A Comparison of Throat and Head Microphones in a PDA-Based Evaluation of Hypophonia in Parkinson's Disease

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This study compared data obtained from throat and head microphone evaluations of conversational speech intensity in a group of 17 individuals with hypophonia caused by Parkinson's disease (PD) and 14 control participants. The two microphones were connected to a personal digital assistant (PDA) system that recorded the participants' conversational speech intensity during five randomly presented levels of multi-talker background noise (50, 55, 60, 65, and 70 dB SPL). Both the throat and head microphone data were associated with a significant increase in speech intensity with increases in the intensity of the background noise. In contrast, only the head microphone data were associated with a significant difference between reduced intensity of the PD participants and higher intensity of the control participants. A linear regression analysis comparing the throat and head data found a significant difference between the slope values for the PD and control participants. It is proposed that these slope results may be related to differences in how the PD and control participants used the size of mouth opening to modulate speech intensity. In general, the results of this study suggest that for conversations that are recorded in various levels of background noise, a head microphone placed close to the mouth may be a more sensitive instrument for measuring hypophonia in PD than a throat microphone.

INTRODUCTION

Hypophonia, or low speech intensity, is one of the most common and frequently treated speech symptoms associated with Parkinson's disease (PD) (Adams & Dykstra, 2009; Duffy, 2005; Ramig, Fox, & Sapir, 2004). Efforts to develop valid and sensitive procedures for quantifying the severity of hypophonia have been challenging. Early acoustic studies conducted in quiet laboratory environments using prepared, read aloud speech stimuli failed to consistently show evidence of reduced speech intensity in PD (Canter, 1963; Ludlow & Bassich, 1984; Metter & Hanson, 1986).

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In contrast, more recent studies involving more natural and possibly more demanding communication environments (e.g., various levels of background noise, different interlocutor distances, concurrent tasks) combined with less artificial or more typical speech production (e.g., conversations, monologues) have consistently demonstrated a significant reduction in the speech intensity of individuals with PD (Adams, Moon, Dykstra, Abrams, Jenkins, & Jog, 2006; Fox & Ramig, 1997; Ho, Bradshaw, Iansek, & Alfredson, 1999). These latter results suggest that continuing to develop evaluation procedures in more ecologically valid contexts (e.g., conversational speech in background noise) may lead to more sensitive measures of the severity of hypophonia in PD.

The present study focused on the evaluation of a portable recording system that could be used to obtain long-term conversational speech samples in various types of background noise conditions outside of the clinic or laboratory. Although an increasing number of potential portable recording devices are available, we decided to evaluate a pocket PC–based device from Core Sound, Inc. because it allowed for two-channel, high-quality audio recordings that could be integrated into the front end of future pocket PC–based software programs (i.e., real-time audio-based biofeedback programs). An important consideration in the recording of individuals with hypophonia in everyday noisy social environments is that the speech signal could become overwhelmed or masked by the intensity of the background noise (Adams, Dykstra, Jenkins, & Jog, 2008). There are many possible methods for attempting to deal with this type of signal-to-noise problem (i.e., filtering), but we decided to examine two very simple potential solutions. First, we placed a high-quality miniature microphone relatively close to the individual's mouth to increase the intensity of the speech signal relative to the background noise. Second, we placed a microphone (accelerometer) on the individual's throat to focus on the primary source of the voiced speech signal (phonation) and to allow the soft tissue of the neck to dampen and reduce the intensity of the background noise. This throat microphone procedure has been previously used in several studies to examine long-term vocal performance (i.e., voice dosimeter) in individuals without PD (Hillman & Cheyne, 2003; Svec, Popolo, & Titze, 2003; Svec, Titze, & Popoloc, 2005).

The purpose of the present study was to compare the effectiveness of throat and head microphones in the evaluation of hypophonia in individuals with PD who are producing conversational speech in different levels of multi-talker background noise.

METHODS

Participants included 17 individuals with hypophonia and idiopathic PD (55–78 years of age) and 14 age-matched control participants (61–80 years of age). All participants were seated in an audiometric booth with the experimenter. The experimenter sat 100 cm in front of the participant. A standard tape recording of multi-talker noise (Audiotech, 4 talker noise) was presented through the loudspeaker positioned 115 cm from the subject. The intensity of the noise (calibrated in dB SPL) was adjusted via a diagnostic audiometer (GSI 10). Participants were engaged in 3 minutes of conversation during each of five randomly presented background noise conditions (50, 55, 60, 65, and 70 dB SPL). During conversations, the participants were asked to discuss topics such as vacations, hobbies, interests, occupational experiences, family members, and so on.

Throughout the study, the participants wore a head microphone and a throat microphone attached to a personal digital assistant (PDA)–based system (pocket PC computer HP/Compaq iPAQ; model 5500) via Core Sound's PDAudio-Compact Flash interface system (Core Sound, Inc. http://www.core-sound.com). Live 2496 audio recording software (http://live2496.com) for the pocket PC was used to record the two audio channels at 24-bit resolution and 32 kilosamples per second. The head microphone was a miniature DPA 4060 microphone (0.54×1.27 cm) attached to an ear clip or hook on the left ear and positioned 8 cm from the participant's mouth. The throat microphone was an accelerometer (Vibro-meter Corp. Model CE501M601; 7Hz–20kHz response) attached 1 to 2 cm above the jugular notch (i.e., at the anterior part of the neck below the larynx on the softest place between the cricoid cartilage and the sternum) with surgical adhesive and electromyography tape (Vivometrics).

The dual-channel speech signal was transferred from the pocket PC to a desktop computer via an SD card. The average speech intensity (dB) was determined for each utterance using the intensity edit and analysis routine in PRAAT software (Boersma & Weenink, 2008). The average speech intensity values were analyzed using a separate two-factor repeated measures analysis of variance (ANOVA) (group and noise conditions) for each of the two data sets obtained from the head and throat microphone recordings.

To compare the head and throat microphone data, a separate regression analysis was performed on the intensity data obtained for each participant. From this analysis, a head versus throat intensity slope value was obtained for each participant and analyzed using a t-test to compare the two participant groups.

RESULTS

To see the possible masking effects of the multi-talker background noise conditions on the participants' speech intensity, we first looked at the speech-to-noise ratio obtained for the head microphone data. Figure 1 shows the results for the signal-to-noise ratio data. As the multi-talker noise increased from 50 to 70 dB, there was a significant reduction in the signal-to-noise values for both participant groups ($P = .001$). The PD participants had significantly lower signal-to-noise levels than the control participants across the noise conditions ($P = .003$). The group by noise level interaction failed to reach significance ($P = .071$).

The results for the conversational speech intensity obtained from the head microphone are shown in Figure 2A. For these results, the PD participants were found to have significantly lower conversational speech intensity than the control participants across all five of the noise conditions ($P = .001$). Both the PD and control participants significantly increased their speech intensity as the noise level increased ($P = .001$), and the pattern of this increase appeared to be very similar or parallel (i.e., no significant difference in the group by noise condition interaction; $P = .689$). In contrast, the results for the conversational speech intensity obtained from the throat microphone were quite different (see Figure 2B). In particular, the speech intensity for the PD and control participants was not significantly different ($P = .052$).

The regression results related to the individual slope values obtained for the throat versus head microphone intensity measures are shown in Figure 3. The slope values for the PD participants (mean, 0.62) were significantly steeper than those of the control participants (mean, 0.37) ($P = .005$).

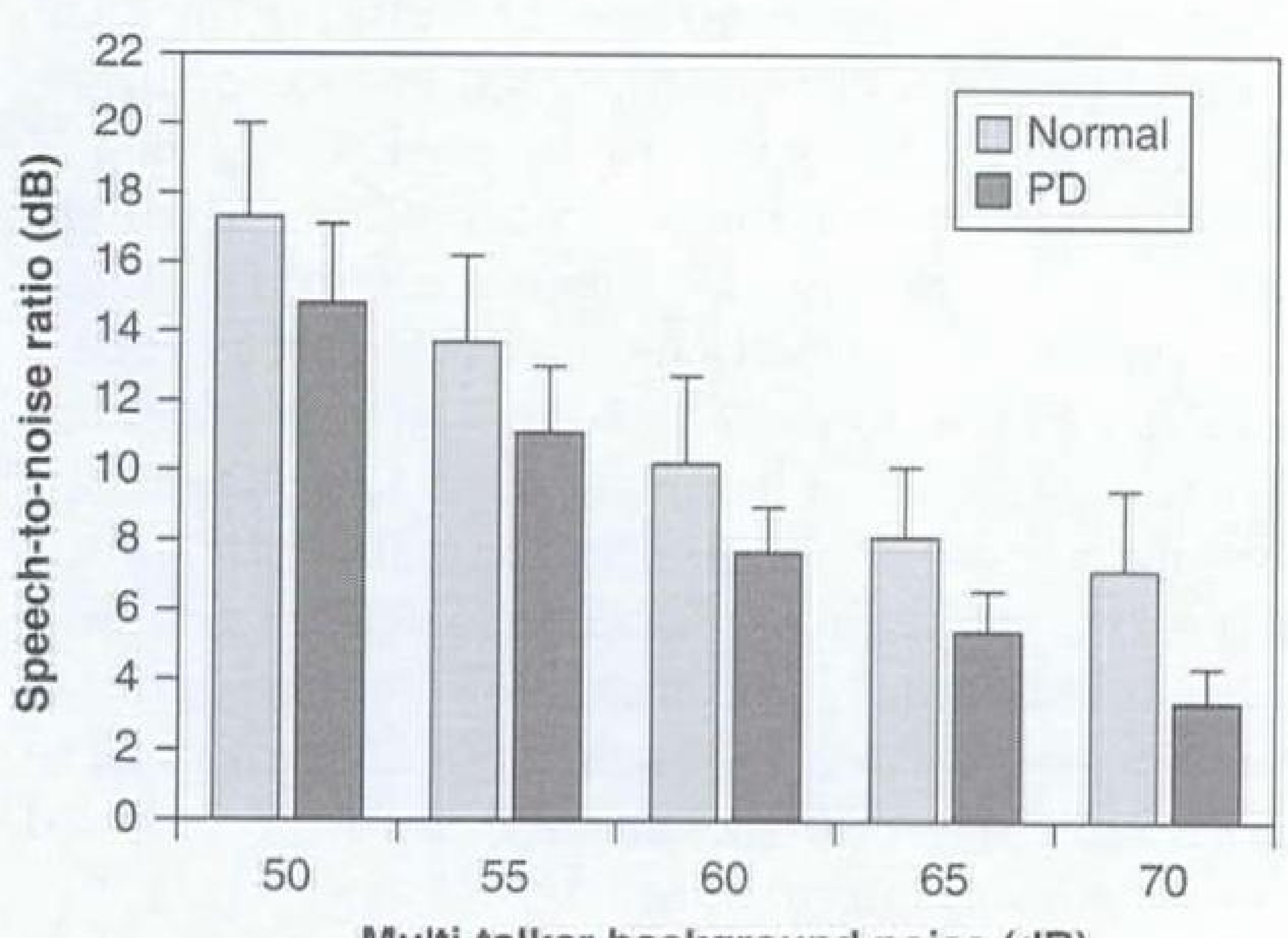

Figure 1. Effect of five levels of multi-talker background noise on the average speech-to-noise values obtained with a head microphone from participants with Parkinson's disease (PD) and control participants.

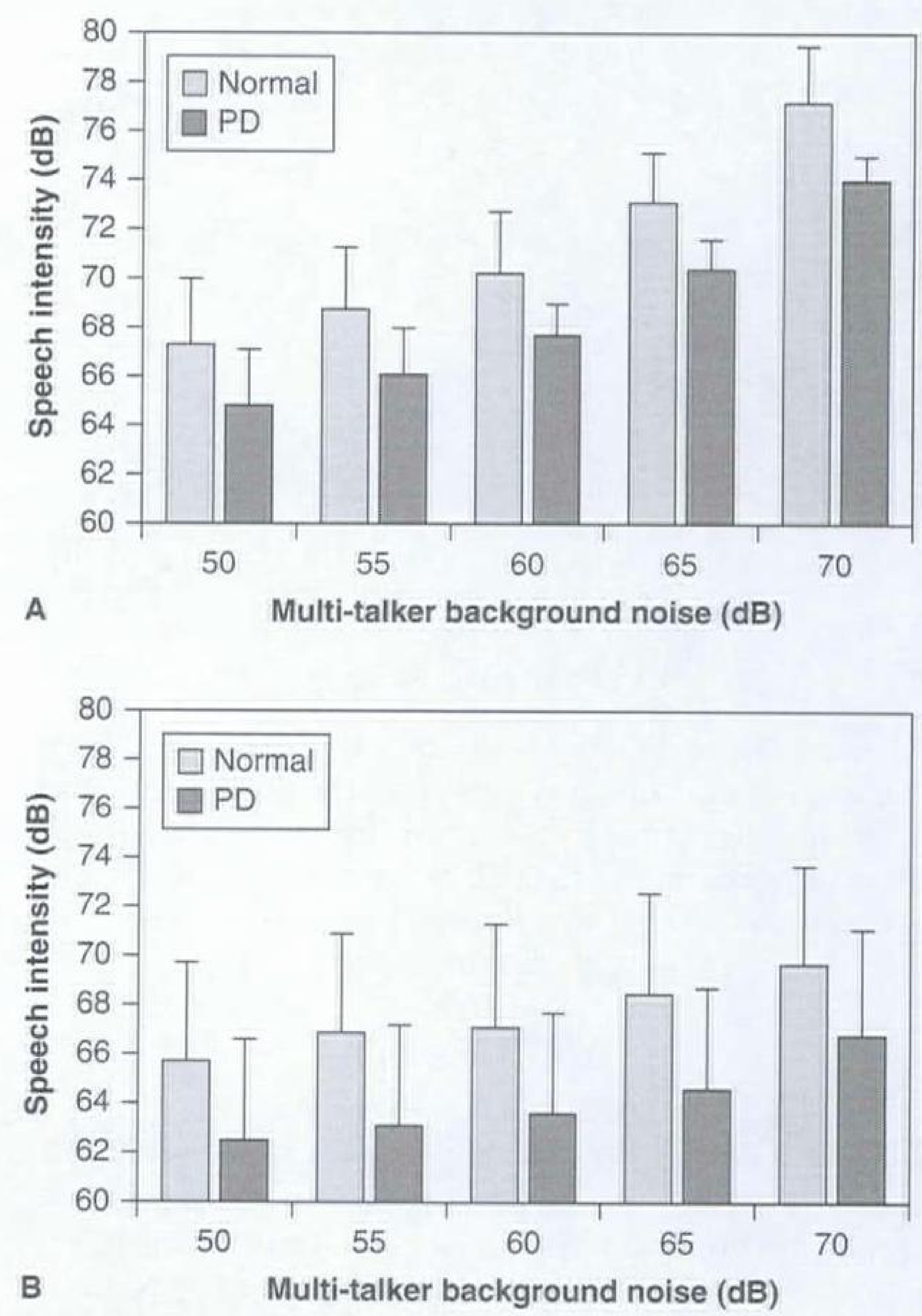

Figure 2. Effect of five levels of multi-talker background noise on the average conversational speech intensity values obtained with a head microphone (**A**) and a throat microphone (**B**) from participants with Parkinson's disease (PD) and control participants.

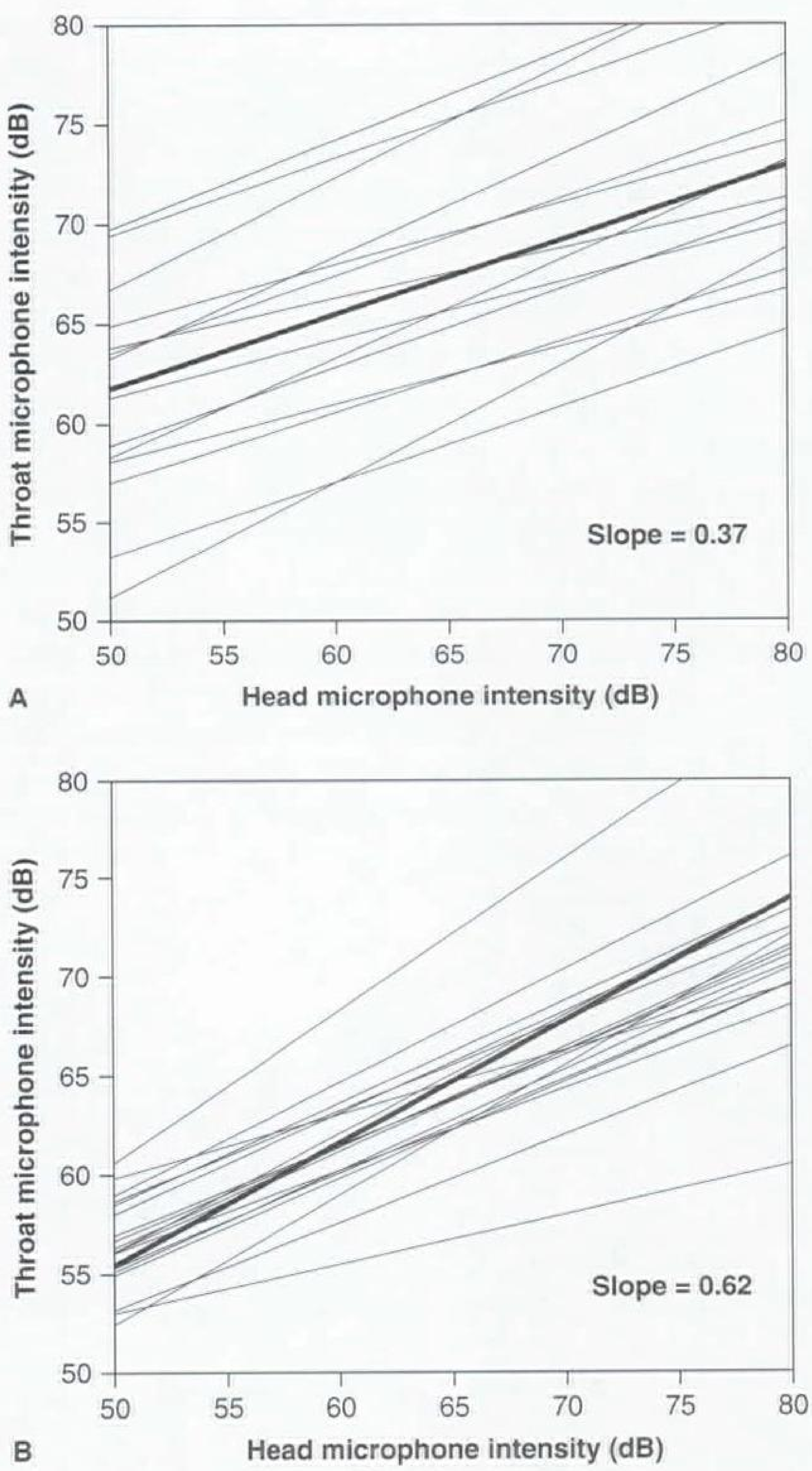

Figure 3. Individual slope lines obtained from the regression analyses of the throat versus head microphone intensity data for control participants (**A**) and participants with Parkinson's disease (**B**). The average slope lines (*dark lines*) and average slope values for each group are also shown.

DISCUSSION

The results related to the signal-to-noise analysis indicate that the head microphone recordings of conversational speech were associated with fairly high signal-to-noise levels across the range of 50 to 70 dB of multi-talker noise. Both participant groups had a high value (15–17 dB) during the 50-dB noise condition. In the 70-dB noise condition, the signal-to-noise ratio was significantly reduced but still remained at about 4 to 8 dB. Thus, the head microphone positioned 8 cm from the mouth did a reasonable job of preventing the 70-dB background noise from overwhelming the speech intensity data. The PD participants had signal-to-noise levels that were significantly less than the control participants by about 2 to 4 dB at each of the noise levels. This group difference looks fairly consistent across the 50 to 65 dB noise levels but at the 70-dB noise level the PD group shows a more dramatic decrease in the signal-to-noise level than the control group. This suggests that if the background noise levels had been increased above 70 dB, the signal-to-noise ratio for the participants with PD may have very quickly approached zero. Additional studies involving higher levels (>70 dB) of background noise are required to examine this possible trend. Smaller mouth-to-microphone distances (i.e., <8 cm) might improve the signal-to-noise levels, but in higher noise conditions (>70 dB), there are likely to be utterances that will have a negative signal-to-noise level. To detect and measure these negative signal-to-noise utterances, a throat microphone or other noise reduction procedure may need to be used in a portable recording system. In the present study, the throat microphone blocked so much of the background noise that it was not possible to obtain accurate signal-to-noise values from the throat microphone audio data. Thus, the throat microphone has the advantage of providing excellent noise reduction but the disadvantage of making it very difficult to obtain useful measures of speech-to-noise level.

The results for the conversational speech intensity showed very different results for the head microphone and throat microphone recordings. For the head microphone recordings, the PD participants were found to have significantly lower conversational speech intensity than the control participants across all five of the noise conditions. In contrast, the throat microphone recordings failed to demonstrate a significant difference between the PD and control participants' conversational intensity. Thus, it appears that speech intensity data obtained from the throat microphone were a less sensitive measure of the PD-related hypophonia than similar data obtained from the head microphone.

The results of the slope analysis found that the PD participants had a significantly steeper average throat versus head intensity slope value (mean, 0.62) than the control participants (mean, 0.37). Although several explanations for these results are possible, we propose that differences in the slopes may be related to the amount of mouth opening that was involved in generating increases in speech intensity. We suggest that the steeper slope found for the PD participants may be a reflection of less mouth opening across the observed increases in speech intensity. The rationale for this proposal can be illustrated by two simple hypothetical examples. First, if mouth opening was kept in a closed position and the voice intensity was gradually increased, the resulting throat versus head microphone intensity plot would be a steep vertical line. On the other hand, if the voice intensity were held at a constant level (e.g., during a prolonged vowel) and the mouth gradually moved from a closed to a wide open position, the resulting throat versus head microphone intensity plot would be a flat horizontal line. Thus, a flatter, more horizontal slope would suggest relatively greater involvement of mouth opening movements in the generation of speech intensity. On the other hand, a steeper, more vertical slope, such as that seen in our PD participants, would suggest relatively less involvement of mouth opening movements in the generation of increased speech intensity. This reduced mouth opening explanation is consistent with several previous kinematic studies that have demonstrated a significant reduction in the size of speech-related lower lip and jaw movements in individuals with PD (Caligiuri, 1987; Connor, Abbs, Cole, & Gracco, 1989; Forrest, Weismer, & Turner, 1989).

In general, the results of this study suggest that for conversations that are recorded in various levels of background noise, a head microphone placed close to the mouth may be a more sensitive instrument for measuring hypophonia in PD than a throat microphone. On the other hand, the simultaneous use of a throat and a head microphone may provide an advantage over the use of either microphone in isolation because the information obtained from both microphones may be useful for measuring speech-to-noise levels in high background noise conditions, and it may provide an indirect indication of a reduction in the size of speech-related mouth opening movements in some individuals with hypophonia related to PD.

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