External auditory feedback from covert oral behavior during silent reading*

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Ss were selected for high levels of covert oral behavior during silent reading. High speech-muscle amplitude during silent reading produced a slightly noxious tone, and a reduction in amplitude removed the tone. Feedback reduced amplitude of the controlling and associated speech muscles, but withdrawal of feedback returned the amplitude to about baseline level, indicating that the reduction was not permanent. More effective controlling techniques are required to determine stringently the function of the covert oral response with this approach.

There are two opposing views of the function of covert oral behavior during the performance of such linguistic tasks as silent reading: the traditional one that "subvocalization" is detrimental (e.g., Wood, 1966) and the alternative (recently revived) that the covert oral response facilitates the reading process (e.g., Edfeldt, 1960; McGuigan & Rodier, 1968; McGuigan, 1970). One approach to help decide between these positions would be to decrease experimentally amplitude of covert oral behavior during silent reading and to observe the consequences on reading proficiency. First, however, we need to develop effective control over the covert oral response. External feedback from the speech musculature might serve for this purpose. To date, however, only sparse and inconclusive data have been reported on efforts to manipulate this response class (e.g., Hardyck, Petrino, & Ellsworth, 1966; McGuigan, 1967; Hardyck & Petrino, 1969).

METHOD

Initial screening produced six Ss with high levels of covert oral behavior during silent reading. Each S was introduced to the laboratory, and sensors were attached to various oral and nonoral regions of the body (see below). Each day S relaxed and then silently read a different passage standardized for his educational level. After a series of daily adaptation sessions of reading without feedback (three to seven, depending on the S),

auditory feedback signals from the speech musculature were introduced. During the feedback sessions (from 2 to 20, depending on the S), electromyographic (EMG) signals from the chin or lips automatically produced a slightly noxious tone (a potential punisher) when the S's response amplitude exceeded a specified level. A reduction of the response amplitude below that level terminated the tone (a potential negative reinforcer). The response amplitude that would produce feedback was specified for each S such that the tone would have been produced about 50% of the time

during the final no-feedback adaptation session. After the feedback sessions, the Ss read for a series of sessions (from 2 to 18) with feedback removed. The criterion for commencing feedback was that the amplitude of the response that was to produce feedback had become reasonably stabilized over sessions. EMGs were integrated and digitized for 10-sec intervals during rest and during reading, and means for each were computed for each S (cf. McGuigan, 1967, and McGuigan & Rodier, 1968, for quantification details and for other information concerning the laboratory and procedures).

RESULTS

Each mean response amplitude during each prereading rest session was subtracted from the corresponding mean value during silent reading for that day. The psychophysiological results for S1 (a female college student) are plotted as a function of session in the lower part of Fig. 1. No external feedback while reading was given during the first six sessions. Feedback from the chin was started during Session 7, but the S was not told why the tone was initiated or terminated. The general increase in chin and tongue amplitude through Session 27 suggests that, without awareness of the function of the tone,

Fig. 1. EMG amplitudes for each session (lower). Feedback started when chin amplitude exceeded 20 microV during Sessions 7-33; thresholds for later sessions were lowered to 16 and 9 microV. Corresponding laboratory reading rates in words per minute (WPM) appear at the top.

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Fig. 2. Effect of feedback presentation and subsequent withdrawal on the triggering covert oral behavior during silent reading. Feedback was from the chin for Ss 1, 3, 4, and 5 and from the lips for Ss 2 and 6.

the S did not learn to reduce her covert oral behavior. At the start of Session 28, the S was told (to her amazement) that she controlled the tone, but she was not told how; a gradual decrease in amplitude of chin EMG then followed (Sessions 28-41). For Sessions 7-33, the tone came on when chin amplitude exceeded 20 microV (root-mean-square). For later sessions, the criterion was lowered to 16 and 9 microV, as specified in Fig. 1. Through this shaping procedure and by being aware that the tone served a feedback function, the S substantially lowered the level of her chin response. The accompanying decrease in tongue EMG suggests that the effect was generalized throughout the oral region.

Nonpreferred arm EMG was stable around zero throughout, indicating that S's originally heightened covert oral behavior during reading was not merely an aspect of general bodily activation; rather, the EMG increase was probably localized in the speech region. Lack of change in arm EMG as a function of feedback condition also suggests that feedback did not have a general disturbing effect and that consequent behavioral changes were localized in the oral region. Finally, when feedback was eliminated (Sessions 42 and 43), chin EMG dramatically increased to approximately the baseline level of Sessions 1-6, indicating that the continuous presence of feedback was

responsible for the changes—there was apparently no permanent change in level of covert oral behavior. There is a hint of a positive relationship between amplitude of speech muscle EMG and laboratory reading rate (top of Fig. 1), but in any event, the relationship is

clearly not inverse (usable tongue and rate measures were missing from Session 43).

The five additional Ss (two male and three female varying in ages between 7 and 19 years) were studied as was S 1, except that after the initial no-feedback adaptation sessions, they were told that the tone was indicative of excessive lip or chin movements and that their task was to prevent the tone's onset. Results (illustrative of the more extended curves) are summarized in Figs. 2 and 3. The values plotted are for the last no-feedback session (when the S was well adapted to the laboratory), for the last feedback session (when feedback had become effective in removing the tone), and for the last session in which feedback was withdrawn. (The value for the last feedback session used for S 1 was under the "unaware" condition.) Figure 2 shows that feedback was always effective in decreasing the amplitude of the covert oral behavior (whether from chin or lips) during silent reading and that its withdrawal returned the behavior to approximately baseline level—the reduced amplitude of covert oral behavior during silent reading is not permanent, and when it did occur, it evidently was not merely due to instructions to reduce response amplitude. These results are thus at variance with the statements of Hardyck et al (1966) that reduction of speech muscle activity to resting levels

Fig. 3. Amplitude of nonoral response measures during feedback and subsequent nonfeedback reading sessions.

is immediate (accomplished by most Ss within 5 min) and long lasting.

The effect of feedback on other covert oral measures was essentially the same as for the one that triggered the feedback: feedback from the lips or chin also depressed associated muscle activity in the lips, chin, and tongue, and the accompanying oral measure typically increased once feedback was removed. The most extreme example was S 6, whose lips triggered feedback. The mean increase in chin amplitude from rest to silent reading for S 6 was 24.7 microV before feedback; with feedback, the difference between resting and reading was -3.0 microV, while when feedback was removed, the difference in mean chin amplitude increased to 8.1 microV.

Figure 3 shows that heightened covert oral behavior during silent reading is generally independent of nonoral measures and that the administration of feedback and its subsequent withdrawal have little systematic effect on these nonoral measures.

The introduction and subsequent withdrawal of feedback was about equally often accompanied by

increased and decreased reading rates, measured as number of words per minute; this measure is probably too insensitive to reflect consequences of the reduced oral response amplitude. Mean comprehension scores during the prefeedback, feedback, and postfeedback sessions were, respectively, 69%, 66%, and 72%, showing that the Ss were comprehending about as well during and after feedback as they were before.

In conclusion, it appears that the presentation of a slightly noxious stimulus contingent on a high level of covert speech muscle activity during silent reading, and the cessation of that stimulus contingent on a decrease in covert oral behavior, is effective in reducing amplitude of both the controlling and associated speech muscles. But, as indicated by subsequent feedback removal, the reduced amplitude is not permanent. The heightened level of covert behavior during silent reading appeared to be localized in the speech region, and nonoral regions sampled were not systematically affected by feedback condition. Covert oral behavior can thus be only temporarily

controlled through feedback techniques as used here. A more prolonged reduction in amplitude would be required before we could apply a "response-reduction" strategy to stringently test alternative hypotheses of the function of covert oral behavior during the performance of such linguistic tasks as silent reading.

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