Acoustic and Electrophysiologic Correlates of Stuttering and Related Developmental Reactions

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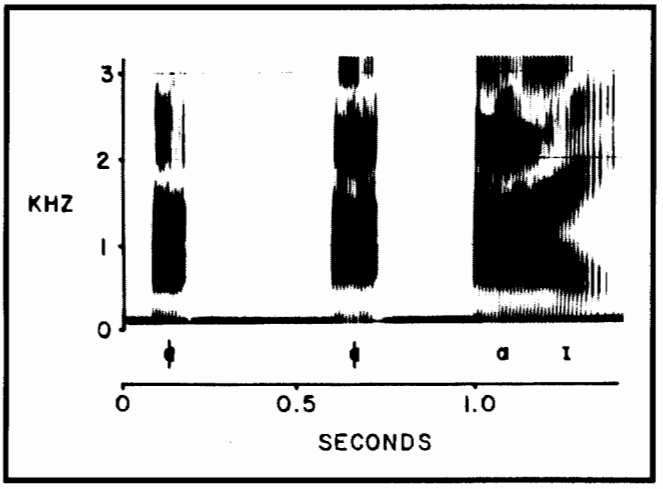
Theory, research, and therapy of stuttering continue to be confounded by over-inclusive definitions of the disorder. In defense of this suggestion, some observations will be summarized concerning the typical development of reactions to what shall be described as the core behavior of stuttering.

As reported earlier (Stromsta, 1965), the coarticulatory and phonatory characteristics of speech disruptions exhibited for less than six months by preschool children labeled as stutterers were analyzed spectrographically and related to estimations of fluency prevailing 10 years later.

The results indicated that repetitions marked by abnormal formant transitions and abnormal terminations of phonation were significantly related to children being stutterers 10 years later. The foregoing features involved *intraphonemic disruption* of vowels resulting in part-sound part-syllable repetitions taken to describe and define the core behavior of stuttering. In contrast, preschool children labeled as stutterers whose whole-sound whole-syllable repetitions did not involve intraphonemic disruptions were not exhibiting either the core behavior or the complicating behaviors of stuttering 10 years later.

Figure 1. Spectrogram illustrating intraphonemic disruptions during the production of the pronoun "I."



An example may help to clarify the concept of intraphonemic disruption. Figure 1 is a spectrogram illustrating the core behavior of stuttering on the personal pronoun "I." The initial repetitions are marked by adequate initiation of phonation as shown by the vertical striations on the spectrogram. Note that phonation is arrested within the expected duration of /ɑ/. As a result, the repetitions show an absence of formant transitions, indicating lack of or faulty coarticulation.

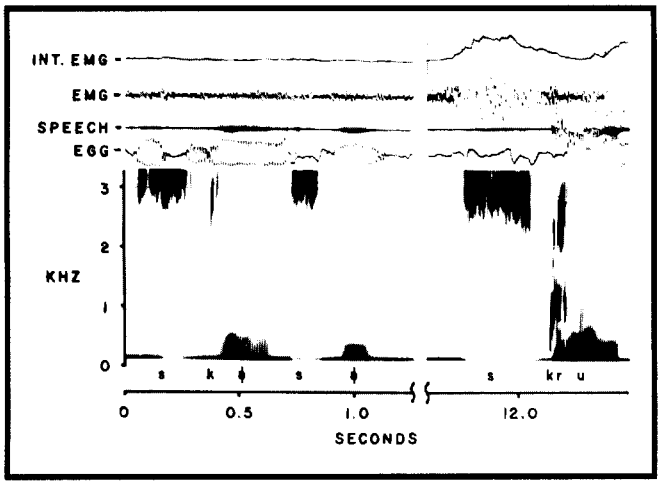
Preschool children exhibiting intraphonemic disruptions were observed to initiate a typical progression of reactions involving static vocal tract positions generally about six months after the advent of their unique repetitions. Along with repetitions came prolongations of phonemes, including stop plosives and affricatives. In these instances intraoral pressure was assumed to be minimized by lack of complete articulatory occlusion. Subsequently, along with the evidence of struggle and force, prolongations of voiced stops were arrested after approximately 300 msec by what was assumed to be complete articulatory occlusion resulting in transglottal pressure differentials incompatible with phonation. Next came arrests of prolonged voiceless stops. Then, characterized by individual differences, arrests of prolonged stops were followed by the onset of aberrant initiation of the voiced and voiceless breathstream for stops and other phonomes. This stage of development of reactions was detected by comparing spectrograms and throat microphone recordings of stuttering and non-stuttering preschool children.

Attempts to verify the foregoing observations have used adult stutterers willing to accept and tolerate detection procedures and tedious recording sessions. Samples from adults have been selected based on similarities of their spectrographic and throat microphone recordings to those observed in the longitudinal study of preschool children. Verification attempts have focused on several questions, three of which will now be discussed.

1. *Do intraphonemic disruptions — the core behavior of stuttering — involve faulty coarticulation?*

In a study conducted with Fibiger (Stromsta & Fibiger, 1980), EMG activity indicating anticipatory labial coarticulation was detected during core behavior repetitions and fluent utterances of 68 syllables containing rounded vowels from 10 stutterers and eight adult nonstutterers. Results indicated that the core repetitions of stutterers had significantly less anticipatory labial activity than the successfully uttered syllables preceded by the repetitions and the fluent utterances of the stutterers and non-stutterers. Figure 2 illustrates faulty labial coarticulation associated with intraphonemic disruption on the word "screw." Note that the top tracing showing integrated EMG activity

Figure 2. EMG activity during production of the word "screw" illustrating faulty (top) and successful coarticulation.

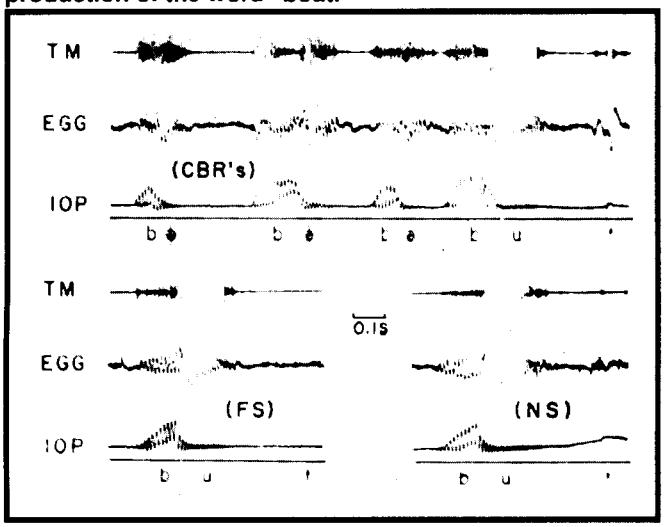


indicates a lack of labial activity associated with the initial repetitions as compared to the labial activity coincident with the initiation of the successful utterance.

2. *Do intraphonemic disruptions involve adequate phonatory onsets?*

From data gathered in the forementioned study, analysis of the first 10 cycles of simultaneously recorded EEG signals showed a lack of noteworthy differences between core repetitions of stutterers, following successfully uttered syllables of stutterers, and the fluent utterances of stutterers and nonstutterers. Similar

Figure 3. Throat microphone (TM), EEG, and voice-modulated intraoral pressure (IOP) recordings of core behavior repetitions (CBRs), a fluent utterance by the same adult stutterer (FS), and an utterance of a nonstutterer during the production of the word "boat."

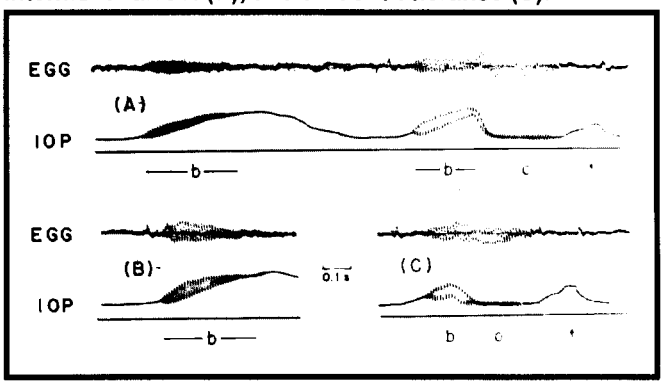


results have been reported by Borden and Baer (1983) insofar as their cycle-by-cycle EEG analysis indicated similar patterns for fluent utterances of stutterers and nonstutterers. Figure 3 displays throat microphone (TM), EEG, and voice-modulated intraoral pressure (IOP) recordings of core behavior repetitions (CBRs), a fluent utterance by the same adult stutterer (FS), and an utterance of an adult nonstutterer (NS) on the word "boat." The results from 28 such comparisons led to the conclusion that intraphonemic disruptions involve adequate phonatory onsets.

3. *Is duration of phonation prior to its arrest by intentionally sustaining articulatory occlusion in voiced stops similar to the 300 msec duration observed in preschool children?*

To address this question, three adult nonstutterers attempted to sustain phonation while intentionally maintaining complete articulatory occlusion associated with production of /b, d, g, d_3/ using excessive respiratory force. The mean duration of phona-

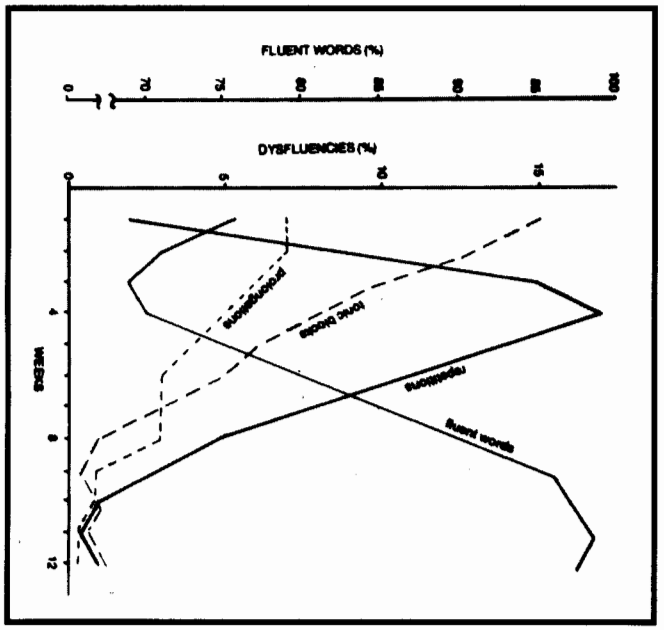
Figure 4. EEG and voice-modulated intraoral pressure (IOP) recordings of the word "boat" by one adult stutterer for an unintentional arrest of prolongation of /b/ (A), an intentional arrest (B), and a fluent utterance (C).



tion pooled for the four phenomes was 283 msec. The reasonable agreement between durations of 300 msec from preschool children and 283 msec from adult nonstutterers lends a degree of credence to the hypothesis that adequately initiated prolongations of voiced stops in the stuttering children were arrested by articulatory occlusion associated with the advent of force and struggle in the development of reactions.

Added credence comes from 11 unintentionally arrested prolongations of voiced stops recorded from six adult stutterers. Figure 4 shows EEG and voice-modulated intraoral pressure (IOP) recordings from one of the adult stutterers. A shows an unintentional arrest of prolongation of /b/ followed by a shorter prolongation leading to utterance of the word "boat." B shows an intentional arrest of phonation by maintaining articulatory occlusion. C shows the stutterer's fluent utterance of "boat." The similarity between the EEG and intraoral pressure envelopes of the initial unintentional and the intentional arrests of adequately initiated phonation characterizes the results

Figure 5. Mean percentages of core behavioral repetitions, prolongations, tonic blocks, and fluent words as a function of therapy for 30 adult stutterers.



obtained for the other 10 tokens. Phonatory onsets of the fluent utterances as shown in C were compared to those of nonstutterers and judged to be without distinguishing differences.

Finally, it is of interest to note how core stuttering and reactions to stuttering are typically alleviated by therapy that emphasizes the strengthening of motoric patterns of coarticulation (Stromsta, 1986). Results from 30 adult stutterers are summarized in Figure 5 which shows mean percentages of core behavior repetitions, prolongations, tonic blocks, and fluent words as a function of therapy for two hours per week for 12 weeks. Other schedules of therapy, such as three hours per week for eight weeks, four hours per week for six weeks, and five hours per week for five weeks show similar families of curves.

Note that at the start of therapy fluent words accounted for 76%, with 15% tonic blocks, 7% prolongations, and 2% repetitions. At three to four weeks, core repetitions increased dramatically while tonic blocks and prolongations progressively reduced without attention directed to them. At the same time, production of fluent words reached its lowest value. However, with sufficient practice of adequate coarticulation, a progressive reduction of dysfluencies and a progressive increase of fluent words were realized.

In general the results indicate that core behavior repetitions should be differentiated from consequential reactions for the purpose of formulating hypotheses in our quest for understanding the basic nature of stuttering. Assume for the moment that advanced-stage stutterers characteristically minimize their innate core behavior repetitions by adopting variable reactions including prolongations and tonic blocks. If true, then the continued unqualified use of advanced-stage stutterers as research subjects in attempting to describe and define the basic nature of stuttering will continue to confound our understanding of the disorder. Because of this, in our opinion, the literature of stuttering, while a commendable source of information related to reactions to stuttering, verges on being vacuous concerning the core behavior of stuttering.

Note:
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