Using Computer Games to Mediate Caregiver-Child Communication for Children with Severe Dysarthria

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The study of vocal control in children with dysarthria typically involves word/phrase repetition or picture naming/description tasks. Moreover, the child's speech production abilities and the listener's ability to decipher the intended message are often studied separately. Communication, however, is a joint act of speaker-listener attunement. The present study sought to establish a new methodology for studying caregiver-child communication in children with severe dysarthria. In particular, three interactive computer games were developed to elicit prosodically distinct vowel productions from five children with severe dysarthria due to cerebral palsy and to measure caregiver accuracy in deciphering among their child's productions. The games examined control of pitch, duration, and combined control of pitch and duration. Caregivers were able to identify prosodic distinctions along pitch and duration parameters; however, combinations of pitch and duration posed greater difficulty. Caregiver accuracy improved across the first and last third of the pitch and duration games indicating that the interactive nature of the games was conducive to fostering speaker-listener attunement. Interactive games provide an innovative means for identifying communicative signals in the vocalizations of children with severe dysarthria as well as for studying how children and caregivers coadapt to better understand each other.

Many individuals with dysarthria prefer to vocalize when interacting with familiar partners (Allaire, Gressard, Blackman, & Hostler, 1991; Smith, 1994). Moreover, familiar listeners learn to decode the speaker's intentions despite severely compromised speech intelligibility (DePaul & Kent, 2000; Spitzer & Liss, 2000). In addition to residual consistencies in the speech segments, studies on adults with severe dysarthria suggest that listeners may be relying on prosodic cues (Ciocca, Whitehill, & Joan, 2004; Le Dorze, Ouellet, & Ryalls, 1994; Patel, 2002, 2003, 2004; Vance, 1994). Preserved prosodic control has been noted for sustained vowel productions (Patel, 2002), sentence productions (Le Dorze et al., 1994; Patel, 2003, 2004; Van Doorn & Sheard, 2001; Yorkston, Beukelman, Minifie, & Sapir, 1984), and conversational discourse (Vance, 1994). In contrast, little is known about prosodic control in children with dysarthria. Although restricted fundamental frequency range and reduced vowel durations are commonly associated with the productions of children with dysarthria (Wit, Maassen, Gabreels, & Thoonen, 1993), perhaps they can signal meaningful differences within this narrowed range (Puyuelo & Rondal, 2005). Furthermore, if listeners can be attuned to a child's prosodic consistencies, it may

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be possible to bootstrap communicative exchanges from otherwise unintelligible utterances.

Word/phrase repetition or picture naming/description tasks are often used to characterize the acoustics or the physiological underpinnings of dysarthria. Additionally, it is common to examine how listeners make sense of these acoustic consistencies. Both approaches attempt to shed light on how speakers and listeners communicate despite, or due to, the disorder. Of central interest is communication—the joint act of speaker-listener attunement (Lindblom, 1990). The present study sought to establish a new methodology for studying caregiver-child communication in children with severe dysarthria.

"Wizard of Oz" experiments are often used in human computer interaction to acquire usage data for a partially implemented system (Dahlback, Jonsson, & Ahrenberg, 1993). Although the user believes they are interacting with a fully functioning system, a human "wizard" is in fact simulating the target system's behavior to guide interface design. This methodology was adapted to create a communicative scenario for obtaining speaker-listener interactions. Three games were developed to elicit prosodically distinct vowel productions from children with severe dysarthria due to cerebral palsy and to measure caregiver accuracy in deciphering their child's productions. The interactive nature of the games provided a basis for examining caregiver-child attunement.

METHOD

Participants

Five children (mean age 9.8 years; range 6–13 years), two males (S1, S5) and three females (S2, S3, S4) with severe dysarthria due to cerebral palsy participated. All children had significant motor impairments and were essentially nonverbal, necessitating the use of augmentative communication. Children served as speakers, and their caregivers (mean age 42.6 years; range 38–46 years) were the listeners. All participants were monolingual speakers of English with adequate visual acuity and pure tone thresholds at 250, 500, 1000, 2000, 4000, and 8000 Hz that fell at or below 25 dB HL in at least one ear.

Interactive Games That Used a Wizard of Oz Methodology

Three interactive computer games were developed to examine control of pitch, duration, and the combination of pitch and duration during production of the vowel /a/. The software simultaneously collected the child's vocalizations and his or her caregiver's perception of those vocalizations. The child's task was to help the computer[1] move various characters on the screen by vocalizing. Each character was associated with a distinct level of pitch, duration, or combination of pitch and duration. Within the pitch and duration protocols, 20 vocalizations were requested at random at each of three pitch levels (high, medium, low) and at three durations (long, medium, short). For the combination protocol, 10 vocalizations were requested at each of nine combinations of pitch and duration (low and short, low and medium, etc.). The caregiver was seated on the other side of an audiometric booth and simulated the computer's intelligence by selecting the character she believed her child intended to move (Figure 1). Caregiver classifications resulted in a movement of the selected character. These animations provided visual feedback to the caregiver and to the child about communicative effectiveness.

RESULTS

The Wizard of Oz game methodology provided a context for eliciting communicative intentions from children with severe dysarthria due to cerebral palsy. Furthermore, caregiver accuracy in identifying the child's intentions served as an index of the child's production abilities. Caregiver accuracy results for the pitch, duration, and combination games are presented in Figure 2. Results of the pitch and duration games were based on a total of 60 trials, 20 at each of the three target levels. Results of the combination game were based on 90 trials, 10 at each of the nine target levels. Additionally, for each game, accuracy results on the first third of all trials was compared with that on the last third to determine whether caregivers were able to attune to their child's attempts at conveying prosodic contrasts over the course of the game.

Overall, caregiver accuracy results within each game varied by speaker. In all three games, care-

[1]Children were told they were playing with a computer to minimize frustration toward the caregiver for incorrect trials.

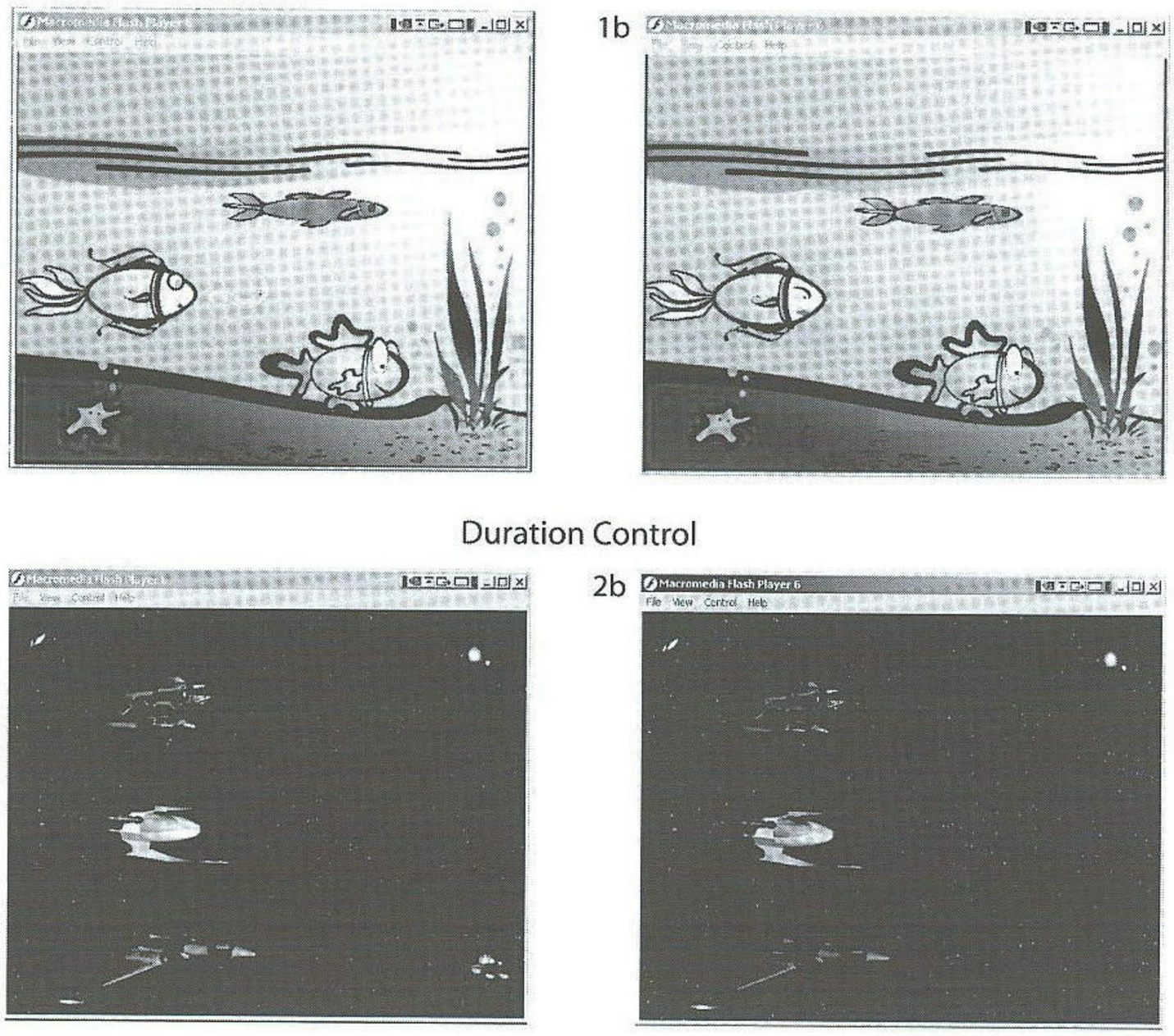

Figure 1. Screenshots of the child and caregiver interfaces for the pitch, duration, and combined pitch and duration games. The child's interface included a target stimulus. For example, in the pitch game, the location of the worm indicates that the medium pitch was being requested. The caregiver interface did not display the worm; her task was to classify each vocalization as either low, medium, or high pitched based solely on the acoustics. Her selection initiated a movement of that fish on both interfaces. If the correct fish was selected it got the worm, otherwise it failed.

giver accuracy was highest for S4 compared to all other children. In general, accuracy scores on the pitch and duration games were higher than on the combined control game.

In terms of pitch control, the low pitch category was most accurately identified across all speakers. In contrast, the high and midpitch categories posed greater difficulty. Caregiver accuracy improved over

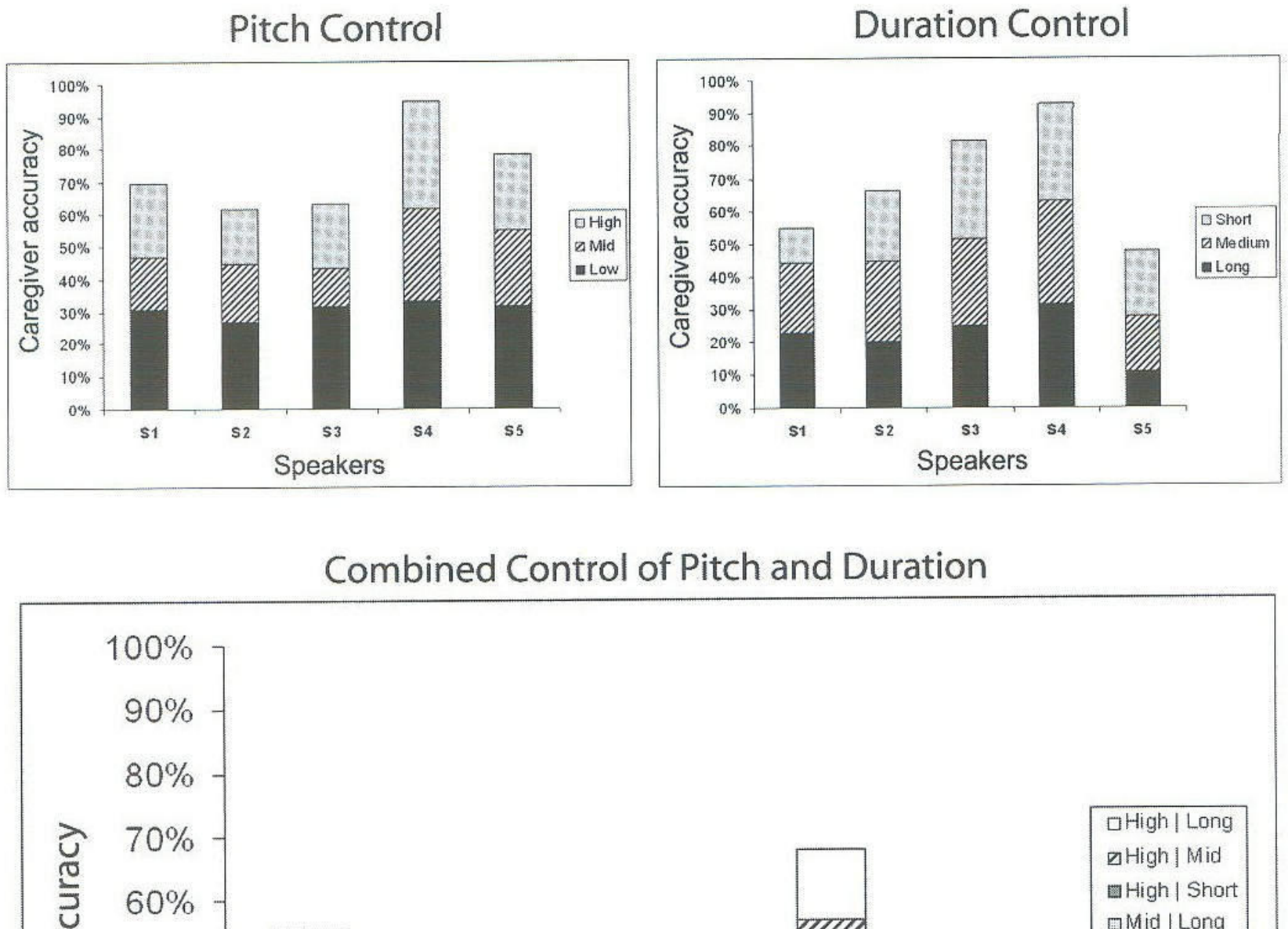

Figure 2. Caregiver accuracy for pitch, duration, and combined control of pitch and duration by each target level per child.

the course of the pitch game for all speakers except S5. For the remaining speakers, accuracy scores improved on the last third of trials between 10 to 35%.

Caregiver accuracy on the duration game varied across speakers. The long duration category, however, posed greatest difficulty for all caregivers. S1's caregiver also had difficulty discerning the short duration category; however, her performance improved over the course of the game. Improvements in caregiver accuracy in identifying duration levels were noted for all speakers except S5. Accuracy gains on the last third of trials ranged from 5 to 20% across speakers.

Identifying pitch and duration combinations posed the greatest difficulty across all speakers. Caregivers with high accuracy scores on the pitch game performed better on the combined control game. Accuracy scores for S2 and S5 fell below chance performance. The three long combination levels (low/long, mid/long, high/long) posed greater difficulty than short and midcombination levels. Additionally, S3's caregiver had difficulty identifying combinations that included high pitch. Interestingly, caregiver accuracy improved by 23% on the last third of trials for S5 but only negligibly, or not at all, for all other speakers.

DISCUSSION

This article describes a methodology for studying prosodic control in children with dysarthria as a function of caregiver accuracy in learning meaningful mappings between their child's vocalizations and intentions. Caregivers were able to identify prosodic distinctions along pitch and duration; however, combinations of pitch and duration posed greater difficulty. Individual differences were noted within each prosodic parameter and across the three games.

Caregivers had more difficulty identifying high pitch compared to low pitch attempts. This finding is consistent with previous work on adults with severe dysarthria in which raising fundamental frequency has been noted to be more difficult than lowering it (Le Dorze et al., 1994; Patel, 2002). Perhaps the narrowed pitch range noted in children with dysarthria (Wit et al., 1993) may be due to difficulties in raising fundamental frequency. Caregivers were also less accurate at identifying the long duration category, presumably due to reduced breath support, which has also been noted among children with dysarthria (Wit et al., 1993). It is not surprising that caregiver accuracies were poorest for the combination game given that maintaining pitch over a given duration is a more complex motor task than individual parameter control.

The game methodology provided a communicative context for studying speaker-listener attunement. Caregiver accuracy improved across the first and last third of the pitch and duration games, suggesting that even in this short adaptation period caregivers and children were able to reach mutual consensus on a signaling pattern. Lindblom (1990) argues that this mutuality provides the foundation of communication. A regression analysis of the acoustic cues that contributed to caregiver accuracy (errors) is currently underway. While this article focused on prosodic control, the paradigm can be modified to examine segmental control as well as other vocal parameters. Future extensions include increasing the sample size to study children with varying degrees of speech impairment across various etiologies, gradually increasing the number of distinct categories requested based on speaker-listener attunement, and exploring ways to extend control of prosodic categories to additional segmental units.

In summary, interactive games provide an innovative means for recording and analyzing communicative behaviors. In particular, it is possible to investigate how speakers and listeners coadapt to better understand each other and whether interventions can be designed to accelerate such coadaptation.

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