Internal Versus External: Oral-Motor Performance as a Function of Attentional Focus

RESEARCH NOTE

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Purpose: Previous studies (e.g., G. Wulf, M. Höß, & W. Prinz, 1998; G. Wulf, B. Lauterbach, & T. Toole, 1999; for a review, see G. Wulf & W. Prinz, 2001) have reported that limb motor performance is enhanced when individuals adopt an external focus (focusing on the effect of the movement) versus an internal focus of attention (focusing on body parts such as the muscles of the hand). This study tested the hypothesis that the effects of attentional focus on limb performance would also occur in the oral-facial system.
Method: Two groups of 23 participants were administered both hand and tongue impulse force control tasks in which each group was randomly assigned either an internal or an external focus of attention. Participants were required to exert rapid pressure bursts to achieve a target force level of 20% of their maximal strength.
Results: Consistent with limb studies, findings revealed a significant advantage of an external focus (greater accuracy, less variability) for both the hand and tongue control tasks, as opposed to an internal focus of attention.
Conclusions: Results are discussed relative to a constrained-action theory of motor control and future application to speech motor learning.

KEY WORDS: oral-motor, constrained action hypothesis, speech motor control, focus of attention

To better understand factors that may enhance speech motor learning, it may be useful to extrapolate from the limb motor learning literature. Many variables have an impact on the performance and/or learning of motor skills (e.g., the amount of feedback, frequency of feedback, contextual interference). Recently, several principles of limb motor learning have been demonstrated to apply to the treatment of speech production in apraxia of speech (AOS). For example, low frequency feedback (Austermann, Maas, Robin, Ballard, & Schmidt, 2004), delayed feedback (Austermann, Robin, Maas, Ballard, & Schmidt, 2005), and random practice (Knock, Ballard, Robin, & Schmidt, 2000) have all been shown to enhance retention and transfer of speech in some individuals with AOS. The present study investigated the effects of an individual's focus of attention (internal vs. external) on the performance of limb and oral-motor movements in order to determine (a) whether similar effects would be found for manual and oral-facial effector systems and (b) whether a participant's directed focus of attention would affect both accuracy and stability of performance.

The idea that an individual's focus of attention might affect motor learning has been considered since well over a century ago (Cattell, 1893). The advantage of adopting an external focus of attention (i.e., a focus

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on the movement effect) relative to an internal focus (i.e., a focus on bodily movements) during motor learning has only recently gained considerable attention in the limb performance literature (e.g., Wulf, Höß, & Prinz, 1998; Wulf, Lauterbach, & Toole, 1999; Wulf & Prinz, 2001). For example, in golf an external focus of attention would be induced by instructing learners to focus on the swing of their golf club; an internal focus would be induced by instructing learners to focus on their arms during the swing. An external focus has been shown to produce more effective performance and learning across a variety of tasks, including those used to teach balance and sport skills (see Wulf & Prinz, 2001, for a review). No studies have explored the role of attentional focus in the performance or learning of oral-facial movements. Though our ultimate concern is the understanding of speech motor learning, a logical first step is to replicate limb findings in the oral-facial system using a nonspeech task that shares properties with speech. In this study, we used a rapid tongue elevation movement to exert force on a pressure transducer positioned on the alveolar ridge (a movement similar to that used when producing certain speech sounds such as /t/ and /d/) in that it requires tongue tip to alveolar ridge movements with a rapid velocity (see Folkins et al., 1995, for more details of this argument). However, we recognize that the relationship between nonspeech tasks such as this and speech production remains controversial (see Ziegler, 2003a, 2003b, for an opposing view).

Theoretical underpinnings for the advantage of an external focus of attention have been postulated by Wulf and colleagues (e.g., McNevin, Shea, & Wulf, 2003; Wulf, McNevin, & Shea, 2001) in the constrained action hypothesis. According to this view, individuals who utilize an internal focus constrain or "freeze" their motor system during a conscious attempt to control it. This also seems to occur when individuals are not provided any attentional focus instructions (e.g., Landers, Wulf, Wallmann, & Guadagnoli, 2005; Wulf et al., 1998; Wulf, Weigelt, Poulter, & McNevin, 2003). Thus, the automaticity necessary for fluid, accurate movements is believed to be interrupted when employing an internal focus of attention, thereby producing a less effective and/or accurate result. In contrast, an external focus of attention on the movement effect allows for the development of more automatically executed motor routines. The advantage of an external focus of attention is in line with the notion that actions are more effective when planned in terms of the outcome, as opposed to the movements themselves or the muscles and sensations involved in the movements (Prinz, 1997).

In the present study, we compared a manual with an oral-motor rapid impulse force control task that shared properties with speech production (a tongue elevation movement used in the production of alveolar sounds such as /d/, /s/, /l/, etc.). Our hypothesis, based on previous findings of limb motor performance, was that participants in the present study trained with an external focus of attention would demonstrate enhanced task performance (increased accuracy, less variability) for both the hand and tongue control tasks, as compared to those utilizing an internal focus of attention.

Method

Participants

Forty-six undergraduate student participants (44 females, 2 males) with no known health conditions or cognitive impairments were recruited from the School of Speech, Language, and Hearing Sciences at San Diego State University and randomly assigned to one of two groups. Group 1 was instructed to utilize an internal and Group 2 an external focus of attention. Informed consent was obtained from all participants prior to the study. None of the participants had highly developed manual or oral-motor skills (e.g., professional guitarists, college debaters) as screened with a questionnaire. None of the participants had previous experience with the task or any knowledge of our experimental questions.

Materials

Maximal hand and tongue strengths were assessed using the Iowa Oral Performance Instrument (IOPI; Robin & Luschei, 1990) (see Figure 1). The IOPI makes use of an air-filled rubber bulb attached to a pressure transducer. The amount of pressure generated by squeezing the bulb with the tongue or hand is displayed on a digital readout that is calibrated in kilopascals (kPa). Pressure bulbs for the tongue were made from 1 ml latex rubber pipette bulbs; the hand bulbs were made from 10 ml rubber syringe bulbs. The end of a 23 cm long

Figure 1. The Iowa Oral Performance Instrument (IOPI).

silastic rubber tube (a 0.040 mm internal diameter) was sealed inside each bulb. Participants had their own bulb previously sheathed in a sterile heat-sealed polyethylene sleeve.

Pre-Task Procedure

Participants in each group (external vs. internal focus) were tested in one session on both manual and oral-motor control tasks, which involved attempting to achieve a target level of 20% of their maximal strengths. The 20% target level was selected for the experiment since speech typically involves use of a relatively low level of overall tongue strength (15%–30%) of an individual's maximal oral-motor strength (Robin, Somodi, & Luschei, 1991). As well, at 20% of maximal strength, participants typically recruit relatively fatigue resistant motor units (Robin et al., 1991), thereby avoiding potential fatigue effects during the experiment. To obtain maximal tongue strengths (Pmax-t), participants followed a standardized procedure in which they were instructed to squeeze the IOPI bulb against the alveolar ridge of their mouth as hard as possible with the front of their tongue (Robin & Luschei, 1990). Thus, participants positioned the small, rubber bulb directly above their front teeth against the gum and exerted full pressure. Participants were instructed not to use their tongue tip to ensure that full tongue strength was being measured. Participants were provided a rest period of 1 min before repeating the maximal pressure task two additional times. The highest pressure obtained from three trials was noted as Pmax-t. The above procedure has been shown to have high validity and high external and internal reliability (Robin & Luschei, 1990).

Hand strength (Pmax-h) was also measured using a standardized protocol and was obtained in a manner similar to that described for Pmax-t (Robin & Luschei, 1990). Participants used their dominant hand. The IOPI bulb was placed in participants' palms in a standard grip position with the rubber bulb enclosed in a clenched fist (with the bulb's air tube facing upwards). Participants were instructed not to use their fingertips when squeezing the bulb to ensure that full handgrip strength was measured. The greatest pressure obtained from three consecutive trials was noted as Pmax-h. Maximal strengths were recalibrated prior to each effector and separately for each participant.

After Pmax-t and Pmax-h were documented, 20% of Pmax-t and Pmax-h were calculated. For instance, if a participant's Pmax-t was 100 kPa, 20% of his or her tongue's maximal strength was noted as 20 kPa.

Task

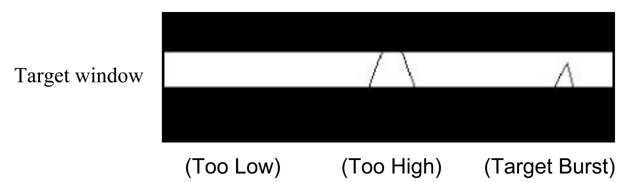
An impulse force task was conducted in which participants practiced generating rapid pressure exertions (with the hand and tongue) to a target level of 20% of their maximal strength. Each participant practiced both manual and oral-motor control tasks in a single session; order of effectors (hand–tongue, tongue–hand) was counterbalanced across participants within each group. Participants were provided approximately 5 min rest before switching to a different effector. Participants were instructed to apply only enough pressure on the bulb in one rapid exertion to see their pressure burst peak appear in the center of a 0.5-in. window slot on a standard 10-in. computer monitor. The center of the window indicated a participant's 20% target pressure level plus or minus 0.25 in. (see Figure 2) and was adjusted accordingly for each participant's 20% target level. Visual feedback was provided to all participants for each pressure burst by means of the target window (i.e., if no signal appeared in the window slot, the generated pressure was too low; if the burst appeared in the window without the peak, the generated pressure was too high; if the peak of the burst appeared in the window, the generated pressure was in the defined 20% target region). A digitally recorded metronome (set at one tick per second) generated a chime every 5 s to signal participants to exert one rapid pressure burst, ensuring that all participants had the same amount of rest during and between trials. Trials for both the hand and tongue were conducted in a single block consisting of a total of 40 bursts per participant. Thus, duration of a block was approximately 200 s for each effector.

Internal focus group participants were instructed to focus on the pressures they exerted with their hands/tongues, whereas external focus group participants were instructed to focus on the pressures they exerted on the IOPI's rubber bulbs. Each participant received the same following instructions (depending on group assignment), which were read by the same experimenter, the first author:

1. Internal: "Keep focusing on your tongue/hand, focus on your tongue/hand. Push with your tongue/hand."
2. External: "Keep focusing on the bulb, focus on the bulb. Push on the bulb."

Reminders to participants about their assigned focus of attention were provided once a minute by the experimenter. Participants were instructed not to look at the

Figure 2. Examples of visual feedback provided after each trial.



object of their focus (e.g., one's hand), but simply to concentrate on it. This was done to avoid possible confounding effects of visual feedback only available during one of the conditions (i.e., the hand is visible to the participant while the tongue is not) and was similar to procedures used in previous studies (e.g., Wulf et al., 1998, 1999, 2001).

Experimental Design and Analyses

The dependent measures analyzed were absolute error (AE) and variable error (VE) (in kPa) of the pressure bursts' peaks during each trial (see Schmidt & Lee, 2005). Briefly, AE is the average absolute deviation from the target (20% of maximal strength in our study) regardless of direction, and is a measure of overall accuracy. VE is a measure of performance variability of the pressure bursts' peaks with regard to the signed differences between participants' errors and their mean values. The statistical analyses involved a mixed model analysis of variance (ANOVA) with group (external vs. internal) as the between-participants factor and effector (hand vs. tongue) as the within-participant factor. The data were thus analyzed in 2 (group) × 2 (effector) mixed ANOVAs, which were performed on log-transformed data to meet the normality assumption and to reduce variability. An alpha level of .05 was used for all statistical tests. Prior to analysis, data points that were greater than 2.5 *SD*s from a participant's mean for each condition were excluded as outliers. The screening procedure resulted in a data loss of less than 1% overall (no participant > 5%), evenly distributed across conditions.

Results

Absolute error and variable error means and standard deviations are given in Table 1.

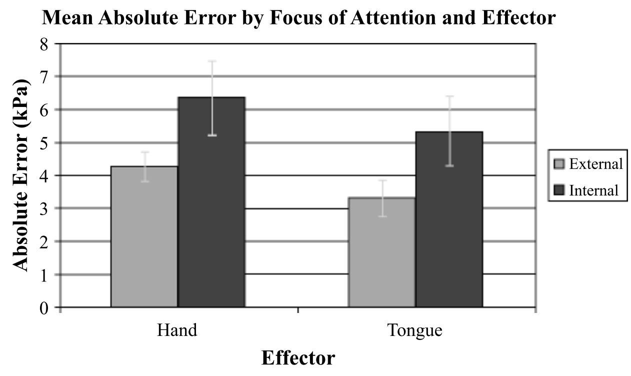
Absolute Error

Results of the ANOVA revealed significant main effects for group, $F(1, 44) = 3.8927$, $p = .05$, indicating that the external group produced smaller absolute error values than the internal group (see Figure 3), and for effector, $F(1, 44) = 16.95$, $p < .001$, indicating that AE was smaller for the tongue than for the hand (see Figure 3). There was no interaction between group and effector, $F(1, 44) < 1$. Effect sizes for both the hand (0.5) and tongue (0.7) were moderate to large (Cohen, 1988).

Table 1. Absolute and variable error means (and standard deviations) by focus of attention and effector.

	Absolute error				Variable error			
	Internal		External		Internal		External	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Hand	6.44	5.51	4.21	2.22	8.06	6.89	5.19	2.36
Tongue	5.48	5.10	3.49	2.80	6.64	5.71	4.28	3.00

Figure 3. Mean absolute error by focus of attention and effector. Error bars are standard errors of the mean.



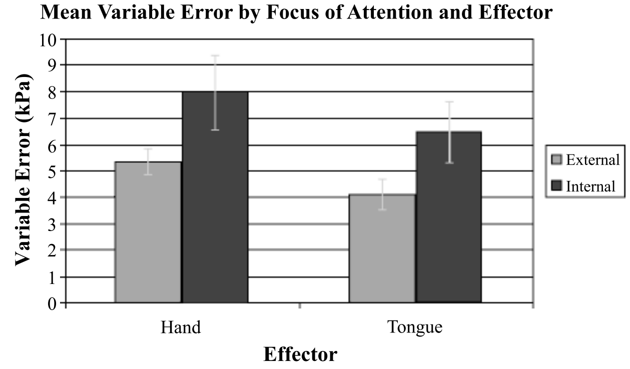
Variable Error

As seen in Figure 4, the external focus group demonstrated less within-participant variability than the internal focus group. This finding was confirmed statistically as a significant main effect of group, $F(1, 44) = 4.11$, $p < .05$. In addition, there was a main effect of effector, $F(1, 44) = 15.33$, $p < .001$, revealing more variable performance for the hand than for the tongue. There was no interaction between group and effector, $F(1, 44) < 1$. Moderate effect sizes (Cohen, 1988) were noted for both the hand (0.5) and tongue (0.5).

Discussion

The present study was designed to replicate and extend previous findings of improved performance during

Figure 4. Mean variable error by focus of attention and effector. Error bars are standard errors of the mean.



limb motor control tasks when adopting an external focus compared to an internal focus of attention (e.g., Wulf et al., 1999, 2003), using an oral-motor impulse force control task. The results of this study suggest that attentional focus indeed exerts an influence on motor control during such a task, extending the range of motor control tasks to which the effects of attentional focus apply to include impulse force control tasks.

The primary purpose of this initial work in the oral-facial system was to determine the extent to which previous limb findings might extend to the oral-facial system (i.e., the tongue), as a first step in understanding the role of attentional focus in producing and learning oral movements, and eventually speech. In particular, it was critical to determine if an external focus of attention would not only result in more effective overall performance (as indicated by AE), but also in more performance stability (as indexed by VE). The study was framed within the constrained action hypothesis, which states that an internal focus of attention interrupts otherwise automatic processes of the motor system. Thus, the theory predicts that an external focus of attention should enhance motor control (i.e., performance will be more accurate and consistent; e.g., Wulf et al., 2001). The results from the present experiment supported the constrained action hypothesis by replicating previous limb findings (hand task) and extending them to the oral-facial system (tongue task), in that the performance for both effectors was enhanced with an external focus of attention. Specifically, the external focus group demonstrated significantly smaller AE and VE values than the internal focus group.

Although this study used a nonspeech task, the findings highlight the intriguing possibility that attentional focus may be an important variable to consider in treatment of speech disorders. If an internal focus impedes oral-motor performance, as it did in the current study, then efforts to learn and improve oral movements or speech may be hampered by opposing effects of an internal attentional focus if such a focus is adopted during treatment.

In conclusion, the results from this study provide additional evidence that directing a participant's focus of attention during manual and oral-facial motor tasks impacts performance. Specifically, the findings reported here extend the data on external focus performance enhancement to (a) a different type of task (impulse force control), (b) a different effector system (the oral-facial system), and (c) an additional performance measure, variable error (in addition to absolute error). Future studies will explore how an external focus of attention affects complex speech motor learning, and how attentional focus may be further implemented in speech treatments. For example, certain complex speech behaviors in typical populations (e.g., tongue twisters, public debating) may be studied to investigate effects of attentional focus. Lastly, work is underway that examines additional benefits of an external focus of attention, such as the amount of necessary muscle activity generated during a motor control task (relating to a possible greater economy of motor neuron recruitment), as measured through electromyography (Vance, Wulf, McNevin, Töllner, & Mercer, 2004).

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