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Compromised speech processing in language disorders

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Abstract

The relationship between the control of processes required for speech and language production were investigated in the context of fluency analysis of natural language samples produced by aphasic speakers. We used a new and objective approach to segmentation and fluency analysis. The procedure reveals two lognormal pause duration distributions and one lognormal speech segment duration distribution. We hypothesized that the short and long pause durations reflect articulatory gestures and cognitive processes respectively. The results can be interpreted by reference to either a modular approach to speech and language, or an integrated approach, where brain damage that impacts on the long pauses will, unless it is very minor, impact on articulatory gestures as well. The results provide support for the use of natural language analysis rather than reliance on diagnostic batteries based in the theory of modularity for clinical diagnosis of verbal communication disorders.

Background

Speech and language disorders are typically considered separately. Therapeutic practices associated with motor speech disorders are designed and implemented on the assumption that the mechanisms underpinning the normal function of speech production and language production are isolable and dependent. Treatment for language disorders generally occurs without reference to the mechanisms required for speech production, and vice versa. These practices implicitly endorse a model of speech and language production based on the theory of modularity and it's corollary, hemispheric specialization.

Recent developments involving Growth Point Theory [1] and Gestural Phonology [2] provide fertile ground for the development of a new perspective about the relationship between speech and language. These theories emphasize the role of integrated, dynamic and distributed neural networks; networks that underpin multimodal human communication. While the growth point theory specifies the unfolding of thought into word and gesture, it does not include provision for articulatory gestures. The iteration of gestural phonology includes provision for prosody but it does not refer to language processes. The relationship between speech and language production has not yet been fully described in the context of dynamic systems models.

Should dynamic accounts of speech and language processing assume that disruption to the control mechanisms required for speech production will impact on those required for language production and vice versa; a relationship that would lead to significant changes to models of both normal and disordered speech and language processing.

Kirsner, Dunn and Hird [3, 4] described a new and objective approach to the analysis of speech and language processes via the measurement of fluency in spontaneous speech samples. The procedure is based on evidence that 'fluency' can be characterized in terms of the means, standard deviations and occurrence rates for the log normal distributions associated with short pauses, long pauses and the speech segments defined by long pauses. The mean and standard deviation of the short and long pause distributions are depicted in Figure 2 for a single participant. The figure also indicates the proportions of short and long pause distributions for the data set. It is further

assumed that the long pauses reflect cognitive processes, for conceptualization, formulation and lexical selection, whereas the short pause are integral to speech production, and differentiate the articulatory gestures into recognizable combinatorial units [5].

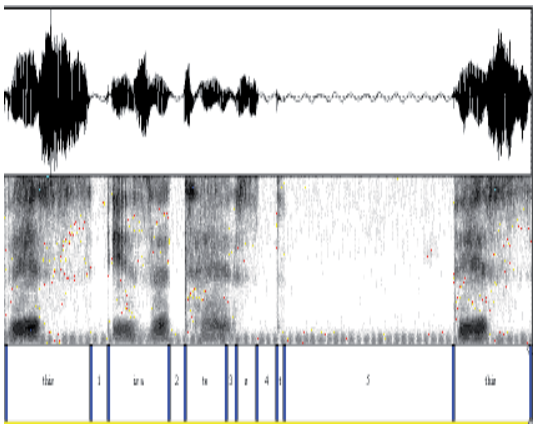

Figure 1: *Example of the way in which pauses are identified and marked in a natural speech segment.*

Hypotheses

We considered two hypotheses. First, if the processes involved in speech production and language production are independent, it follows that the presence of change in the parameters associated with the short pause distribution can be accompanied by no change in the long pause parameters or by change – in either direction – among the long pause parameters. The reverse is also possible, so that increases in mean long pause duration could be accompanied by a reduction, no change or an increase in the duration of the short pause or speech production parameters [8]. Thus, the presence of change in mean short pause duration has no predictive value for mean long pause duration.

Method

Natural discourse was sampled across three speaking contexts from 8 participants classified with aphasia in accordance with the Boston Diagnostic Aphasia Examination. Participants were classified with fluent and non–fluent aphasia and ranged in severity from 1 – 5. An experienced speech pathologist judged each participant as producing highly intelligible speech without evidence of motor speech disorder. Speech samples ranging in duration from 1.51 - 3.75 minutes were collated and analysed according to the procedure described by Kirsner et al. [3]. See Figure 1. Correct Information Unit analysis was conducted according to the procedure described by Nicholas and Brookshire [6]. The results were transformed to a measure of seconds per Correct Information Unit to reflect communicative efficiency. All participant scores were converted to Crawford's t (for small samples) and were individually compared to the reference distribution derived from performance of a group of 13 normal controls.

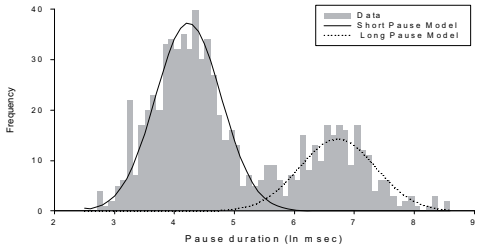

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Figure 3: *The same set of results following lognormal transformation. The short pause distribution reflects 'speech' production' whereas the long pause distribution reflects 'language production'.*

Results

The results for eight cases fitted our expectations. Two patients produced short pause characteristics that were outside the 95% Confidence Interval for the reference distribution based on a non-patient sample of 13 participants while maintaining long pause characteristics inside the 95% Confidence Interval for the control sample. These patients were classified as Fluent – Conduction (Severity Level 1) and Fluent – Anomic (Severity Level 4). Three patients produced values outside the 95% Confidence Intervals for the reference group for both short and long pauses. These patients were classified as Non-fluent - Broca, (Severity Level 5),

Non-fluent – Transcortical (Severity Level 5), and Unclassified (Severity Level 5). The two remaining cases produced short and long pause characteristics that were within the 95% confidence interval for the control participants

		Long Pause (Language)	
		'inside 95% CI'	'outside 95% CI'
Short Pause (Speech)	'inside 95% CI'	2	0
	'outside 95% CI'	2	3

Figure 4. Distribution of cases across short pause (speech) and long pause (language) categories

Discussion

The overall pattern is summarized in Figure 4. The pattern includes two participants with selective impairment to speech production and not language production; three participants with impairment to both speech production and language production, and two participants without impairment to either system.

Inference is of course limited by the sample size. However the results are consistent with either of two propositions. The first of these is that the control processes for language production and speech production are independent, and that double or even reversed associations are possible [8]. The second proposition is that the underlying distribution reflects a negative association where impairment of speech production is invariably accompanied by an impairment involving language production, but that the data analysis is not sufficiently sensitive to detect the relevant change. Scrutiny of the individual pause duration distributions suggests that this might be the case, but a cautious approach is required at this point.

The first of these hypotheses is consistent with the traditional assumption, that speech and language involve unique and independent processes. However the second is consistent with proposition that brain damage sufficient to produce change in speech production will also produce change in language production processes.

How could we explain the second of these propositions? The first and most obvious assumption is in a sense a widely held view; it is that the benefit associated with distributed cortical representation are or have been so great that it is inevitable that serious brain damage will impair multiple processes. A second explanation can be derived from the concept of duality of patterning [5]. The key argument is that a symbiotic link has been established between the processes required for speech and language production because they are both critical for communication, or even because their timing mechanisms cannot operate independently.

It is evident from out data language processing difficulties do not occur in complete isolation. In six of the eight cases reported in this paper, there were statically significant deviations in short pause characteristics which reflect some modification of the mechanisms underpinning speech production despite the absence of a perceptually obvious speech impairment.

The method of fluency analysis involving natural language samples segmented in sufficient detail to uncover systematic changes in motor patterns provides the context to reveal some evidence of yoked distortions in both the language units and speech gestures.

This finding has significance from a number of perspectives. First, it challenges the notion that processes involved in language and speech production operate independently and, as a corollary, that these processes can be impaired in a way that is dissociated from the other function [7].

This assumption of modularity is the basis on which the majority of diagnostic batteries and management strategies for

acquired and developmental neurogenic communication disorders are developed [8].The implication is that current diagnostic practices may not be sufficiently comprehensive to identify the nature of the disorder and the cognitive cost they place on the speaker. If the speaker is compensating for sub-perceptual changes in motor speech patterning in addition to difficulty in language processing, the impact of an additional cognitive load is an issue.

Secondly the use of acoustic analysis for the fine grain analysis of speaking fluency shows that perceptual judgments may lack the specificity and reliability needed to gain a more specific understanding of the way in which language and speech are represented in the brain. Fluency analysis involving acoustic segmentation of natural speech samples, permits the identification of phonological gestures and the efficiency in which they are combined. Goldstein et al., suggest that articulatory gestures, which may have played an important part in the evolution of language as a linked and infinitely generative means symbolic system [5].

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