A previous report suggested that visual augmented feedback provided by electromagnetic articulography (EMA) may help patients recover speech motor control in apraxia of speech (AOS) following stroke (Katz, Bharadwaj, & Carstens, 1999). The study used frequent (100%) feedback, a condition thought to increase the rate of skill acquisition but diminish long-term maintenance and generalization. The present study used a multiple-baseline design in the short-term treatment of consonants produced by an individual with aphasia and AOS. Frequent (100%) and infrequent feedback (50%) conditions were included to determine whether properties of feedback scheduling reported in the limb motor literature also apply to the treatment of speech motor control.

Methods

Participant

The participant (AOS2) was a 51-year-old, male monolingual speaker of American English who sustained a left-hemisphere CVA three years before treatment. He was diagnosed with Broca's aphasia based on clinical examination and results of the Short Form BDAE-3 (Goodglass, Kaplan, & Barresi, 2000). Behavioral testing indicated moderate-to-severe AOS and moderate oral apraxia. Participant behaviors were consistent with the unique speech characteristics of AOS as described by McNeil, Robin, & Schmidt (1997) and additionally showed decreased initiation, highly variable speech errors, distortions, groping behaviors, and occasional word perseverations.

Procedure

The experimental design was a multiple-baseline across behaviors and feedback conditions (frequent/infrequent). Treated sounds (/s/, /d/, and /ʃ/) and an untreated control (unvoiced "th", or /θ/) were selected based on errors within a 200-item list of phonetically-balanced single words.

Treated sounds were assigned in counterbalanced fashion to frequent and infrequent feedback conditions, with /s/ and /ʃ/ receiving 100% feedback, and /d/ receiving 50% feedback. Two repetitions of a probe list containing five bi-syllabic words for each treated, untreated (to determine response generalization), and control sound were recorded at the beginning of each session. These words were balanced across the 12 vowels and three diphthongs of American English.

The first four sessions measured the subject's baseline performance. Following baseline, treatment was applied sequentially to the five words representing the selected sounds (one sound at a time) for six consecutive sessions. Long-term maintenance was determined in two sessions conducted one month post-treatment.

The participant was seated in a sound-treated room wearing the articulograph helmet with a receiver coil attached to the tongue tip. He faced a monitor displaying an image of his current tongue position. Investigators designated a "target zone" corresponding to the participant's accurate placement of the tongue tip for the selected speech sound. With this information he guided his tongue toward the correct place of articulation during training. Target words were repeated following a spoken and written example provided by the investigator. Accurate productions were followed by a tone, and a rising balloon moved on the display. Forty target hits were required before proceeding to the following word.

Scoring procedure and reliability

Productions from each digitally-recorded probe list were played to a trained examiner (DG). The examiner determined whether the phoneme of interest was realized correctly in the word. Productions were considered "correct" if the medial position target sound was produced phonemically on target and without distortion. Fifteen percent of the data were randomly selected for a reliability check by a second examiner (WK). Inter-rater reliability was 92%.

Results

Overall, the data indicate that the intervention resulted in both a treatment (acquisition) effect and generalization of learning to untreated speech targets. Figure 1 shows baseline, treatment (phases shaded), maintenance, and long term maintenance (follow-up) for all stimuli. The first treated sound, /s/, was poorly produced at baseline. Four of the five treated items ("bison", "fussy", "passage", "vessel") improved through the treatment phase, and short-term maintenance was observed for three of these words ("fussy", "passage", "vessel"). However, probes at one month post-treatment (sessions #23, 24) indicated that performance decreased to baseline levels. Two of the five untreated /s/-targets ("muscle", "listen") showed evidence of acquisition and maintenance. Generalization of the /s/ treatment was also noted for five /d/-target words ("powder", "loading", "edit", "ladder", "woody"), one /ʃ/-target word ("gashes"), and three control unvoiced "th" targets ("bath-oil", "rethink", "something"). Seventy percent of the control words and 90% of the /ʃ/-target words showed stable baselines during the /s/ treatment, suggesting /s/ acquisition was related to training and not to more general factors. The 50% generalization to /d/-target words is also evidence of generalization of learning to consonants of the same place of articulation.

The next treated sound class, /d/, was produced with higher overall baseline accuracy than /s/, and with considerably more variability. Beyond the rising baselines noted for five of the /d/ probes (resulting from positive /s/ training generalization), two of the five treated /d/-target words ("edit", "powder") showed generalization. There was also generalization to two of the five untreated /d/-target words ("cadet", "hiding"). For the /d/-target words showing positive acquisition or generalization effects, accuracy was maintained through the experiment and at follow-up. Finally, /d/ treatment generalized to three previously-treated /s/-target words ("fussy", "passage", "vessel"), three /ʃ/-target words ('worship", "caution", "cushion"), and three unvoiced "th" control words ("author", "bath-oil", "rethink"). As with /s/, the 70% of the control words and most of the /s/ and /ʃ/ treated items showed little change during /d/ training, suggesting that the increases in /d/ accuracy could be attributed to the intervention.

The third treated sound, /ʃ/, had the poorest overall outcome, in spite of low and stable baseline values for all words. There was acquisition for two treated items (“gashes”, “worship”), and no generalization to untreated /ʃ/-target words. Generalization arguably extended to two previously-treated /s/-target words (“muscle”, “usage”) and to one unvoiced “th”-target word (“Bethel”).

Flat patterns were noted for 8/10 of the control unvoiced “th” target words. Six of these showed near-zero accuracy, while two had slightly higher averages (“something”, 25%; “nothing”, 48%). “Rethink” was produced with zero accuracy at baseline, showed destabilization during /s/, /d/, and /ʃ/ treatment, and ended with an average of 50% accuracy at one month follow-up. “Bath-oil” demonstrated 25% accuracy during baselines, with subsequent improvement during /s/ and /d/ treatment phases, ending with 100% accuracy throughout the experiment and at one-month follow-up. In summary, with the possible exceptions of “bath-oil” and “rethink,” the control data suggest that the gains noted for treated items did not result from across-the-board improvement or unassisted recovery.

Discussion

There are three basic findings from this study. First, augmented feedback improved production for some, but not all, treated targets. These limited results may be due to the fact that treatment was restricted to six sessions, rather than a criterion for mastery. Second, the training of an alveolar fricative generalized to a stop consonant having the same place of articulation. Third, frequent feedback scheduling resulted in rapid learning but poor generalization and long-term retention, while infrequent feedback was associated with better maintenance. The findings of this study provide additional evidence for the previous finding (Katz, et al., 1999) that kinematic biofeedback improved the speech of an individual with AOS. Systematic replication of this technique on additional individuals with varying (1) severities of AOS, (2) schedules of feedback, (3) methods of stimulus hierarchy selection (e.g. speech production targets), and (4) presentation schedules (e.g. consistent versus varied practice) will help determine the conditions under which this technique is efficacious and effective.

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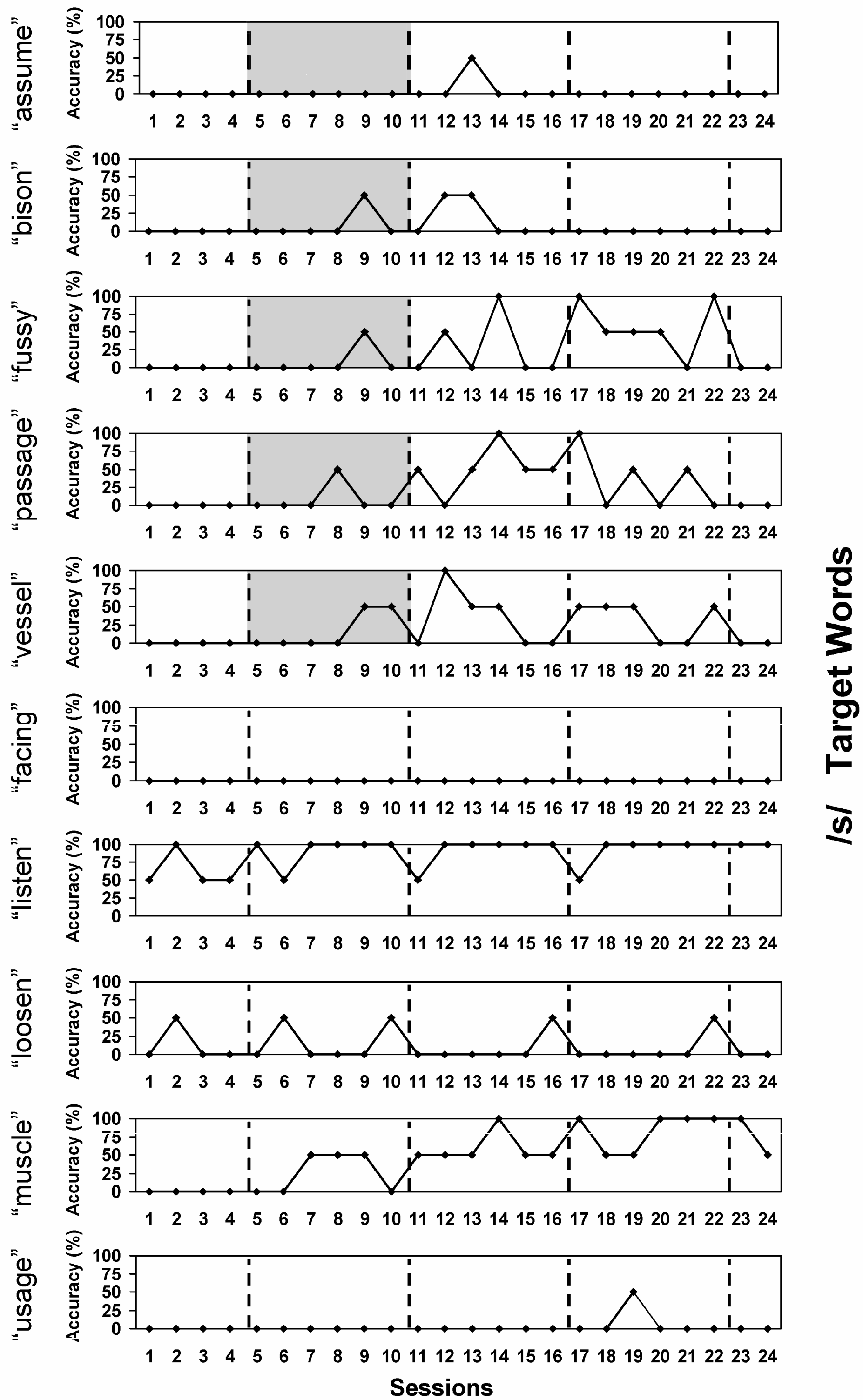
References

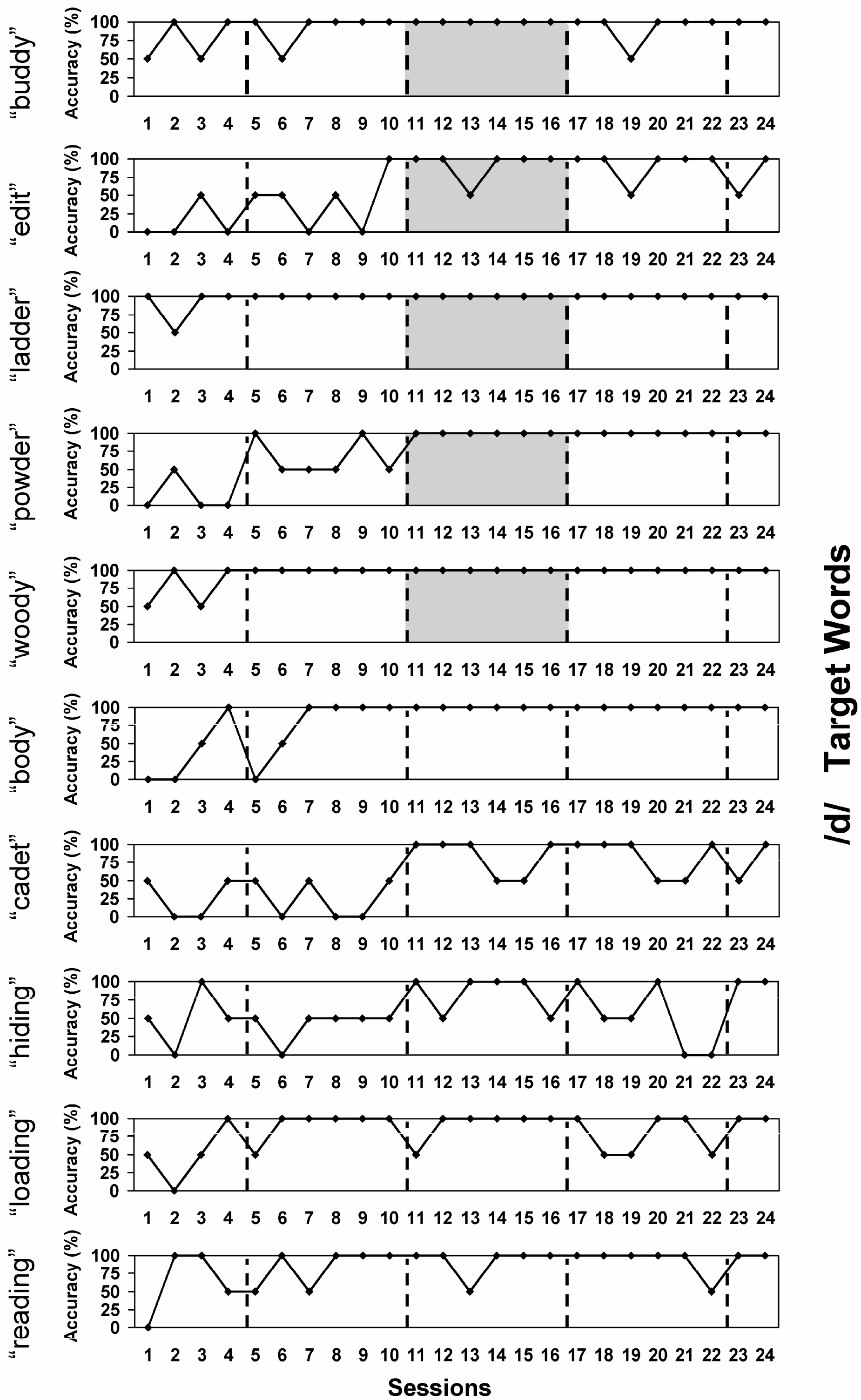
Goodglass, H., Kaplan, E., & Barresi, B. (2000). *The assessment of aphasia and related disorders, 3rd edition*. Philadelphia: Lippincott, Williams & Wilkins.

Katz, W.F., Bharadwaj, S.V., & Carstens, B. (1999). Electromagnetic articulography treatment for an adult with Broca's aphasia and apraxia of speech. *Journal of Speech, Language, and Hearing Research, 42*, 1355-1366.

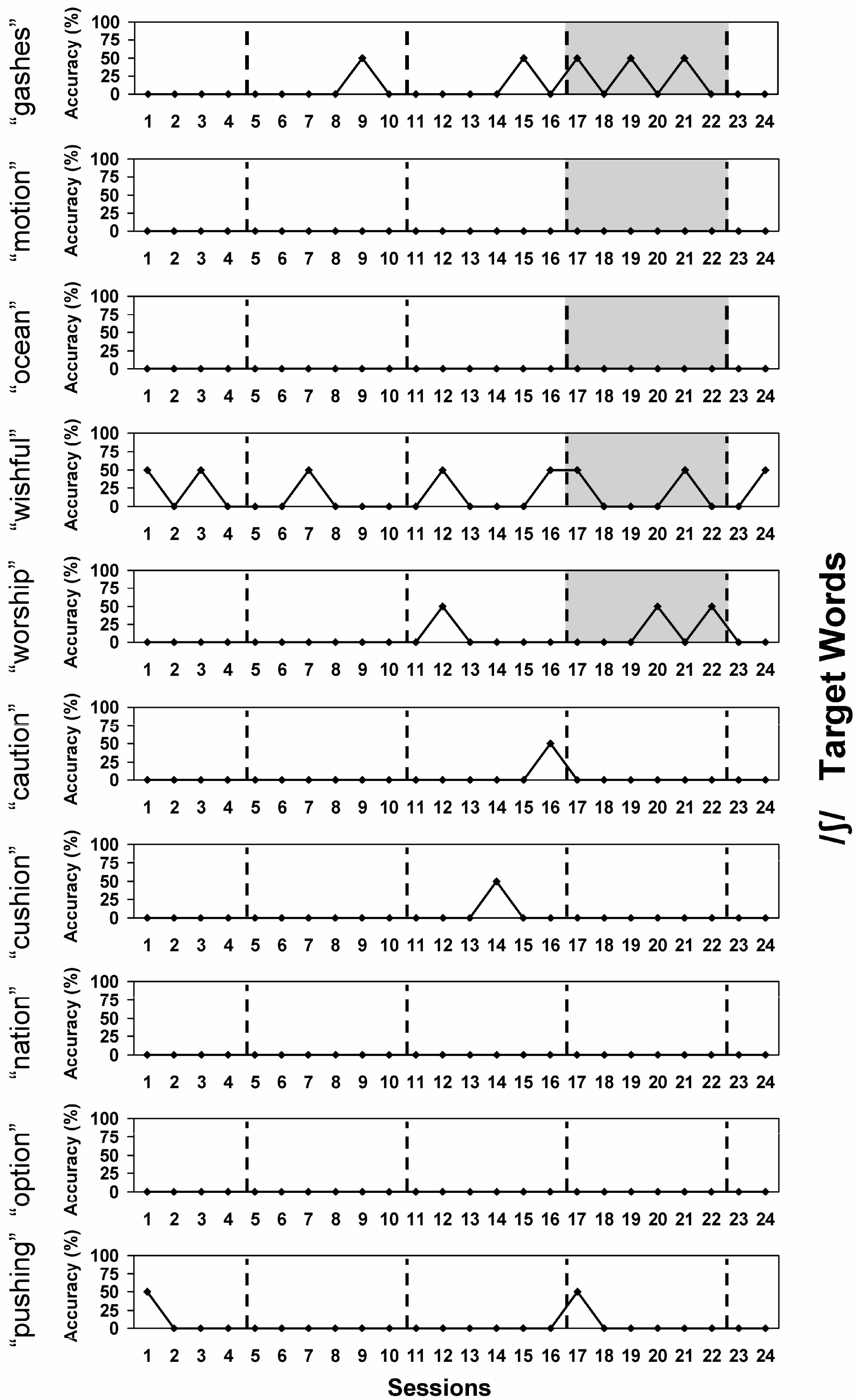
McNeil, M.R., Robin, D.A., & Schmidt, R.A. (1997). Apraxia of speech: Definition, differentiation and treatment (311-344). In M.R. McNeil (Ed.), *Clinical management of sensorimotor speech disorders*. New York: Thieme Medical Publishers.

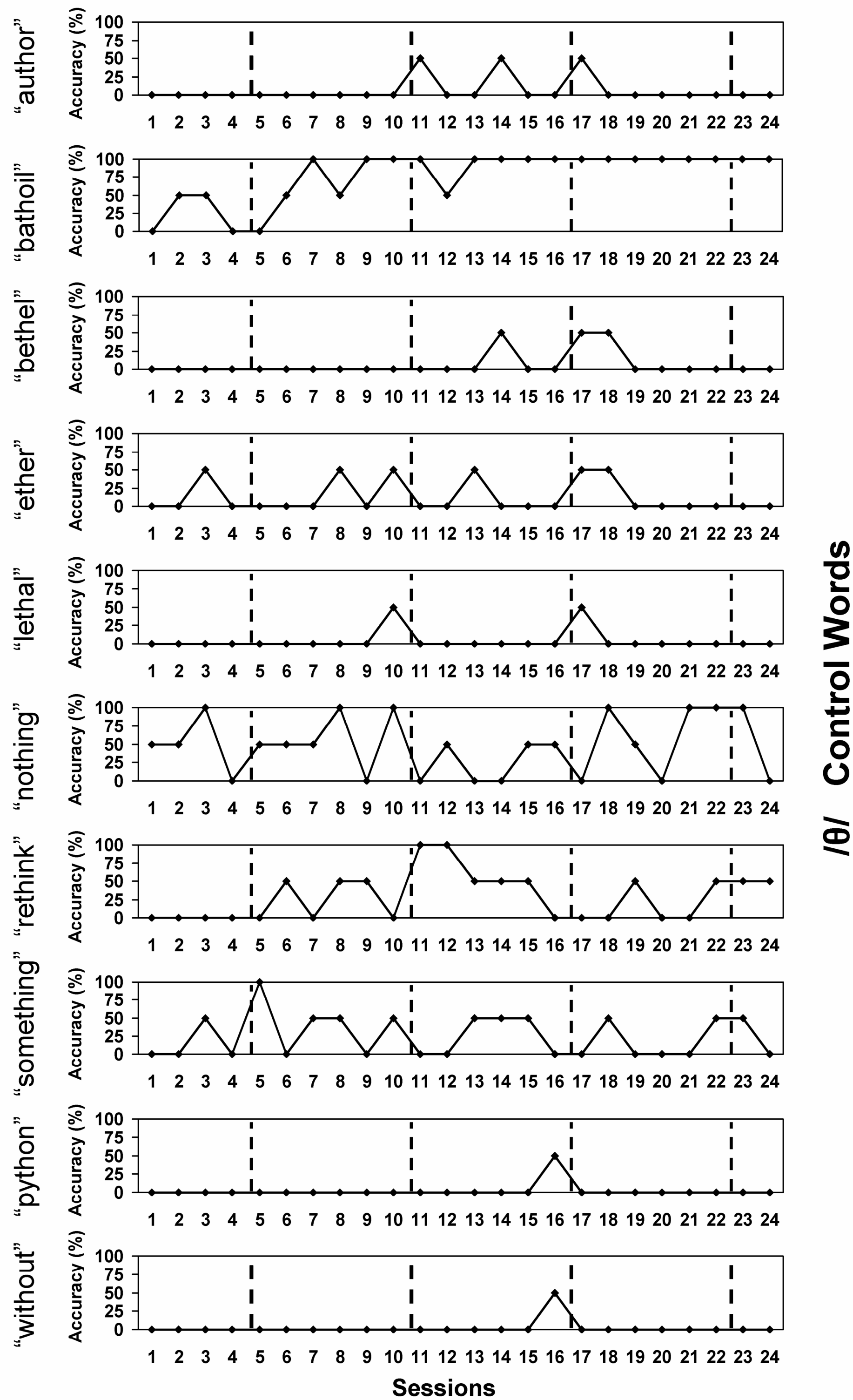
Figure 1


"assume"
"bison"
"fussy"
"passage"
"vessel"
"facing"
"listen"
"loosen"
"muscle"
"usage"
Accuracy (%)
Sessions
/s/ Target Words



/d/ Target Words
"buddy"
"edit"
"ladder"
"powder"
"woody"
"body"
"cadet"
"hiding"
"loading"
"reading"
Accuracy (%)
0
25
50
75
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Sessions


/ʃ/ Target Words
"gashes"
"motion"
"ocean"
"wishful"
"worship"
"caution"
"cushion"
"nation"
"option"
"pushing"
Accuracy (%)
100
75
50
25
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Sessions



/θ/ Control Words
"author"
"batholl"
"bethel"
"ether"
"lethal"
"nothing"
"rethink"
"something"
"python"
"without"
Accuracy (%)
Sessions