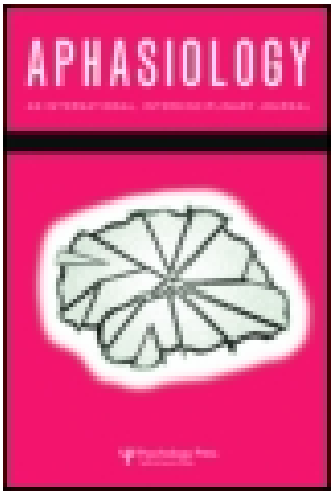

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Major Review

On the measures of fluency in the assessment of spontaneous speech production by aphasic subjects

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Abstract

Traditionally, 'fluency' is used first to refer to an aphasic syndrome and second to describe only a symptom, a defining speech output feature. Both of these uses may be questioned. Different dimensions of fluency, for instance articulatory agility and use of grammatical words, may be found independent; thus fluency does not identify with a consistent association of speech characteristics. When these dimensions are considered separately, other methodological and theoretical problems arise because the several decisions which are made in assessing the rate and ease of speaking do not relate explicitly to current models of speech production. The alternatives to fluency measures are various qualitative analyses of speech on the morpheme and sentence levels. Nevertheless, the inclusion of temporal variables remains useful when combined with a description of the morphological and structural aspects of the performance, when narratives are studied on the discourse level and, in a clinical setting, when therapists have specifically to deal with changes in fluency during the treatment of single cases of aphasia.

Introduction

Most examinations of aphasia include a measure of fluency to assess spontaneous speech. For instance, it is the case with the Boston Diagnostic Aphasia Examination (Goodglass and Kaplan 1972), the Aachen Aphasie Test (Huber *et al.* 1984), the Western Aphasia Battery (Kertesz 1982), and recently the Shewan Spontaneous Language Analysis system (Shewan 1988a). These measures may serve two different purposes: the evaluation of verbal impairments in the oral expressive modality and the classification of the subject in aphasia subtype. Typically, global, Broca's and transcortical motor aphasias are non-fluent while Wernicke's, conduction and transcortical sensory aphasias are their respective

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fluent counterparts. Both of these usages have recently been questioned. For Marshall (1986) *inter alii*, the fluency measures exhibit 'somewhat strange psychometric properties' (p. 10), lack theoretical foundations and, since one does not know which processing mechanism is involved, they are inappropriate in the assessment of aphasia. Likewise, Caplan (1987) wrote that 'phrase length has no status in either linguistic theory or models of language processing' (p. 155) in order to criticize the phrase length ratio as a way to classify aphasias. There is nowadays a general distrust of the classical syndrome complexes resulting from standard aphasia batteries because resulting classifications, especially the fluent/non-fluent distinction, do not relate to current models of linguistic processing (see, for example Caplan 1987: Chap. 11, Caramazza and Badeker 1989, Schwartz 1984, Shallice 1988).

The two problems in measuring fluency, theoretical relevance and discriminating value, are linked. As we do not know what fluency is, it cannot be used in the definition of aphasia subtype. Thus one may ask the question: Is the notion of fluency still useful? Our answer is articulated in three parts. First, we shall examine various conceptions of fluency in order to show that this notion refers to diverse aspects of verbal performance which must be distinguished. Indeed, since the early descriptions of different aphasic syndromes, several measures have been proposed to assess fluency from the characteristics of spontaneous speech in a reliable way (for reviews see Hadar and Rose 1988, Poeck 1989). Second, we shall mention some recent advances in the psychology of language that make fluency measures old-fashioned. Finally, we shall consider some alternatives and indicate restricted conditions in which we think fluency measures remain appropriate.

What is fluency?

'Fluency' has at least two meanings in aphasiology. Historically, the term was used to refer to an aphasic syndrome from its most typical feature. It is also used in a more restrictive way when it refers merely to a symptom, a selected speech output characteristic. In the latter case it may serve just the same as a criterion to assign patients to a syndrome category.

Fluency as an aphasic syndrome

Historical background

Around the year 1960, major works in psycholinguistics influenced systematic and quantitative approaches to aphasic performance. Howes (1964) referred to Zipf's equations and he based descriptions of language disorders on word frequency distributions and emission rate (see also Howes 1967/1973). He distinguished two types of aphasia, a fluent type A and a non-fluent type B, on the basis of several associated parameters. The notion of word frequency was also central in parallel studies by Wepman and co-workers, who stated that in some cases of aphasia vocabulary was reduced to the most frequent items, mainly function words, while in other cases, using a telegraphic speech, only meaningful words were uttered and syntactic words were often omitted. Henceforth they proposed to classify aphasics from the noun–pronoun ratio (Wepman *et al.* 1956, Wepman and Jones 1966b). This measure related to mean productivity (number

of words in responses to stimuli pictures) and to the type–token ratio. The convergence of the two lines of research was acknowledged by Geschwind (see Wepman and Jones 1966a: Discussion) who wrote:

> There is a type of aphasic who usually has no hemiplegia, whose speech is fluent and paraphasic, and whose speech rate is high. This group shows little change in the vocabulary parameter, little loss of grammatical words, and few repetitions of words. None of these changes in this group, except perhaps those in rate, correlate with severity of aphasia. By contrast, there is another type of aphasic who is nonfluent, speaks slowly, and usually has a hemiplegia. In this group there is an increased number of repetitions, a noticeable tendency to omit small grammatical words, and a shift in the vocabulary parameter. The changes in the different measures are definitely intercorrelated and tend to be more marked the more functionally severe the aphasic impairment (p. 167).

Access to the least frequent words usually requires more time. Thus, one may understand the association between low productivity and slow speech tempo. However, from such a perspective the restriction of the available vocabulary to low-frequency items remains problematic. Therefore the reduction of aphasia to word-finding difficulties was criticized by Jakobson (see Howes (1964: Discussion). He wrote:

> The count of word frequency cannot exhaust the description of aphasic impairments . . . Word statistics which pay no attention to the morphological properties and syntactic functions of the counted words are unable to disclose and characterize the diverse types of aphasia, whereas a grammatical analysis leads to a precise classification of aphasic impairments (pp. 75–76).

In the same discussion (see Howes 1964), Cherry raised the question of whether *words* are selected individually (his italics) and he added: 'We don't speak words surely, we speak utterances' (p. 78). Thus, it was underlined that the quantitative analyses of aphasic speech did not capture all the subtleties of language a scholarly linguist or an experienced speech therapist may grasp. We shall now develop this theme.

Relationships between measures

The identification of fluent and non-fluent subtypes of aphasia obviously relies on the assumption that different speech characteristics form clusters. This conception was explicit in the study of Benson (1967), who grouped aphasic patients on the basis of an additive combination of 10 three-point scales. A normal versus abnormal judgement was elicited for the following variables: rate of speech (number of words per minute), prosody, pronunciation, phrase length, effort in initiation of speech, press of speech (i.e. total number of words in responding). Word choice (substantive versus relational) and pauses, perseverations, and paraphasias (rare or frequent) were also rated. The distribution of the sums of 10 scores in 100 subjects was found bimodal, and different from the rectangular distribution which would be observed if the various variables were not associated.

A clearer demonstration of the relation between speech rate and each of the nine other measures was provided in another study bearing on 47 subjects (Kerschensteiner *et al.* 1972). However, several interpretations of the association between fluency measures remain possible. One may assume that a single deficit, in sentence planning for example, simultaneously affects availability of function words, speech rate, and length of utterance. Or coincidence of several impairments may be spurious if, for example, one considers that persistent non-fluency generally results from large cerebral lesions or from interruptions of the subcortical pathways by which different cortical regions are connected (Knopman *et al.* 1983, Naeser *et al.* 1989).

Psychometric approaches. The definition of these syndromes of fluent and non-fluent aphasias was revisited by means of the more sophisticated methods of factor analyses. The aim of the technique is to find the best description of a multidimensional space from the smallest number of 'factors', i.e. abstract entities summarizing information from several sources. Different measures which are loaded on the same factor are assumed to relate to each other, and they may be considered redundant. However, a single complex measure may be loaded on several factors. In the study of Wagenaar *et al.* (1975), six factors accounted for 84% of the variance to be explained (details of the computational method were not reported). The main dimension (47% of variance explained) was interpreted as relating to 'fluency' because measures such as speech tempo, mean length of utterances (MLU) and syntactic complexity loaded on this factor. The other, less important factors were called 'telegraphic speech' (number of nouns, omission of function words), 'grammatical errors' (word order, tense, or unclassified mistakes), 'articulation' (speech tempo, melody, incomprehensible sounds), 'verbal paraphasia', and 'empty speech' (automatisms, personal pronouns).

This study was disputed on methodological grounds because inclusion of algebraically or logically related measures (for instance, the rating of syntactic complexity and the number of complex utterances) artificially inflated the dependencies between the measures (Vermeulen *et al.* 1989). A new analysis was conducted in a sample of 121 aphasics (the 74 subjects studied by Wagenaar *et al.* and 47 additional cases) on 18 selected measures by means of the factor analysis subprogram of the SPSS (Statistical Package for the Social Sciences). Four factors accounted equally for about 10% of variance. The first one was interpreted as relating to 'syntactic ability' (words per minute, MLU, number of auxiliary verbs and of conjunctions), the second to 'phonological paraphasias' (phoneme addition, substitition, etc.), the third to 'neologistic paraphasia', the fourth to 'articulatory impairment'. The last interpreted factor, 'vocabulary', related to naming ability and use of prepositions (6% of variance explained).

The results of these studies remain ambiguous with regard to the grouping of speech characteristics into meaningful syndromes. On the one hand, some degree of commonality between measures such as speech rate and MLU was shown. However, the factorial method did not demonstrate that these measures depend purely on a single factor. In the study of Wagenaar *et al.* (1975), speech tempo and MLU both loaded on fluency and also on another factor, articulation. Moreover, as shown by the comparison of the two cited studies, the mathematical solution that is found depends largely on the nature of the measures entered. For instance, in the study of Vermeulen *et al.* (1989), rate of speaking, MLU, use of

conjunctions and auxiliary verbs related to fluency, while in the former study several measures dealing with the use of function words loaded on a second factor called 'telegraphic speech'. On the other hand, orthogonality may be imposed in some factorial computation (we do not know whether, in the two cited studies, rotations were actually orthogonal or oblique). This imposed orthogonality does not imply factual independence between observed measures. For instance, fluency and use of nouns (or naming ability) may load on two different factors, but cases exist in which low speech rate results from naming impairments and long hesitation pauses. Thus, the dissociation found in the analysis of a large sample might simply result from the small proportion of subjects whose dysfluencies relate to word-finding difficulties.

The case for dissociations: fluency is multidimensional. It remains unclear from the preceding discussion whether fluency refers to a consistent association of reduced speech rate, shortened length of utterance, articulatory impairments and omission of function words, or only one of these characteristics. We have argued that psychometric attempts to construct a concept of fluency on the basis of intercorrelated measures were inconclusive. Furthermore, several studies have shown that the various variables involved in the assessment of fluency may dissociate in cases of aphasia. First, inconsistencies in patient classification and frequent use of the label 'mixed aphasia' may be noted (see for example, Marshall 1986). One may guess that taking into account different dimensions of the performance (e.g. a phonetic/phonemic distinction in the analysis of the speech errors) affects the clinical rating of articulation but not another measure such as speech tempo. Second, the assumption that non-fluency equates with omission of function words (or high proportion of content words) may seriously be questioned. In the series sampled by Feyereisen *et al.* (1986), the use of nouns which is representative of the proportion of content words in the spontaneous speech did not correlate with speech tempo, mean silence duration and clinical evaluation. Partial explanation for that absence of correlation can be found in a qualitative analysis of the sentence production (see the companion paper, by Feyereisen 1984). Narratives were found to depend on strategic choices which were assumed to depend on psychological factors such as the limitations of working memory and the accessibility of lexical items. Accordingly, a Broca's aphasic may use function words in short sentences (for instance, in the construction *it's* + NP) and an anomic use content words in circumlocutions. Likewise, in another study, a detailed analysis of sentence production in 10 non-fluent subjects (rate of speech below 80 words per minute) allowed the distinction between two kinds of patients, agrammatic or non-agrammatic (Saffran *et al.* 1989). The groups differed in several respects when the values of morphological measures (e.g. proportion of closed class words) and those of structural measures (e.g. proportion of words in 'sentences') were compared. A similar analysis by Byng and Black (1989) confirmed the relevance of distinguishing non-fluent subjects, who mainly produce isolated elements or incomplete sentences, from other non-fluent aphasics who are able to construct well formed sentences and to realize predicate–argument structures.

Further dissociations between different aspects of fluency and use of grammatical words were found in studies on the use of syntax by aphasic subjects. First, we have the non-fluent speech in absence of grammatical impairments that

characterizes the so-called 'dynamic' or transcortical motor aphasia (see, for example, de Lacy Costello and Warrington 1989). Second, there are the more numerous reports on the inverse dissociation of syntactic impairments in fluent subjects. For instance, Nadeau (1988) documented two cases of aphasia resulting from frontal lobe lesions. Grammatical impairments were found in several production tasks (sentence completion, story completion, sentence anagram tests) but spontaneous speech was said to be fluent. On the basis of observations of other cases the distinction between agrammatism, i.e. the omission of function words in non-fluent aphasias, and paragrammatism, i.e. the substitution of function words in fluent aphasias, was disputed (see, for example, De Bleser 1987, Heeschen 1985, Miceli *et al.* 1989, Parisi 1987 and also the 1987 Butterworth and Howard's analyses). In that context the progressive replacement of omission of grammatical words by substitution errors was demonstrated in the longitudinal study of MC., a case previously described as non-fluent and agrammatic (Dordain *et al.* 1988, Nespoulous *et al.* 1988).

At the same time, agrammatism itself was not found to be a homogeneous syndrome; thus other dissociations between non-fluency and use of function words were described. Some subjects who were non-fluent and agrammatic in spontaneous speech were able to process function words correctly and to produce regular constructions in a sentence anagram task (e.g. De Bleser *et al.* 1988, Kolk and Van Grunsven 1985; Nespoulous *et al.* 1988). More critically, the cases A.P. and R.W. did not suffer from articulatory impairments, and their narratives contained closed-class words in normal proportion, but a syntactic breakdown was nevertheless shown by low MLU and low proportion of well formed sentences (Martin *et al.* 1989). For R.W., however, the performance differed in a picture description task. Lastly, in a sample of 20 non-fluent, agrammatic patients, a wide range of variations in the patterns of omission and substitution of grammatical morphemes was noted. The percentage of these errors did not correlate with speech rate and MLU; thus no support was found for the internal validity of the construct of agrammatism (Miceli *et al.* 1989, Spearman's coefficients of correlations computed from the data of Tables 2, 4 and 8). Furthermore, neither the class of content words (mainly nouns and verbs), nor that of grammatical words, nor categories like that of prepositions, articles and pronouns are homogeneous; thus different kinds of impairments may affect the use of these parts of speech. Reduction of the speech rate and of the MLU definitely does not equate with omission of function words or agrammatism. These diverse observations do not fit the assumption of a central syntactic deficit in Broca's aphasia (see Pillon (1987) for a more extensive discussion).

Fluency as merely a speech output characteristic

The impression that speech is fluent is certainly due to many contributing linguistic as well as extralinguistic factors (Fillmore 1979). Despite the pervasive use of the notion of fluency as the basis for major subdivisions into aphasic types, there does not exist any general agreement—either about the speech characteristics the notion of fluency refers to, or about the way of capturing them through objective measures. When asking linguists or speech therapists for a definition of 'fluency', or when looking at the implicit meaning of 'fluency' in neurolinguistic descriptions, different aspects of the notion, although not quite

independent, emerge. These aspects relate altogether to temporal features of spontaneous speech such as the rate of speaking, and to more qualitative features, vaguely called 'ease of speaking' or 'richness of content'.

The rate of speaking

Subjective ratings. In the neurolinguistic literature we find descriptions of patients whose spontaneous speech is characterized by a 'low rate' or a 'normal rate' of speaking. In some cases the subject's spontaneous speech is labelled 'logorrhoeic', a notion that refers to a particular rapidity or overabundance of verbal output. This diagnosis of logorrhoea refers to both quantitative and qualitative aspects; thus it may be subject to examiner's biases. In fact, were an objective measure computed or not, it seems that the low versus normal rate distinction relies on the answer to the question: 'Does the patient speak at a socially acceptable rate?'. Therefore, the fluent/non-fluent dichotomy refers to sociopragmatic constraints of communication, as most often assessed through the listener's own criteria.

Clinical ratings of 'fluency' nevertheless present some advantages over measures that require tedious transcriptions or use of recording apparatus, which may be unavailable in bedside examinations. Accordingly, several standardized rating scales were proposed in which fluency was defined in various ways. Besides other measures, the Boston Diagnostic Aphasia Examination includes ratings of melodic line, articulatory agility and phrase length, in order to measure 'speech characteristics which are difficult to quantify objectively' (Goodglass and Kaplan 1972). This latter seven-point scale of phrase length replaces the phrase length ratio formerly defined by Goodglass *et al.* (1964). It probably yields similar results to the more formal computation of the MLU largely used (but also criticized) in studies on language acquisition (Brown 1973, Rondal *et al.* 1987).

The study of Feyereisen *et al* (1986) demonstrated high inter-judge agreement in clinical rating of fluency and substantial correlations with objective measures. Thus, one may argue that non-fluency is obvious enough in aphasics for a precise quantification to be unnecessary. However, subjective ratings of fluency might be biased by the examiner's preconceived notions about some general symptoms clustering such as, for example, agrammatism and low speech rate, jargonaphasia and normal fluency or logorrhoea. But though there probably exist certain speech characteristics which tend to co-occur in aphasia, these associations have only a statistical value. Exceptions exist, and they demonstrate that a single deficit cannot account for the observed cluster of symptoms. To illustrate this point, let us only mention two cases (but see also the entire section on 'The case for dissociations'). The patient T.F. reported by Miceli *et al.* (1983) was fluent (the speech rate of 96 words/minute was within normal range), without dysarthria but he nevertheless presented agrammatic disorders. Inversely, Illes *et al.* (1986) described a patient who was considered jargonaphasic in spite of a low verbal rate as compared to a control speaker. They suggested that logorrhoea was in part a listener's phenomenon:

> Certainly, we have all shared the experience of listening to a person speaking a foreign language at a normal speech rate and have the impression that the output is extremely abundant and rapid. Indeed, to normal speakers, the language of the jargoning Wernicke's aphasic is very foreign (Illes *et al.* 1986: p. 89).

Designing objective measures of the temporal aspects of spontaneous speech protects against these bias. However, other important methodological and theoretical problems are raised.

Objective measures. First of all, a major difficulty arises with the distinction between normal and pathological ranges of fluency values. We would need some normal speaking standards to which aphasics' performance could be compared. As far as we know, such norms are not available. Furthermore, normal speaking rate is subject to important inter- and intra-individual variations. For instance, rate of speaking has been shown to vary with situational factors such as familiarity with the conversational topic, degree of intimacy between the speaker and the listener, their role and status, and task characteristics (Goldman-Eisler 1968). Therefore, the method of contrasting aphasics' productions in one condition to those of a control group of normal subjects (chosen to match the aphasics on the variables of age, gender, education, etc.) might be inappropriate. Moreover, computing the rate of speaking, i.e. a ratio of number of linguistic units per time unit, requires that the two terms of the ratio be accurately defined, which poses serious methodological problems.

(1) *The linguistic units.* Three types of unit are possible candidates for constituting the numerator: a sublexical unit, the syllable; and two lexical units, the word or the morpheme. The syllable is probably the speech segment easiest to define. It also offers the advantage of being identifiable even in severely impaired speech (for instance in subjects whose output is limited to CV recurring utterances; see e.g. Blanken *et al.* 1988). However, since syllables have probably to be considered as articulatory programming units (Crompton 1981), a measure of fluency based on the number of syllables might not be representative of higher linguistic processing. For this purpose, counting lexical tokens in a speech sample, i.e. units that associate form and meaning, would be more appropriate.

Although for linguists the minimal meaningful unit in speech is the morpheme, it is the word unit that up to now has been extensively used as the basic lexical unit for measuring rate of speaking. The identification of words in written sentences does not raise any problem: a word is a grapheme sequence delimited with blanks. However, in oral speech production no linguistic criterion has been found relevant to objectivize this intuitively evident psychological unit. The lack of operational criteria for extracting words from the speech flow results in many doubts, which can only be resolved by rather arbitrary decisions, in the case of segments such as compound nouns and verbs, nominal, adjectival or adverbial locutions, presentatives, set phrases, etc. For instance, an expression like *it's* may count as one or two words. Despite these uncertainties about what constitutes the unit of lexical representation and retrieval, it was pervasively assumed, at least implicitly, that the word was the best candidate. This assumption is now seriously challenged.

Indeed, from the analysis of speech errors produced by normal and aphasic subjects, it has been proposed that the mental lexicon does not contain a full listing of whole-word forms, but only stem forms (e.g. Caramazza 1988, Garrett 1980, 1982, Miceli and Caramazza 1988, Stemberger 1984, 1985, Stemberger and MacWhinney 1986, and the objections by Butterworth 1983; see also discussion in Pillon *et al.* 1991). On this view morphologically composed words, i.e. words

that are composed of a stem + derivational and/or inflectional affixes, have to be retrieved by applying derivational and/or inflectional operations to stem forms. A word such as *disappeared*, for instance, would not be represented as an independent unit in the lexicon but only the stem *appear* would be directly retrieved; morphological mechanisms should then be applied to combine the derivational affix *dis-* and the inflectional affix *-ed* with the stem. This contention must be qualified, however. In languages such as English or French there are many instances of word formation that cannot be described by general semantic or morphophonemic rules because the word formation processes are idiosyncratic.

Therefore, the assumption of a morphemically organized lexicon is tenable only if regularly and irregularly affixed forms are functionally distinguished. Several authors introduced a further distinction between high-frequency and low-frequency words (Bybee 1985, Stemberger and MacWhinney 1986, Miceli and Caramazza 1988). Moreover, according to Miceli and Caramazza (1988), derivational operations are applied only to newly created words and not to already-known derived words. Thus the word *disappeared* would require only the application of an inflectional rule adding *-ed* to the unit *disappear-*, which would be represented as a single unit in the lexicon. All these discussions imply that, in order to be psychologically relevant, a morphemically based counting of lexical units in speech samples could not simply rely on the morphological properties of words as they can be drawn from a linguistic analysis. Only low-frequency composed words that are regularly inflected or derived would be decomposed in several morphemes. Such a speech sample analysis will prove to be really tricky and complicated, not only because it requires to take into account several factors such as morphological composition, regularity of the composition, and frequency of the whole word, but above all because we lack linguistic and psycholinguistic criteria to define cut-off points on the two critical dimensions of frequency and regularity. Surely, affixed words are viewed as regularly affixed if they are derivable by general rules from a stem. However, besides clearly regularly and clearly irregularly affixed words, many words are formed by processes that are effective only in a more or less restricted range. We do not know how 'frequent' must be a word and how 'irregular' must be its formation to be stored as a whole form in lexicon.

(2) *The time of speaking.* When the speech rate is defined from the number of units per second, a further choice must be made to compute the denominator. Conversation time comprises four kinds of events: vocalization by the target subject, subject's silence during the partner's vocalization, mutual silence, and simultaneous speech. The number of units may be divided by values which correspond to different combinations of these durations. A particular problem arises from the decision about the proper treatment that various kinds of silence require. Comparison of studies may become difficult if the details of the computation are not reported.

The work of Goldman-Eisler (1968) significantly increased our knowledge about the factors determining rate of speaking in normal subjects. In fact, two different components determine the time taken for the realization of utterances: the time taken for articulatory activities, and the time taken by pauses and hesitations. The total time of speaking almost exclusively depends on this second component. The correlation between pause time and rate is of −0·94 (the more

interval there is the slowest the rate will be) while it is of 0·17 between articulation rate and overall rate (Goldman-Eisler 1968). Thus, normal speech is not slowed by limitation of articulatory mechanisms, but by central linguistic operations. Hence, individual variations observed in normal speakers are mainly due to variations in pause time. Therefore, the ratio 'number of linguistic unit/total time of speaking' might be a relevant evaluation of fluency in normal subjects. Rate of speaking of aphasic subjects may be determined by other components, however. Deloche *et al.* (1979) analysed five aphasic patients' spontaneous speech samples collected in two situations (interview and picture description), in order to assess the role of three components of speech rate: the number of pauses, their mean duration and the phonation rate. This latter value was computed by dividing the number of syllables uttered by the articulation time (obtained by dropping silent pauses longer than 250 ms from total speaking time). It was found that two components, the phonation rate and the mean duration of pauses, played an important role in the verbal rate, the total number of pauses having a lesser effect. Thus, unlike results in normal subjects, variations in verbal rate of aphasics may be caused by a variation in phonation. Moreover, the study indicated that the respective contributions of each component on speech rate differed according to the subjects' characteristics.

Finally, it may be added that fluency is more easily measured when speech is not deformed too extensively. Typically, patients suffering from jargonaphasia, or from articulatory disorders which make their speech unintelligible, were excluded from studies on fluency (there was a similar selection on the basis of speech intelligibility in studies on language development in children: see, for example, Brown 1973). A paradoxical implication is that fluency measures are more appropriate in the study of normal than of pathological speech.

Indeed, the methodological problems that relate to the choice of linguistic unit and time measure by computing rate of speaking concern the analysis of aphasic speech as well as normal speech. But one comes up against additional problems for which no clear answer may be found when aphasics' speech samples are analysed, for these samples present with numerous linguistic deviations. Phonetic and phonemic deviations may cause difficulties in identifying the number and nature of the target lexical units. Such a difficulty also arises in the case of homophonic utterances that can be understood in different ways. For instance, the same sound may be understood as the article *a* or the filled pause *uh*. The listener is probably biased towards an interpretation that corresponds to well-formed sentences even if odd ones have actually been uttered. Explicit decisions are required by phonemic paraphasias, 'conduites d'approche', word fragments, and substitutions (verbal paraphasias) which may be counted as speech units or be deleted (cf. Wepman and Jones 1966a: pp. 162–165). One has also to decide whether verbal paraphasias will be treated like neologisms or not. Still other decisions must be taken as to the way the various disruptive phenomena will be taken into consideration. Shall we disregard the linguistic units that belong to repetitions, comments, circumlocutions, false starts and filled hesitation pauses? If so, must the time taken to utter these phenomena then be extracted from the total time of speaking to compute the rate of speech ratio? These questions are far from being rhetorical. Upon the answers that will be given will depend not only the quantitative results of the measure but, more importantly, its psychological significance. And here stands, finally, the core of the problem. Which aspects of spontaneous speech

impairment are we searching to assess through the measurement of the rate of speaking, and which are the most accurate measures of these aspects?

The ease of speaking

The objective measures of speech rate, whether the total speaking time or only the articulation time considered, do not suffice to capture the subjective impression of an effortless/effortful speech. Among all the speech phenomena converging on that intuitive evaluation, at least some of them can be identified and quantified.

Disruptive phenomena. The ease of speaking may be inferred from the quantity and distribution of disruptions in the flow of spontaneous speech. There are indeed many ways to cope with normal or pathological output difficulties other than slowing speech tempo. Disruptions may take the form not only of more or less long silent pauses, but also that of filled pauses (such as *uh*), syllable lengthening, interjections, false starts, repetitions, comments (bearing on the speaker's own verbal output). These phenomena may reveal word-finding difficulties (more than pause times, as no correlation has been found between the performance of an aphasic on a naming test and latencies in spontaneous speech), as well as syntactic or discourse planning difficulties.

Syntactic complexity. The relative syntactic complexity of sentences in spontaneous speech, independent of their well-formedness, also contributes to the intuitive impression of fluency. Its quantification turned out to be problematic, however. The MLU has been pervasively employed as an indicator of expressive syntactic ability in aphasia. The theoretical import of this index is nonetheless suspect when applied to adult speech. Indeed, this measure was designed to assess early syntactic development in children (Brown 1973). It is based on the observation that, in these early stages of language acquisition, any structural progress causes utterance lengthening. But this relation is no longer found in later acquisition stages when an increase in structural complexity may cause no change in length. Stated otherwise, MLU, at least in normal adult speech, cannot give any relevant indication of structural complexity. In fact, it reflects nothing but utterance length.

One can argue that MLU can still be a significant index when used to assess the severity of aphasic structural impairments, as part of the so-called syndrome of agrammatism. But the main problem encountered when attempting to compute MLU (or any other syntactic index) on agrammatic speech samples involves the segmentation of connected speech into analysable utterances. Many studies of agrammatic disturbances used pauses to determine utterance boundaries. As Parisi (1987) pointed out, this procedure is unsatisfactory. First, there is no means to decide otherwise than arbitrarily which pause duration will be used to separate utterances. Furthermore, suprathreshold pauses caused by, for example, word-finding difficulties, may appear between two words structurally related and, inversely, two consecutive sentences may not be separated by a suprathreshold pause. This is certainly the reason why many authors found it necessary to use additional criteria such as prosodic and syntactic indicators, reliance on semantic content, or well-formedness (e.g. Goodglass *et al.* 1964, Miceli *et al.* 1983, Saffran *et al.* 1989). Finally, the picture became quite confused and one can find as many segmentation procedures as there are aphasic speech studies.

To our mind a possible solution could be to identify utterances in aphasic speech in the same way as we identify them in normal speech. That means that the construction units to be analysed have to be identified by using only syntactic and semantic cues actually present in the speech. Note that, by doing so, the problem of imputing target structures to patient utterances is avoided at the segmentation stage. This was the solution proposed by Parisi (1987). In his analysis of aphasics' speech samples the measurement of the overall syntactic constructional ability is expressed as the average length (in content words) of the syntactic constructions actually produced. He considered that two adjacent words were 'in construction' if 'there are syntactic and semantic reasons for doing so. Two words are not considered in construction if this would require supplying a content word supposedly missing from the text' (Parisi, 1987: p. 213). It must be mentioned that Parisi's methodological proposal not only has the advantage of being easily and consistently applied; it is also based on structural units that are theoretically justified within a procedural model of sentence production. The construction length measure he proposed can be interpreted within this theoretical model as a degree of disruption of the sentence construction procedure. Of course, more fine-grained measures could further be devised. To objectivize intuitive differences across patients it may be profitable to compute, for instance, the proportion of sub-sentential versus sentential utterances, and among the latter the proportion of sentences containing embedded clauses. An index of sentence elaboration can also be obtained by counting the average number of words in NP and VP constituents of sentences (see, for example, Saffran *et al.* 1989), or by weighting each clause or sentence by the number of non-minimal constituents they contain, etc. Anyway, due to the great diversity—in both severity and nature—of syntactic impairment patterns (see e.g. Berndt 1987, Miceli *et al.* 1989, Parisi 1987), it seems obvious that, whichever index is used, none of them taken in isolation could give a precise and discriminating picture of the syntactic abilities and impairments in aphasic patients.

The richness of content. The impression of fluency may finally be related to the richness of the expressed content. The perceived semantic richness of discourse is, however, difficult to objectivize through a single measure since it probably relies on a variety of speech characteristics. These could include, to name a few, the relative redundancy of discourse, its structural cohesion, the number and complexity of the concepts and semantic relations expressed, and the diversity of topics. Moreover, very few attempts have been made at present to assess each of these speech dimensions through reliable measures. Lexical measures such as the Type/Token Ratio (TTR), word frequencies distribution, number of 'empty words' and fillers, etc., can no doubt be taken as reflecting at least one aspect of the semantic elaboration of discourse. But difficulties arise with the identification of larger discrete semantic units in discourse when the assessment involves aspects of content that are expressed through supralexical units, and suprasentential units all the more. Yorkston and Beukelman (1980) proposed to measure the amount of information in aphasics' speech samples by counting the 'content units' expressed. To allow comparisons between subjects, speech samples were elicited through a picture description task ('Cookie Theft' picture). However, on the basis of the few examples given in the paper, it seems that the procedure adopted for subdividing discourse in content units would not yield information other than that

which can be extracted from the simple counting of content words. A content unit was defined as 'a grouping of information that was always expressed as a unit by normal speakers' (p. 30) in the picture description. For instance, the word string *on the stool* was considered one unit because *on* was never produced by normals without *the stool*. Inversely, the string *little boy* was counted two units because several samples mentioned *boy* without qualification.

More importantly, the question arises whether content measures can validly be used to compare different speech samples produced by the same or by different speakers. Indeed, the content of speech is not predictable. Among the multiple determinants of the content actually communicated, the most critical are not under the examiner's control. The content to be expressed is primarily determined by what the speaker is interested in saying—and this remains true even in a 'controlled' expressive task such as a picture description task. Moreover, the speaker's communicative intent is contextually dependent on what he or she presupposes about the hearer's knowledge of the topic, and what he or she supposes the hearer is expecting to hear. Note that these hearer's expectations will, in turn, determine the subjective assessment of richness/paucity of the information expressed. Therefore, any attempt at quantifying the amount of information conveyed in aphasic patients' spontaneous speech has to be considered with caution.

Current models of speech production

We briefly mentioned, at the beginning of this paper, that fluency measures were originally proposed in the context of psycholinguistic models which have now evolved. Therefore, some of the criticisms addressed to the notion of fluency results from its irrelevance with regard to current views on speech production deficits.

Recent perspectives on sentence production

The model proposed by Garrett (1982) has influenced most contemporary studies on speech production. It constitutes the basis of further proposals (see e.g. Bock 1987, Dell 1986, Levelt 1989, Stemberger 1985) and offers a sound basis for the analysis of expressive disorders in aphasia (Buckingham 1986, 1987, Caramazza and Hillis 1989, Saffran 1982, Schwartz 1987).

The basic architecture of the model is the distinction between five levels of computation. First, on the 'message' level, the propositional content of the sentence is conceptualized from speaking intentions, situational and social constraints, encyclopaedic knowledge, etc. Second, on the 'functional' level, a sentence frame is built from content words, the meaning and the grammatical class of which is defined. Third, on the 'positional' level, word order is defined, function words and inflections are selected, and the sentence is phonologically interpreted. On the fourth level this information is recoded into a 'phonetic representation' that, finally, feeds the articulatory processes by which the 'motor' representation of the utterance is computed.

Disagreements about such a proposal mainly concerned the idea of a sequential organization of computational stages. Analyses of speech errors in normal subjects rather suggest interactions between the functional level in which words are

characterized by their semantic and syntactic functions and the positional level in which the surface shape is defined. Bottom-up activation allows for the occurrence of slips of the tongue that are both semantically and phonologically related to the target (Dell 1986, Stemberger 1985). Likewise, according to Bock (1987), assignments of thematic roles on the functional level may be influenced by the availability of word form on the positional level. The distinction between the two levels of encoding is not disputed, but the organization of the information transfer is not conceived on a serial mode. The different processing levels may be represented by parallel networks of interconnected nodes that exchange information. Each active node is characterized by a level of activation superior to zero. That activation spreads towards all the connected nodes according to time-dependent functions (progressive accumulation or decay). Some connections may also be inhibitive. Such a model may account for the increased number of speech errors under time pressure, for instance when the speaker is requested to repeat words at a fast rate (Dell 1988; see also MacKay 1982, Motley *et al.* 1983).

In that context, discussions arose about the monitoring processes during sentence preparation. Control over speech production may be exerted either via a specific device checking adequacy of the plan to the intention (e.g. Levelt 1989) or as a by-product of top-down and bottom-up interactions by which the target accumulates more activation than unintended speech units do (e.g. MacKay 1987, see the thorough treatment of that issue in Berg 1986). The two models can account for error detection and for a speed–accuracy trade-off (monitoring is time-consuming and differences in activation levels of speech units increase with time). However, the edition of self-repairs which are frequent events in the spontaneous speech of normal subjects is more difficult to explain in the framework of parallel and distributed processing.

These conceptions of the speech production processes have implications on the evaluation of fluency measures in the assessment of spontaneous speech. On the one hand, as word selection and sentence formulation are thought to result from several and partially parallel processes, words may be temporarily unavailable or utterances may be shortened because of impairments at different levels. Therefore, shallow measures such as speech rate or MLU are inadequate when the assessment is aimed at the identification of the defective mechanism. To some extent, however, it is also the case with any procedure by which mental processes are inferred from overt behaviour. On the other hand, connectionist approaches to sentence production renew interest for temporal variables in the study of spontaneous speech; thus they might offer some theoretical foundations for the real-time analysis of speech production. Considerations to hesitation pauses or self-repairs which typically influence fluency measures also have implications for the analysis of the trade-off between rapid transmission of information and control over speech quality.

On the time-course of speech units activation

Response speed and accuracy are among the favourite dependent variables that psychologists elect to study language processes. With error analysis, recording pauses and vocal response times are the main tools used to describe the covert operations underlying speech production (for reviews, see Butterworth 1980, Garrett 1982). These dynamic approaches to language processing distinguish psychological studies from more linguistic-oriented conceptions (see, for example

MacKay 1982). However, while the number of studies on on-line processing during speech comprehension is slowly growing, there have been few attempts to analyse real-time execution of speech plan or use of attentional resource during sentence planning in cases of aphasia. Likewise, we do not know any experiment using the vocal response time as dependent variables in naming and in repetition tasks by aphasic subjects.

Nevertheless, temporal variables were sometimes used in the analysis of aphasic production (e.g. Quinting 1971). New perspectives were opened in the study of jargonaphasia by careful analyses of hesitation phenomena. From the high proportion of neologisms following a hesitation pause in the case K.C., Butterworth (1979) favoured the 'anomia' explanation over the 'disinhibition' explanation of jargon (see also Hofmann 1980, Lecours *et al.* 1980). Further insight on the nature of the impairment is given by longitudinal studies. In the case of Mrs D., increased number of pauses over time and correlative reduction of fluency related to a better control on the production of neologisms (Illes *et al.* 1986). In the Italian case P.Z., on the contrary, fluency (number of syllables per time unit) did not change in relation to the reduction of neologism and the improvement in naming ability, but stereotyped utterances such as the expression '*Dio bono*' were produced in higher proportion without hesitation pauses (Panzeri *et al.* 1987). To our knowledge there are no comparable longitudinal studies of non-fluent speech. However, such studies would be critical for the assessment of the hypothesis that agrammatism results from strategic adaptations to limited resource in working memory (Kolk *et al.* 1985, Kolk and Heeschen 1990).

Are measures of fluency still useful?

Assessment of speech production

The shortcomings of fluency measures encourage the search for alternative tools of assessment. A clear conclusion from the preceding discussions is that computing speech rate and MLU or rating fluency cannot give a sufficiently detailed picture for the assessment of spontaneous speech in aphasia, or for the neurolinguistic study of sentence production. From the theoretical perspectives briefly summarized in the preceding section it appears that oral expression has first to be studied through qualitative analyses of spoken language. Therefore, current studies on the production of words and sentences are mainly based on the description of the morphological and structural aspects of the performance. We have mentioned some proposals in the analysis of agrammatic production (see section on 'Syntactic complexity'). Similarly, at the word level subgroups of fluent aphasics may be differentiated by the nature of the errors: neologistic, phonemic, verbal, or semantic paraphasias. In that context special attention was paid to the contrast between phonetic and phonemic paraphasias elicited in naming, reading and repetition tasks. A description of the 'tip of the tongue' phenomenon also allows for a distinction between different kinds of anomia.

Some insights may also be found in the study of repairs, i.e. self-correction of speech errors, and 'prepairs', i.e. searching behaviour characterized by silent pauses, filled pauses, repetitions, phonemic approximations or comments (Schlenck *et al.* 1987, Valdois *et al.* 1989). The frequency of various 'trouble-indicating' cues did not relate to scores of auditory comprehension; it was

thus concluded that speech monitoring did not depend on the comprehension system. That conclusion is also supported by two other studies showing that the number of self-corrections did not differ in fluent and non-fluent aphasics when fluency was rated following the criteria of the Boston Diagnostic Aphasia Examination (Farmer *et al.* 1978, Marshall and Tompkins 1982).

Furthermore, connecting empirical data with theoretical models requires some control over task demands and a comparison of different input and output processes. Subjects found unable to form a sentence in one condition may perform normally in other conditions when they are given all the lexical items (e.g. repetition, reading and anagram tasks) or when they are provided with the syntactic structure (e.g. sentence completion tasks). A more efficient exploitation of temporal variables may result from increased attention to the comparison of performance in various conditions: interview, referential communication, picture description, narratives, etc. In such a procedure, measures of temporal variables have to be complemented by error analysis.

On the proper use of fluency measures

The study of narrative performance

We have previously argued that analysing fluency is more useful when speech output is not disrupted to a large extent. Speech rate measures relate to higher-level processes in sentence production; thus study of the temporal variables may be relevant in the assessment of, for instance, what Garrett (1982) labelled the 'message' formulation. These processes, indeed, may be impaired in cases of brain damage which do not necessarily entail aphasia (see for example, Ehrlich 1988). Similarly, fluency may be considered a component of pragmatic competence. This proposition implies that some impairments of fluency may result from non-aphasic language disturbances, or from thought disorders such as those observed in schizophrenic and manic subjects (see Andreasen and Grove 1979 for an example, and Hotchkiss and Harvey 1986 for a review).

Clinical use

Changes in temporal characteristics of speech output, be they reduced fluency or overflow, constitute specific impairments with which the therapist has to deal. Indeed, numerous aphasic patients or their partners express complaints about fluency (Shewan and Cameron 1984). The non-fluent aphasics feel that their 'slow rate' is socially inadequate by causing breakdown of communication, impatience in listeners, etc. By contrast, in some logorrhoeic Wernicke's aphasics who are generally anosognosic, the particular rapidity of verbal output or the pressure of speech—which we previously described as a listener's phenomenon—is pointed out by the near relatives. A similar complaint is formulated by some conduction aphasics themselves who, because of their numerous phonemic approximations, sometimes give the wrong impression of increasing their rate of speaking. In these subjects, inhibition of some uninformative verbal productions may be an objective of the therapy. Finally, some other fluent patients with residual signs of aphasia are disturbed in their lexical search while attempting to recover their former, perhaps too high, speaking rate. Training may be directed towards slowing down speech output in order to prevent blendings, or to provide the patient

with the necessary time to use learned strategies for word retrieval. Thus, modifications of fluency may result from different impairments, may cause suffering of different kinds, and must be treated in relation to the individual characteristics of the subject unless we consider 'fluency' as a synonym of 'linguistic competence', a general standard along which any case may be measured.

During the time-course of recovery in aphasia, fluency measures together with other indices are commonly computed in order to assess the evolution of performance by patients who present 'pathological rate of speaking' in tasks such as spontaneous speech or narratives. Improvements, whatever their origins (spontaneous recovery, non-specific outcomes of speech therapy, or specific consequences of well designed rehabilitation strategies) and generalization of treatment effects have to be identified through different verbal tasks. Among these, natural speech elicited in interviews or in free narratives has been considered particularly sensitive to recovery in some patients for a long time (see, for example, Shewan 1988b).

Thus, and by taking into account the different methodological problems mentioned above, fluency measures associated with other measures and with error analyses can be used as indications of the recovery of specific language processes in tasks that are close to the verbal activities of daily life. Some examples may be given.

First, in several cases of slow speech tempo due to apraxia of speech or articulatory impairments, fluency measures (and particularly phonation rate) computed from spontaneous speech or narratives allow the quantification of the recovery of articulatory agility in tasks other than those in which only isolated words are processed, or those in which all the lexical information is provided (repetition, reading, etc.).

Second, in the recovery of agrammatism it may be useful to examine whether increases in syntactical complexity of sentences relate to changes in speaking rate. The clinical impression of higher fluency may be due to qualitative changes, and it has to be verified by objective measures. In this way, Jones (1986) and Byng and Coltheart (1986) demonstrated a generalization of the effects of specific treatments in agrammatics who presented specific difficulty in mapping thematic roles onto syntactic structures. Mean length sentences measures, and various syntactical analyses showed effects on spontaneous speech and narratives of treatments involving no overt oral production.

Third, measures of fluency and of lexical diversity are of interest in the study of word-finding difficulties, particularly when pauses are overabundant in spontaneous speech. In comparison with the production of single words, access to lexical information in the context of connected discourse may turn out to be either facilitated, if some items are primed, or disrupted, because of increased task demands.

Fourth, in fluent patients treated for speech tempo which is too fast, the fluency measures can be used in order to control directly the effect of rehabilitation. For the same reasons that made them inappropriate in the classification of aphasia, and in the analysis of specific language impairments, fluency measures display a versatility and an ecological relevance that allow for several adequate uses in the study and treatment of single cases of aphasia.

General conclusions

Descriptions of aphasic subjects still often mention the fluent or non-fluent character of their speech production. We hope that this review has introduced outsiders to the rather opaque meaning of that notion in aphasiology. At the same time our critical approach invites both experts and novices in the field to restrict the use of the term to these circumstances in which one word stands for a longer discourse, and to consider a variety of other measures when the goal is to analyse aphasic speech production for scientific or clinical purposes.

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