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A COMPARISON OF NORMALS' AND APHASICS' ABILITY TO PLAN RESPIRATORY ACTIVITY IN OVERT AND COVERT SPEECH[1]

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ABSTRACT

Disturbances of aphasic patients in the planning of spoken utterances have hitherto mainly been investigated through patterns of paraphasic errors, the scope of these errors usually not involving more extensive units than the word. In contrast, comparatively little is known about disturbances at the level of larger planning units. In the present study we focus on respiratory activity, asking how normals and one apraxic aphasic link the linguistic-phonetic demands of an utterance in terms of length, loudness, and tempo to appropriate patterns of respiratory motor activity. We further wished to determine the extent to which covert speech may take account of the airflow requirements of the planned utterance and speculated that inclusion of this experimental condition could help to throw more precise light on the levels of the speech production system where planning deficiences can occur in apraxic speakers.

1. INTRODUCTION

The question of how aphasic patients prepare for the articulatory realisation of a grammatically encoded sentence has so far been studied mainly on the background of lexical retrieval and segmental-phonological encoding processes. Only few authors have looked at suprasegmental aspects of utterance planning (e.g. Danly & Shapiro 1982). Although speech breathing parameters are considered valuable in the analysis of speech planning processes (cf. Winkworth, Davis, Adams & Ellis, 1995), they have to our knowledge not been used in the study of aphasic output disorders.

We present here our experience with the development of a speech breathing paradigm, illustrating its application to a group of normal subjects and a first clinical case (apraxia of speech). The paradigm focussed on the influence of *loudness level and sentence length* in *overt and covert speech*

2. METHODS

2.1 Subjects

The experimental subject of this study was a male patient, 49 years, with an infarction of the left middle cerebral artery. Time since onset was 14 months. The patient had a mild non-classifiable aphasia with good comprehension, mild naming impairment, mild agraphia, and mild-to-moderate apraxia of speech. This patient was chosen as a first clinical subject on the following grounds: Assuming that apraxic speakers have no basic motor problems in the control of respiratory activity it is of interest whether such patients´ presumed speech motor programming deficit would show-up in their speech breathing pattern.

A group of five healthy males (28-46 yrs) served as controls.

2.2 Procedure

The speech material consisted of 10 short sentences (5 syllables; e.g. *Der Fuchs streicht durch´s Gras*) and 10 long sentences (29-31 syllables; e.g. *Die beiden unbekannten Taschendiebe flohen aus der Lebensmittelabteilung eines Hamburger Kaufhauses*). The syntactic structure of long and

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short sentences was as homogeneous as possible, e.g no long sentences employed subordinate clauses. These 20 sentences were each elicited in all combinations of 3 Delivery Modes: *Normal, Fast, Loud* and 2 Speech Modes: *Overt, Covert*.

The resulting 120 utterances were elicited in random order using the following procedure:

1. *Familiarization*: Orthographic presentation of the sentence to the subject on display terminal; subject scans sentence for as long as desired; subject operates push-button to terminate this phase.
2. *Prompt*: On the expiratory phase of the following cycle of quiet breathing investigator prompts subject verbally with required combination of Speech- and Delivery Mode.
3. *Speech Task*: Subject speaks / reads sentence exactly once; operates push-button again on completion.
4. *Return to quiet breathing*: Investigator allows one cycle of quiet tidal breathing to be completed before triggering next item.

For the covert speech condition the subject was asked to imagine the tempo and loudness he would employ if speaking the utterance aloud.

Stimulus presentation and data collection was performed under computer control. The following signals were acquired: speech signal, thoracic and abdominal respiratory activity monitored by means of Respiratory Inductive Plethysmography, push-button activation. The respiratory signals were monitored online by the investigator. In addition to the speech tasks, the subjects also performed calibration tasks with a pneumotach to allow least-squares prediction of total lung-volume changes from a weighted combination of the two Respitrace signals.

2.3 Rationale for the design

The paradigm we employed can be regarded as maximizing the opportunity for pre-planning. A first purpose of the investigation was thus to establish to what extent the inspiratory volumes of normal subjects anticipate the volume demands of the spoken utterance under such conditions. Increased loudness has been reliably reported to be accompanied by increased magnitudes of inspiratory volumes (e.g Stathopoulos & Sapienza, 1993). Somewhat surprisingly, the relation between utterance length and inspiratory volume is less clear (Winkworth, Davis, Ellis & Adams, 1994). The inclusion of the fast delivery mode was related to this concern. It was hypothesized that the fast rate could favour pre-planning activity since to achieve a fast rate speakers might need to minimize the necessity for within-utterance inspirations (cf. Grosjean & Collins, 1979). With regard to covert speech, and following on from observations of Conrad & Schönle (1979), we asked whether normals and aphasics would differ in the extent to which covert speech could shift breathing activity towards a speech-breathing pattern.

3. RESULTS

For reasons of space we will confine our attention here to the thoracic signal, since this was the respiratory signal showing the most consistent effect of the experimental variables. For the analysis of overt (i.e spoken) speech, the focus will be on inspiratory amplitude prior to the utterance, as an index for anticipation of the ensuing expiratory volume demands. For covert speech, analysis was conducted primarily in terms of the ratio of inspiratory to expiratory duration for the breath cycle following the prompt given by the investigator. Conrad & Schönle (1979) had used this ratio to demonstrate a continuum of respiratory behaviour from quiet tidal breathing via sub-vocal speech tasks to normal spoken utterances.

3.1 Overt speech

Table 1 summarizes the results of ANOVAs carried out to examine the effect of Sentence Length and Delivery Mode on inspiratory amplitude.

These results suggest firstly, and much as expected, that sentence length and delivery mode have a consistent influence on inspiratory amplitude (for subject N3 , who was the only one not to show an effect of delivery mode, this was due to several major outliers for the long sentences. For the short sentences, delivery mode was highly significant). They indicate secondly the absence of any drastic differences between patient and normal subjects.

Table 1: *Effects of ´Sentence Length´ and ´Delivery Mode´ on inspiratory amplitude for each subject (ANOVA; **: p<0.01; *: p<0.05; ns: not significant)*

Subject	N1	N2	N3	N4	N5	PAT
Sentence length	**	**	**	*	**	*
Delivery Mode:	**	**	ns	**	**	**

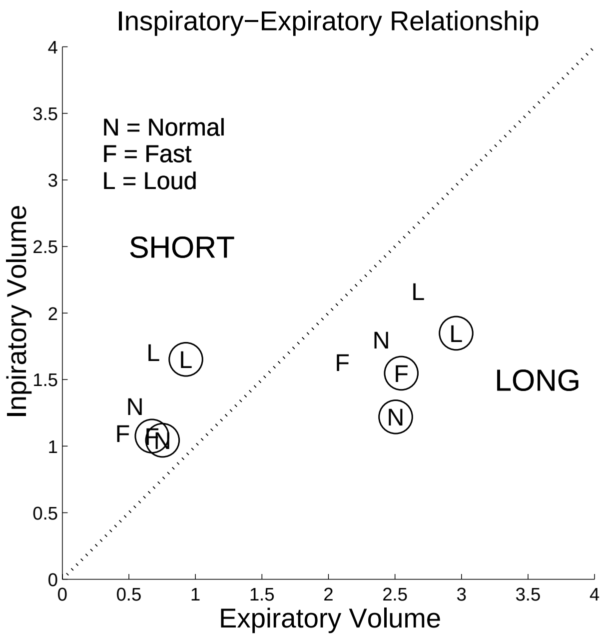

Fig. 1: *Amplitude (normalized units) of inspiratory and expiratory activity for the two `Sentence Length´ and the three ´Delivery Mode´ conditions. Averaged normal-speaker data (without circles); patient data (with circles).*

Relating the inspiratory volume to the volume actually expired during speech reveals more precisely the relative potency of "Sentence Length" and "Delivery Mode" in influencing inspiratory activity. Fig. 1 shows this relationship for the average values of each of the 6 experimental conditions. (Each subject's data was first normalized by the standard deviation of expiratory amplitude.)

The figure includes a dashed line with a gradient of +1. Data points would be located on this line under the "simple-minded" hypothesis that subjects inspire by an amount corresponding to the expected volume requirements. Looking first at the values averaged over all 5 normal subjects (data points without circles), it will be observed that short utterances are located above the diagonal: Virtually all utterances are initiated at volume levels greater than the end-inspiratory level of tidal breathing, and short utterances do not occupy the totality of the ensuing expiratory limb. Long utterances are below the diagonal: they typically encroach on the expiratory reserve volume below the end-expiratory level of tidal breathing. The figure shows that the effect of sentence length on inspiratory volume is really quite modest when seen in relation to the substantial change in expiratory volume going from short to long utterances.

The patient (data points with circles) conforms to the basic pattern of short and long utterances on opposite sides of the +1 gradient. The increase in inspiratory volume for long vs. short utterances is less pronounced than that found for the averaged normal subjects, however; the effect of sentence length only just reached statistical significance.

(A note on the fast delivery condition: This does not in fact appear to reinforce preplanning. This would have been visible in a disproportionately large inspiratory volume. On the contrary, but perfectly logically, the normal speakers inspired less, anticipating the lower expiratory volumes of fast utterances. The patient does not show this pattern, but little importance should be attached to this, since due to articulatory difficulties he had only a limited capacity to accelerate his speech rate in the first place.)

The next two figures leave fast delivery out of consideration and aim firstly to drive home the fact that loudness contrasts on the one hand and length contrast on the other hand differ markedly in the strength of their influence on inspiratory activity. Secondly they allow a closer look at the extent to which the patient falls within the range of the normal subject.

Figure 2 places the average of each subject's short utterances at the origin and shows by a vector the changes in inspiratory and expiratory volume associated with a transition to long utterances. Clearly, only a small proportion of the increased volume demands of long utterances are anticipated in the pre-utterance inspiration.

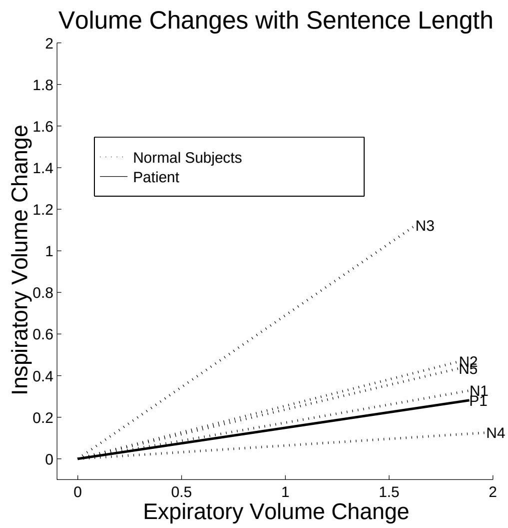

Fig. 2: *Inspiratory and expiratory volume changes shown separately for each subject for short vs. long sentences (normalized units as in figure 1).*

Figure 3 places normal-delivery utterances at the origin and shows by a vector the changes in inspiratory and expiratory volume associated with a transition to loud delivery. Thus, the increase in inspiratory amplitude may well *exceed* the increase in the air actually expired in the utterance. This could be interpreted as exploitation of larger recoil forces to help generate loud speech. Regarding the patient, the most interesting issue is whether his comparatively limited inspiratory anticipation of the volume requirements of long utterances is indeed so weak as to be outside the normal range: The shallower the gradient, the weaker the anticipation. Clearly such a conclusion would be premature on the basis of the limited data available at present.

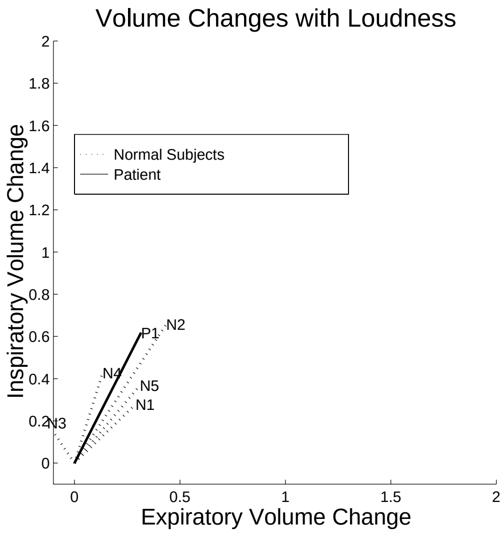

Fig. 3: *Inspiratory and expiratory volume changes shown separately for each subject for normal delivery vs. loud utterances (normalized units as in figure 1).*

3.2 Covert speech

The majority of normal subjects showed for long sentences quite consistent departures from the non-speech tidal breathing pattern. Three normal subjects (N1, N2 and N4) showed highly significant differences between long and short sentences with respect to the ratio of inspiratory to expiratory duration. One normal subject (N3) showed no effect there but did show a highly significant difference in inspiratory *volume* for long vs. short sentences. (In addition, these four subjects all showed a highly significant effect of *delivery* with respect to inspiratory volume.) One normal subject (N5) showed no tendency whatsoever to depart from tidal breathing patterns during the covert speech tasks. He was remarkable for extremely fast completion of the tasks, even long-sentence stimuli often being terminated before the end of the inspiratory phase following the prompt.

The patient showed similar behaviour to this normal subject in showing negligible departure from tidal breathing in the covert speech tasks, but nonetheless differed markedly both from him as well from all other normal subjects in that long-sentence stimuli typically required more than one respiratory cycle for completion (whereas his *spoken* utterances were with very few exceptions produced on a single expiratory limb).

To round off this section the following speculation is offered: Covert speech normally requires activation of the complete speech motor system with subsequent inhibition of the articulatory and laryngeal subsystems to avoid actual sound generation. Due to a lower degree of subsystem integration in the apraxic speaker the respiratory system does not become activated at all.

4. CONCLUSIONS - OUTLOOK

Taking into account the fact that the current investigation is still at an exploratory stage the following conclusions can be advanced: (i) Combination of length and loudness variation appears to offer a promising framework for examining respiratory activity, with potential application to quite a wide range of speech disorders; (ii) Observation of respiratory activity in overt and covert speech may extend current knowledge on the organisation of mental motor activity and on the status of inner speech within speech production models.

In further work, additional kinematic analysis of respiratory behaviour will be supplemented by more linguistically-oriented analysis of within-utterance inspirations and their relation to syntactic boundaries, repairs etc.

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