TCMA and three near-variants of TCMA. Classical TCMA is characterised by reduced spontaneous speech without any other linguistic impairments (i.e., articulation, naming, comprehension, and repetition are normal). However, it should be noted that 5/7 patients that Freedman identified with classical TCMA were also anomic. Near-variant syndromes of TCMA are characterised by impairments of articulation, stuttering or comprehension in the context of reduced spontaneous speech and intact repetition.

These accounts of TCMA have primarily focused on describing clinical symptoms. Since Lichtheim's seminal work in 1885, there has been a surprising paucity of theoretical accounts for TCMA. Indeed, to the best of our knowledge no theoretical explanation has been offered regarding the cognitive mechanism underpinning the core impairment of TCMA, namely the marked reduction in propositional speech.

Recently, three studies have described patients with reduced verbal output and sharing some of the same characteristics as TCMA, although they were not classed as TCMAs (McCarthy & Kartsounis, 2000; Schwartz & Hodgson, 2002; Wilshire & McCarthy, 2002). These studies focussed on the level of single word production and lemma selection rather than on the level of propositional speech. The patient reported by Schwartz and Hodgson, MP, was given complex scene description tasks. MP performed poorly when describing complex scenes, as did our patient. There were, however, considerable differences between their performance. MP's poor performance was entirely attributable to severe anomic difficulties. Our patient, however, had no difficulty in producing content words in either scenes or standard picture naming tests. One further relevant case is AB, who had a left frontal haematoma and may relate to our patient CH (Martin, Shelton, & Yaffee, 1994). AB's spontaneous speech was empty of content with word-finding difficulties resembling the clinical category of anomic aphasia (Romani & Martin, 1999). On a semantic relatedness task AB's performance decreased with more options, which the authors attributed to a semantic STM deficit (Martin & Freedman, 2001). However, it was of interest to note that similar to CH, the number of response options was a critical variable for AB.

Explanations of dynamic aphasia

Can the main accounts for dynamic aphasia explain the pattern of language impairment observed in CH? We are going to first discuss the accounts interpreting the deficit as extending beyond the domain of language. Dynamic aphasia has been explained as a failure in the strategy used to search lexical/semantic networks (Gold et al., 1997). The patient Gold and colleagues described was impaired on a semantic categorisation task. In addition, the patient's dynamic aphasia was associated with impaired design fluency. CH's performance was entirely normal on a semantic categorisation task. Also, his semantic fluency was superior to his phonemic fluency and he did not have a design fluency impairment. Indeed, CH was unimpaired on a large series of nonverbal generation tasks (gesture fluency, random number generation, motor movement selection). These findings suggest that CH had an intact ability to use a semantic strategy to search the lexicon. Thus, CH's dynamic aphasia is not underpinned by a semantic strategy deficit and his verbal generation deficit does not extend beyond the verbal domain.

Can dynamic aphasia be due to a deficit in appropriate strategy use? A deficit in appropriate strategy use has been suggested to account for reduced verbal initiation on the Hayling test by patients with frontal lobe lesions (Burgess & Shallice, 1996), and for reduced word fluency performance in an autistic population (Turner, 1999). If a deficit in appropriate strategy use underpins reduced verbal generation, we would expect a more generalised deficit on generation tasks. For example, Turner argued that design fluency tasks place even greater demands upon generative skills than word fluency tasks. This is because stored knowledge is of little use in design fluency tasks as all responses must be original. However, CH was able to generate nonverbal designs on five different design fluency tasks. This would argue against a general deficit in appropriate strategy use. Moreover, this intact performance rules out a deficit in producing novel responses. Within verbal based tasks, we only need to examine CH's intact performance in the unrelated sentence completion task (Test 9b). CH was able to produce unrelated single words in a systematic manner that strongly suggested that he was able to form an appropriate strategy and produce novel responses. Thus, it seems that a deficit in appropriate strategy use, or indeed in producing novel responses, cannot explain CH's dynamic aphasia.

To consider the accounts of dynamic aphasia that interpret the disorder within the domain of language. Luria's (1970, 1973) account proposed the critical deficit to be an inability to form a linear scheme of a sentence; namely, the transitional stage of internal speech breaks down (see, for empirical support, Esmonde et al., 1996; Snowden et al., 1996). The account described by Luria is vague at several key points. First, Luria did not define either the process of translating internal speech into a plan or internal speech. Second, the plan that arises from this translation process is what, in Luria's formulation, should initiate verbal expression of thought. A breakdown in this translation process would presumably result in a more generalised verbal generation impairment. One could speculate that this would affect every attempt to generate verbal output when formation of a sentence scheme is required. However, this cannot explain why CH was able to generate a verbal response when a dominant response was activated by a stimulus.

A second account is that dynamic aphasia arises from a selective impairment in verbal planning (Costello & Warrington, 1989). These authors specify that it is "the initial thought or plan that is impoverished not the ability to implement it" (p. 111). A diagnostic indicator of a verbal planning impairment for these authors was a deficit on a sentence construction task. However, CH, in a similar fashion to the pure dynamic aphasic patient ANG (Robinson et al., 1998), was able to order constituent words to form a sentence. The extent to which this task relates to the online production of language is unclear. Further, CH's good performance on the Reporter Test (language baseline) indicates that he does not have a general deficit in the initial planning of language.

Robinson et al.'s (1998) account of dynamic aphasia

Robinson et al. (1998) previously proposed that dynamic aphasia could be explained in terms of a deficit in the ability to select between competing verbal response options. Our account focused on the basic idea that activated verbal response options compete with each other through mutual inhibition. The greater the number of competing verbal response options activated by a stimulus, the greater the amount of inhibition each response receives from its competitors and the lower the probability of one response option becoming dominant.

Within a model of the language system, the level of the units at which response competition may be occurring needs to be considered. CH demonstrated that impairment in the ability to select between verbal response options applies not only to the sentences and phrases studied in ANG but also to single word generation. Thus, the degree of stimulus–response association determined CH's ability to generate a single word to complete a sentence (Test 9a). CH did not have a verbal generation impairment when a dominant or prepotent response was strongly associated with a stimulus (highly constrained sentences). However, as the constraint became weaker moving from medium to low to very low constraint sentences, CH's ability to generate a word from a sentence frame became increasingly impaired. These data indicate that with increasing strength of stimulus–response association he was more able to overcome competition between alternative responses.

Our investigation suggests that CH's impairment was within the language domain. CH did not present with a response generation impairment in any other nonverbal domain encompassing the generation of designs, gestures, and motor movements. Therefore, an account of CH's impairment needs to be given within the context of a model of speech production. In most speech production models, the stage of processing on which we have been focusing is not well addressed. An exception is Levelt's (1989, 1999) model for producing spoken language, which is also one of the most detailed. It contains a number of processing components that are involved in speech generation. According to this model, once the *surface structure* of the utterance—namely, a linear, relational pattern of lexical items ("lemmas")—is achieved, the phonological/phonetic system will then translate it into overt speech. The mechanisms involved in the production of the *surface structure* are the mechanisms we have been focused on in this study. In particular, Levelt specifies that two processing components play a key role in the realisation of the *surface structure*. The first processing component is termed *conceptual preparation.* In the *conceptual preparation* component, the speaker generates a message. Messages are conceptual structures. According to Levelt, conceptual structures consist of lexical concepts, namely concepts for which there are words in the language. Levelt acknowledged that not all concepts are lexical, but in his model a message must eschew those that are not expressible in words. In Levelt's model, the message is then realised by the *grammatical encoding* processing component. Specifically, it is assumed that the lexical concepts of the message activate the corresponding syntactic words (lemmas) in the mental lexicon. The speaker uses this lexical-syntactic information to build up the appropriate syntactic pattern (the *surface structure*).

In terms of the Levelt model, CH would have impairments arising both at the level of *grammatical encoding* as well as at the level of *conceptual preparation.* His agrammatism would be due to difficulties in realising the message by *grammatical encoding*. His severe propositional speech impairment would be due to an impairment in *conceptual preparation*; in other words, he has difficulties in the generation of lexical concepts. Our account of CH's dynamic aphasia attempts to specify some of the complex mechanisms involved in the generation of lexical concepts. We suggest that when many competing verbal response options are activated by a stimulus, additional stress is placed on the *conceptual preparation* processes. When these processes are damaged, difficulties will arise when one verbal response must become preferentially activated over the other competing responses in order to satisfy task requirements. This in turn will not allow the speaker to achieve a satisfactory message that is able to drive *grammatical encoding* and lemma selection. By contrast, when there is a single dominant verbal response option, as for example in naming or describing scenes and actions, less stress is placed on the damaged *conceptual preparation* processes. These are then able to successfully generate lexical concepts[1] that in turn successfully activate lemma selection. Thus, damage to some of the complex processes involved in *conceptual preparation* processing may result in a highly selective verbal generation impairment characterised by an inability to select a verbal response option from amongst competitors. Cases of dynamic aphasia such as CH add to our understanding of this postulated processing stage, to which so far very little empirical evidence directly relates.

Neuroanatomical substrates for verbal generation skills

Recent reviews of imaging studies indicate a role for the prefrontal cortex in almost all high-level cognitive tasks, but often in conjunction with dorsolateral activation (e.g., Duncan, 2001). Frith (2000) identified a tendency for bilateral activation when tasks involve nonverbal material, such as joystick and finger movements (Dieber et al., 1991; Frith, Friston, Liddle, & Frackowiak, 1991b; Rowe, Toni, Josephs, Frackowiak, & Passingham, 2000). Consistent with this, the reported dynamic aphasic patient with a bilateral lesion also had impaired design fluency (Gold et al., 1997). Nonlanguage tasks have been associated with left BA 44 activation, including imitating gestures and executing movements in response to objects (Grezes, Armony, Rowe, & Passingham, 2003) and imagery of motion (Binkofski et al., 2000). On the basis of an extensive review, Cabeza and Nyberg (2000) concluded that the ventrolateral prefrontal cortex (BA 45/47) was involved in selecting, comparing, or deciding on information held in short-term and long-term memory. Right BA 44 activation was reported when engaged by episodic retrieval tasks whilst left BA 44 activation was commonly found for reading, verbal working memory, and semantic generation. PET and fMRI studies have shown associated increased activation of the left prefrontal cortex in word generation

[1] A related perspective on dynamic aphasia has been put forward very recently (Warren, Warren, Fox, & Warrington, 2003).

tasks (e.g., BA 45/46, Frith, Friston, Liddle, & Frackowiak, 1991a; BA 45/46, Phelps, Hyder, Blamire, & Shulman, 1997; BA 44/45/46/47, Warburton et al., 1996). In addition, PET has shown greater left frontal activation (BA 44/46) for letter-based word fluency than category fluency, which has been associated with more left inferolateral temporal activation (Mummery, Patterson, Hodges, & Wise, 1996).

Three recent PET studies have attempted to investigate sentence or narrative production. All have involved activation of the left frontal operculum, which is the area of greatest atrophy in our patient CH. Indefrey et al. (2001) showed that syntactic encoding during sentence production was associated with increased activation in the left operculum (BA 6/44). Two studies have investigated narrative production. Braun, Guillemin, Hosey, and Varga (2001) investigated narrative production in spoken English and American Sign Language. They analysed the common activation that they hypothesised would reflect the conceptual formulation and lexical access stages. PET showed a bilateral posterior network and a left lateralised anterior network that included the left operculum (BA 45/47). Blank, Scott, Murphy, Warburton, and Wise (2002) compared narrative production to automatic speech. They showed that propositional language prior to articulation was associated with a neural system that included the anterior left temporal cortex, the left operculum (BA 44), and the left superior frontal gyrus (BA 10). These authors inferred that disconnection of the left temporal cortex from the left superior frontal gyrus would be associated with impaired propositional speech.

PET studies based on the Hayling have found associated increased activation in the left inferior frontal and middle temporal gyri (Nathaniel-James, Fletcher, & Frith, 1997). Nathaniel-James and Frith (2002) adapted the Hayling so that the level of constraint varied (similar to our Test 9). They found increased BA46/9 activity only for low-constraint sentences in the meaningful completion task and for all levels of constraint in the unrelated sentence completion task. Collette, Van der Linden, Delfiore, Degueldre, Luxen, and Salmon (2001) adapted the Hayling and found meaningful sentence completion was associated with increased activation in the left inferior frontal gyrus (BA 45/47). By contrast, unrelated sentence completion was associated with increased activation in a network of left prefrontal areas that included middle (BA 9/10) and inferior (BA 45) frontal areas. Desmond, Gabrieli, and Glover (1998) used fMRI to compare activity in a word stem completion task. Normal individuals either completed word stems with *many* possible completions or completed word stems with *few* possible completions. They found that stem completion in the *many* condition was associated with increased activity in the left dorsolateral prefrontal cortex (BA 9/10).

Of more direct relevance, Thompson-Schill and colleagues (Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997; Thompson-Schill, Swick, Farah, D'Esposito, Kan, & Knight, 1998) have conducted fMRI and lesion studies designed to address the question of whether the left inferior frontal gyrus (IFG) has a role in the selection of semantic knowledge. In a fMRI study of healthy controls, they systematically varied the selection demands of three different semantic tasks and found an associated increase in activation in the left IFG when the selection demands were high. These results were thought consistent with the notion that "left IFG activity reflects the degree of selection among competing alternatives, and not the amount of semantic retrieval per se" (Thompson-Schill et al., 1997, p. 14796). In a further study, they compared 4 patients with left posterior IFG lesions with 10 other frontal patients (5 left and 5 right) on a single verb generation task (Thompson-Schill et al., 1998). Whether or not these patients had dynamic aphasia is unclear, as this study did not involve a detailed investigation of the patients, including other aspects of their language skills. The patients with left IFG lesions were selectively impaired in generating verbs that had high selection demands among competitors. For example, *cat* (a high demand item) compared to *scissors* (a low demand item). The increased error rate, as measured by a no response or a non-verb response, was strongly related to the size of the lesion in BA 44. On the basis of these studies, Thompson-Schill et al. have concluded that the left IFG "subserves a mechanism . . . which can be described as the selection of a response among competing information" (1998, p. 15860). This pattern of results is in accordance with our findings on CH.

Very recently, the left IFG (specifically BA 45) has been associated with interference effects in both imaging and lesion studies using a verbal working memory task, in particular single letter-recognition (Jonides, Badre, Curtis, Thompson-Schill, & Smith, 2002; J.K. Nelson, Reuter-Lorenz, Sylvester, Jonides, & Smith, 2003; Thompson-Schill et al., 2002).These investigators proposed that the left IFG is involved in conflict resolution by selecting relevant information from competing alternatives. Indeed, Nelson and colleagues identified two types of conflict (response-conflict and high-familiarity conflict) using this task in a fMRI study. High-familiarity conflict was thought to occur at a representational level of processing, with interference resolved by selecting from among competing attributes of a stimulus. This was associated with left IFG activation.

How does the left frontal operculum/IFG correspond to the lesion cases of dynamic aphasia? Reduced verbal output is frequently observed in patients with frontal lobe damage and the left frontal lobe has been traditionally implicated in the production and organisation of verbal output (Benton, 1968; Milner, 1982). The classic literature for dynamic aphasia suggests involvement of the inferior left frontal lobe, anterior to Broca's area (Luria, 1973; Luria & Tsvetkova, 1968). The neurodegenerative cases with dynamic aphasia presented with frontal involvement or frontal lobe degeneration (Esmonde et al., 1996; Snowden et al., 1996). The patients with dynamic aphasia and focal lesions all support the role of the left IFG. In particular, ROH had a tumour in the left posterior frontal region (Costello & Warrington, 1989) and MP had infarction in the left frontal subcortical region, including part of the anterior insula (Raymer et al., 2002). The pure dynamic aphasic ANG had a frontal meningioma in the anterior part of the left IFG particularly affecting BA 45 (Robinson et al., 1998). This was tentatively taken to support the notion that the left IFG is involved in verbal generation and specifically in the selection between competing verbal responses.

Conclusion

At the time of this investigation, our patient CH had focal atrophy in the left frontal and temporal lobes, particularly involving the superior and inferior frontal gyri. More specifically, BA 44 was maximally involved and BA 45 was judged as somewhat less impaired. The greater involvement of BA 44 in CH, compared to that of BA 45 in ANG, may reflect his additional articulatory and syntactical impairments. This is in line with Indefrey et al.'s (2001) conclusion that the posterior region of BA 44, adjacent to BA 6, plays a role in syntactical processing. Thus, the lesion cases of CH and ANG allow us to suggest that the left posterior IFG is involved in a high-level process responsible for the generation of verbal output, and particularly in the selection between competing verbal responses at Levelt's pre-message level. This is consistent with neuroimaging findings (e.g., Thompson-Schill et al., 1997, 1998).

In sum, we have reported the case of CH, who presented with a dynamic aphasia in the context of nonfluent progressive aphasia. CH presented with a verbal generation impairment only when many competing verbal response options were activated. This impairment encompassed the generation of phrases, sentences, and single words. Further, for the first time, we demonstrated that this verbal generation impairment was specific to the production of language. In the context of the neuroimaging literature, which specifically implicates the left IFG in the selection of verbal responses, CH allows us to suggest that this region plays a crucial role as a language control system responsible for the generation of verbal output.

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APPENDIX A

Item Analysis for Test 9a: Number of occasions a correct response was generated for each sentence across three trials

	Number correct			
Level of constraint	*3/3 trials*	*2/3 trials*	*1/3 trials*	*0/3 trials*
Very high constraint (VHC) = .93	27	3	0	2
Medium-high constraint (MHC) = .73	19	8	4	1
Low constraint (LC) = .53	15	9	4	4
Very low constraint (VLC) = .20	9	8	8	7