SPEAKING RATE AND LINGUISTIC PROCESSING SPEED IN CHILDREN AFTER ACQUIRED BRAIN INJURY

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ABSTRACT

Two studies were conducted to examine speaking rate following pediatric traumatic brain injury (TBI). In Study 1, five of nine subjects with severe TBI were found to have significantly slowed speaking rates, measured physically and perceptually, up to 13 months post injury. Study 2 revealed that reduced articulatory speed and increased pausing believed to be associated with linguistic processing difficulties may contribute independently to these speaking rate reductions.

INTRODUCTION

Interest in the speech and language abilities of children following traumatic brain injury (TBI) has grown significantly over the past decade. However, virtually no empirical evidence is available concerning one of the most commonly reported sequelae of TBI: significantly slowed speaking rate.

There are several plausible reasons why TBI might result in slowed speaking rates. First, complex motoric skills are known to be vulnerable to disruption by the diffuse damage characteristic of severe TBI [1]. Second, increased latency and slowed speed of response have been reported on a variety of neuro-psychological measures following TBI, particularly when processing demands are high [2]. This generally slowed processing speed could result in reduced speaking rate due to deficits in the processes needed to support such linguistic operations as lexical retrieval and syntactic formulation [3].

The present investigation consisted of two studies. In the first, we documented the magnitude of speech rate reductions longitudinally in nine children and adolescents with severe TBI. In Study 2, we examined the contributions of two potential influences on slowed speaking rate: reduced articulatory speed and increased pausing presumably reflective of deficits in linguistic processing.

STUDY 1: METHOD

Subjects

The subjects with TBI included 4 males and 5 females, ranging in age from 5;8 to 16;2 (years;months) at the time of injury. According to parent and school report, each subject had English as a first language, and none had received speech, language, or psychological treatment prior to injury. All subjects were classified as severely head-injured based on a post-injury period of at least 72 hours of unconsciousness, defined as a Glasgow Comas Score less than 11. Descriptions of these subjects' neurological, language, and cognitive profiles are available in Campbell and Dollaghan [4]. Each subject with TBI was matched with a normally developing control subject according to sex and chronological age at the time of injury (±3 months). By parent report, control subjects attended regular classrooms, and had no history of neurological disease or insult. Control subjects scored at or above their ages on a standardized vocabulary test.

Procedures

Speaking rate was measured in spontaneous speech samples obtained from each subject with TBI and his or her control subject during three different sampling sessions. The first sampling session occurred one month after the subject had been discharged from the acute care hospital and had begun attempting to communicate intentionally. The second and third sessions occurred seven and thirteen months after the first.

Speech samples were collected using an on-line video narration task [5] in which subjects describe the events occurring on a silent, 108-second videotaped cartoon. The video narration context represents a demanding language production task because of the time constraints imposed by the rapidly changing events on the cartoon. In addition, this task ensures the consistency (in rate, complexity, and sequence) of the events to be described across speakers and sampling sessions.

Utterances were recorded using a high quality audiotape recorder and external microphone for orthographic and phonetic transcription by trained research assistants.

Physical Measurement of Speaking Rate

Speaking rate was calculated for each subject using CSpeech, a computer assisted waveform analysis program [6]. Speaking rate, expressed in syllables per second, was calculated by dividing the total number of syllables produced (including interjections and other "maze" [7] phenomena) by the duration of the utterances, which included any silent pauses that occurred within utterance boundaries.

Perceptual Judgments of Speaking Rate

An important clinical question about any speaking rate reductions concerns their perceptual significance to naive listeners. To address this question, a direct magnitude estimation (DME) paradigm without modulus [8] was used to obtain perceptual ratings of speaking rate for individual subjects with TBI and control subjects at the final sampling session. To control for listener bias, the 18 video narration samples from the final session were dubbed from the original recordings onto a stimulus audiotape in random order for presentation to naive listeners. The direct magnitude estimates of speaking rate from each listener were converted to a common scale, and the means were computed for each subject with TBI and each control subject.

STUDY 1: RESULTS

The control group produced more syllables per second than the group with TBI at all three sessions, and average speaking rate changed little in either group over the three sampling sessions At Session 3, the control group's mean speaking rate was 4.74 syllables/s (SD = 1.07); the mean speaking rate in the group with TBI was 3.10 syllables/s (SD = 1.39).

Visual inspection of the speaking rate data within each subject pair, however, suggested marked differences between the TBI and control subjects in only five pairs at the final sampling session. Evaluating the significance of such visually determined differences is difficult. One approach is to calculate a "normal performance quotient" (NPQ) [9], defined as the ratio of the performance of each subject with TBI to that of his or her control subject. NPQs for the five subjects with TBI for whom speaking rate reductions were visually apparent were $\leq$ 0.6; none of the remaining four subjects with TBI had an NPQ lower than 0.78.

The naive listeners rated the final samples from five subjects with TBI as significantly slower than those of their matched controls. Importantly, these were the same five subjects whose slower physically measured speaking rates were visually apparent, and whose NPQs were 0.6 or lower.

The results of Study 1 confirmed slowed speech rate as a significant sequela of TBI in some children and adolescents. Objective and subjective speaking rate measurements revealed significantly slowed speaking rates persisting more than one year post injury in five of these nine subjects with severe TBI.

STUDY 2

In Study 2, we examined the influence of two potential determinants of speaking rate. As noted earlier, generalized slowing of fine motor performance is a well-known outcome of TBI. Therefore, it is reasonable to speculate that slowed speaking rates might result from damage to the speech motor system. Alternatively, speaking rate could be slowed by reductions in the speed with which subjects conduct the cognitive-linguistic operations needed to access lexical items, construct syntactic frames and perform discourse processing operations. Perhaps most plausibly, speaking rate reductions in subjects with TBI could be associated with both sets of factors.

The influence of distinct motor-articulatory and cognitive-linguistic variables on speaking rate has been discussed by other investigators. One recent proposal [10] is that connected speech rate is determined by two factors: the speed of the articulators and the frequency and duration of silent pauses. These investigators suggested that "articulation rate" (i.e., number of syllables per second, calculated on runs of speech containing no pauses longer than 250 ms), may best reflect articulator speed and speech motoric performance. By contrast, they proposed that the frequency and duration of pauses longer than 250 ms may best reflect the operation of cognitive and linguistic factors.

In Study 2 we examined the interaction of these two factors in the speaking rates of our subjects. Specifically, we asked whether all subjects with slowed speaking rates exhibited slowed articulation rates in conjunction with increased percentages of within-utterance pause time, or whether these factors appeared to operate independently.

STUDY 2: METHOD

The first 50 syllables produced by each of the nine subjects with TBI at the final sampling session were analyzed. Duration and number of lexical syllables produced in runs of speech containing no pauses longer than 100 ms were calculated, yielding a measure of articulation rate in the form of average syllable duration. In addition, the duration of each pause longer than 100 ms was measured, yielding a measure of within-utterance pause time which was used to calculate the average percentage of time spent in silence within the utterance. Finally, to obtain a clinical judgment of speech-motor function, an experienced speech-language pathologist, blind to subject status, also independently rated samples from all subjects for the presence of dysarthria.

STUDY 2: RESULTS

Three of the five subjects with TBI who had slow speaking rates, based on the previous physical and perceptual measures, had average syllable durations more than two standard deviations above the average duration for the control group, clearly suggesting a contribution of speech motoric deficits to their slowed rates. Further confirmation of the existence of speech motor deficits in these three subjects was provided by the fact that these three subjects, and only these three, were rated as dysarthric by an independent speech-language pathologist. Four of the five subjects with TBI who were originally found to have slow speaking rates also had percentages of pause time more than two

standard deviations above the average for the control group, suggesting that cognitive-linguistic factors contributed to their slow speaking rates.

Data from one subject illustrate the extent to which motoric and cognitive-linguistic contributions to slowed speaking rate can be dissociated. This subject's percentage of pause time was greater than that of the control subjects, but average syllable duration was not. It appears that this subject's slow connected speech rate can be attributed to linguistic formulation difficulties rather than to speech motor deficits, an interpretation that is bolstered by the fact that this subject was not rated as dysarthric.

The results of these exploratory analyses suggest that "articulation speed" and what might be called "cognitive-linguistic speed" may be dissociable in individual patients more than one year after TBI.

CONCLUSIONS

Study 1 provided the first empirical confirmation of the widespread clinical observation that slowed speech rate may be a significant sequela of TBI in children. Both objective and subjective speaking rate measurements revealed significantly slowed speaking rates persisting more than one year post injury in five of these nine severely brain-injured subjects. Study 2 revealed that these slowed speaking rates may not originate from a single source. Reductions in speaking rate after TBI may have different origins, and different implications.

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