Semantic Priming of Motor Task Performance in Young Adults: Implications for Occupational Therapy

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OBJECTIVE. To investigate whether the performance of a multisegment motor task is influenced by reading a segment-specific action word.

METHOD. Twenty-four participants performed tasks that involved reaching for a bottle, grasping it, lifting and placing it on a shelf, and returning their hand to the starting position. At the initiation of each task, participants read either aloud or silently five randomly provided, task-related words (reach, grasp, lift, place, and return).

RESULTS. Reading task-related words significantly affected the reach and lift/place segments in the direction of the hypothesis ($p < 0.05$) but not the return segments. Grasp times were shorter and grasp velocities were higher when participants read aloud or silently the words grasp and place for the grasp segment ($p < 0.05$).

CONCLUSIONS. The results suggest that in young adults, motor performance may be influenced by pre- or priming the brain with performance-related words. A meaning of a motor performance can be manipulated by contextually relevant language, which can facilitate performance.

impact on this cognitive interpretation of performance and thereby can affect the performance. Recently, several studies observed that visual presentation of contextually relevant words can theoretically influence the cognitive programming, or interpretation, of a performance, and such influence can be reflected in the performance (Gentilucci, Benuzzi, Bertolani, Daprati, & Gangitano, 2000; Glover & Dixon, 2002; Maitra et al., 2003).

The part of the human brain responsible for speech production is Broca’s area, located in the ventral premotor cortex. Both functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) scans have shown Broca’s area to be active during observation of a person’s hand movements as well as during active hand movements (Bonda, Petrides, Frey, & Evans, 1994; Schlag, Knorr, & Seitz, 1994). Because Broca’s area is active during observation of hand actions as well as during performance of hand actions, and because Broca’s area is also responsible for speech production, it can be assumed that speech production and movement production areas probably overlap in the human brain. This overlap suggests that speech and other motor areas might influence one another (Pulvermüller, 2005).

In a study conducted by Maitra et al. (2003), participants completed a common reaching task under four different conditions of vocalizing the word yeah before beginning the task: (a) no vocalization, (b) synchronized self-vocalization, (c) external (experimenter) vocalization, and (d) imagery vocalization. The task involved reaching for a cup and placing it on a shelf. The results demonstrated that self and external vocalization conditions resulted in faster and smoother movement patterns. Such results indicate that motor performance is influenced by speech production (vocalization). This experiment was one of the important behavioral experiments that suggested a link among speech, language, and motor performance.

Along with including a speech component, communication also includes comprehending others’ speech and language in the spoken, written, or gesturing form. A separate brain area known as Wernicke’s area is responsible for comprehension. Research shows that the meaning of a word label printed on a target object can have major effects on the reaching velocity and initial grasping aperture (Glover & Dixon, 2002). Gentilucci and colleagues (2000) discovered that both peak velocity of finger aperture and maximal finger aperture were greater in grasping an object when participants silently read the word large printed on the object, compared to when they read the word small. The results of their study suggest that participants unconsciously activated a grasp program for a larger object when the word large was presented. In the same study, Gentilucci and colleagues also found an influence on arm peak velocity and arm peak acceleration during reaching for an object while silently reading the printed word high. These two reach components were greater in the presence of the word high than in the presence of the word low. According to Gentilucci et al., participants automatically associated the meaning of certain words with the corresponding properties of the objects they were to pick up, which subsequently activated a reach or grasp motor program influenced by the word. Some words were more influential on the reach component of the motor task, whereas other words were more influential on the grasp component of the motor task.

Speech production and comprehension include both meaningful and nonmeaningful speech. The results of Gentilucci et al.’s (2000) experiment included how the perception (comprehension) of meaningful speech influenced arm and hand movements. The printed words that the participants read were related to the components of the reaching and grasping tasks performed. Meaningful speech is speech that is coupled with a person’s actions, as opposed to nonmeaningful speech, which simply includes vocalizations that have no correlation with the actions. Nonmeaningful speech consists of phonemes (e.g., la, ga, etc.). A few recent studies found that production of such phonemes not only activates the hand motor system in the brain but also facilitates arm and hand movements (Floel, Ellger, Breitenstein, & Knecht, 2003; Maitra et al., 2003).

Currently, no studies have been conducted to compare and contrast the influence of meaningful (task-specific) speech production and meaningful speech comprehension on arm movements. Because both the speech production area and the speech comprehension area in the brain appear to influence the movement production area, and because the specifics about these influences are unclear, an attempt should be made to investigate how these areas influence motor performance. For occupational therapy, the findings from this research could be valuable in opening a novel approach for motor rehabilitation.

**Purpose**

The purpose of this study consists of two components: (a) to investigate whether the performance during a specific segment of a motor task is influenced by reading aloud or silently a segment-specific action word and (b) to determine whether reading aloud a printed segment-specific word influences performance differently than silently reading the same word.
Two principal dependent variables were studied: movement time and peak velocity of the movement. Movement time—the time taken to complete a task—was computed for each segment by subtracting movement onset and offset time. Movement onset and offset were determined by using a commonly used criterion velocity of 0.025 m/s (Glover & Dixon, 2002). Peak velocity is the maximum velocity achieved during a movement. In an attempt to investigate such concepts, specific hypotheses were formulated. In a sequential motor task consisting of four segments—reaching for a bottle, grasping the bottle, lifting and placing the bottle on a shelf (one continuous movement), and returning the hand to initial position—we hypothesized the following for (a) reach, (b) lift/place, and (c) return:

a. Movement time will be shorter and peak velocity will be higher when participants concurrently read the words reach, lift, place, and return, compared to not reading during movement within each segment.

b. Movement time will be shorter and peak velocity will be higher when participants concurrently read aloud the words reach, lift, place, and return, compared to movement time and peak velocity when participants read silently the same words.

We also hypothesized that for the (d) grasp segment,

c. Peak grasp aperture velocity will be higher while reading the word grasp and grasping for a bottle, compared to not reading while grasping.

d. Peak grasp aperture velocity will be higher when reading aloud the word grasp while grasping for the bottle, compared to silently reading the same word while grasping.

Method

Participants

Twenty-eight (13 men, 15 women) healthy young adults (mean age = 24.57 ± 3.08 years) from the local Toledo, Ohio, area were voluntarily recruited to participate in the present study. All participants were blind to the purpose of the experiment. Data from 4 participants (3 men, 1 woman) could not be analyzed owing to technical difficulties. Before recruitment and experimentation, the study was approved by the Medical University of Ohio at Toledo—Institutional Review Board for human subject research. Inclusion criteria consisted of participants’ reports that they were right-handed and between ages 18 and 35 years. No past history of orthopedic conditions affecting their right upper extremities was also a requirement for inclusion. All participants were clinically observed to be neurologically intact. Each signed an informed consent form before participation.

Task and Apparatus

All tests were performed in the motor control laboratory of the occupational therapy department of the Medical University of Ohio. The laboratory setup included a table, a chair for the participants (both the table and chair were of standard height), a coaster, a bottle, a shelf, and a red disc-switch placed on the table. A laptop computer monitor was also placed on the table. Figure 1 depicts the experimental setup.

A three-dimensional movement recording system based on infrared technology (Qualisys Track Manager, QTM Version 3.0; Qualisys AB, Packhusgatan 6, S-411 13 Gothenburg, Sweden) was used to record arm, hand, and finger movements. The system used four cameras to read and detect infrared reflecting markers. Seven motion markers were used in the experiments. Six markers/sensors were placed on the participants’ right upper extremity. The first two sensors, monitoring grasp, were placed on the base of the nail of the thumb and index fingers, respectively. The third sensor, monitoring wrist movement, was placed on the second metacarpal bone of the wrist approximately 3 cm proximal to the metacarpal joint of the index finger. The fourth sensor, monitoring distal reach, was positioned approximately 1 cm proximal to the radial styloid process, and the fifth sensor, monitoring upper-extremity movement, was placed on the distal end of the humerus approximately 5 cm proximal to both the elbow and lateral epicondyle of the humerus. The sixth sensor was placed on the acromioclavicular joint to monitor shoulder stability during the action. The seventh sensor was placed on top of the bottle to monitor bottle movement during the motor task. For
the present study, movement of the fourth sensor was used to analyze the transport of the hand during the reach, lift/place, and return movements. The movements of the index finger and thumb motion markers were used to analyze the grasp. Other sensors were used to monitor stability of the hand–arm system and to isolate any confounding movements.

After reading and signing the informed consent form, participants sat on a chair in front of the table with their knees flexed to 90° and their hips in neutral position. The initial starting position (disc-switch starting position, or DS-SP) consisted of participants placing their thumb and index finger in a pinch position on the middle of the disc switch located on the midsagittal plane of the table. The distance from the middle of the switch to the edge of the table measured approximately 4 cm. A 25-cm bottle filled with water, measuring a circumference of 5.1 cm and weighing 0.3 kg, was placed on the middle of a coaster, approximately 12 cm from DS-SP. A circular shelf, sitting 11.7 cm high, was positioned at a 30° elevation from and 13.2 cm left of the coaster (see Figure 1). These distances were adapted after Gentilucci, Negrotti, and Gangitano (1997) and have been observed, during previous studies and our own pilot studies, to be performed comfortably with the hand and arm without the participant leaning forward.

A laptop monitor also was placed on the table, positioned just behind the coaster (see Figure 1). Presentation slides were displayed on the monitor throughout the experiment. Five task-related words were randomly displayed on the laptop monitor, along with a control condition. Before each word appeared, there was a slide instructing the participant to read the word either aloud or silently. A white screen with a solid black box in the middle served as the control condition. There were 11 conditions: (a) read silently reach; (b) read aloud reach; (c) read silently grasp; (d) read aloud grasp; (e) read silently lift; (f) read aloud lift; (g) read silently place; (h) read aloud place; (i) read silently return; (j) read aloud return; (k) control. A custom-made, computer-generated randomization was used. Each participant had a unique counterbalanced randomization design of the 11 conditions generated by Random Allocation Software, Version 1.0.0. Table 1 depicts the unique counterbalanced sequence for a representative participant. All conditions were performed three times by each participant, for a total of 33 times.

### Procedure

The primary researcher and one co-researcher were both present to prepare the setup and the computer system. The room lights were dimmed during the procedure. Only the primary researcher explained the procedure to each participant. Each participant was instructed to sit at a comfortable distance from the table so that when completing the task he or she did not have to lean forward at the waist. All participants used their right hand to complete the motor task. The participants were first connected to the EMG electrodes and required to reach toward the bottle and shelf to ensure that they could reach without restriction from the wires. The headset used to record speech was applied next. Participants were asked to speak into the microphone to ensure proper recording.

Participants were given specific instructions for performing the motor task. First, they were instructed to place the ulnar side of their hand on the red disc-switch so that it was depressed, making sure also to place their thumb and index finger in a pinch position before initiating each trial (DS-SP). Their left hand was to remain resting on their lap. Participants were informed that presentation slides would appear before them on the laptop monitor in sets of three. The instruction slide would read “read aloud” (RA) or “read silently” (RS), or would show a black rectangular box on a white screen (control condition). It was explained that the
instruction slide would appear for only a few seconds and would then dissolve into a second slide. This second slide would either display the task-related word in bold black print or, in the case of the control condition, a blank white screen would appear. The final slide would be a black screen, and on seeing this screen, participants were to return the bottle to the start position on the coaster and return their hand to the DS-SP.

After receiving procedural instructions, participants were given one practice trial of each condition. They were told that the word hi would appear as the second slide during the practice trial but that different words would appear during the actual experiment. Participants were instructed to read the word as instructed and then initiate the task as soon as their reading was finished.

For each trial, participants were required to reach and grasp the bottle (sitting on the coaster) with their right hand and then lift, transport, and place it onto the shelf at a comfortable pace. Participants were then to return their right hand to the DS-SP. The task-related word was displayed on the computer monitor until the participant completed the movement.

Data Processing and Analysis
The marker data was digitized at a rate of 120 Hz, using the Qualisys Track Manager (QTM) motion capture system, which has been found to be reliable and accurate for motion capture measurements within 1 mm. Before each experiment, the instrument was calibrated and checked for accuracy according to the system manual. During acquisition, the QTM took real-time two-dimensional camera information, and processed and converted it into three-dimensional using advanced algorithms. During the experiment the data was stored in C3D format for off-line analysis.

The movement data was filtered by a custom routine build by the Visual 3D software (C-motion Analysis, Inc., 15821-A Crabbs Branch Way, Rockville, MD 20855). The routine was used to filter the data using a second-order Butterworth filter with forward and backward passes at a low-pass cutoff frequency of 6 Hz. The movement data was digitally differentiated to obtain movement velocity profile. From the velocity data, each movement was divided and extracted into three segments: an initial reach segment, a middle lift-and-place segment, and a final return segment. Transverse (X), forward (Y), and upward (Z) movement components from each of these three segments were extracted. The start and stop of each segment was defined from the magnitude of the resolved vector of the movement. The resolved vector produced three defined velocity peaks for the three segments. From these three velocity profiles, the start and stop of a segment was defined as the velocity of a segment exceeded and decreased to 4 mm/s. The velocity of the wrist was taken as criterion velocity to define the start and stop of a segment because, in pilot analysis, wrist velocity was found to be maximally consistent to apply the custom routine. In case of missing data, a linear spline in the Qualisys program was applied to interpolate the missing data up to 10 points. Only 5% of analyzed data required interpolation. Other sensors’ data did not require interpolation. Trials with missing data of more than 10 points in the thumb data were not analyzed.

Once the X, Y, and Z components of the reach, lift/place, and return segments were isolated, peak velocities of each component were extracted for kinematic comparisons. The time required to reach, lift/place, and return was calculated by subtracting stop time from start time of each segment. For the present study, the dependent variables were each segment time and the principal velocity components of each segment.

For the reach phase, the components were Y (forward movement) and Z (upward movement). For the lift phase, X (horizontal movement) and Z (upward movement) were analyzed. In the return phase, X (horizontal movement), Y (forward movement), and Z (upward movement) were analyzed. The grip aperture phase was studied through two kinematic parameters: maximal grasp aperture and peak grasp aperture velocity. Such directional component analyses were necessary to isolate the semantic effect on the specific direction of the movement (Gentilucci, 2003).

A one-way repeated measure analysis of variance (ANOVA) was used to test the significance of kinematic parameters between the 11 levels of speech/language conditions to test hypotheses (a) and (b). Pair-wise comparisons after significant findings from the ANOVA were performed to test hypotheses (c) and (d). Additionally, a standard time-series analysis of different components of reach and grasp actions was performed to examine the performance.

Results
Reach Segment
Table 2 shows the effects of the 10 task-related words and the control (no speech) condition on the mean values of the reach parameters. The one-way ANOVA results showed a significant effect of speech factors on the reach time (REACH_Time), forward peak-velocity component (PV [Y]), and upward peak-velocity component (PV [Z]). Post hoc pair-wise comparison revealed that, compared to control condition, the time taken to complete the reach component of the motor task was significantly decreased in the condition where the participants read aloud the word reach.
presented on the laptop monitor. In addition, compared to the control condition, the forward (PV [Y]) and upward (PV [Z]) peak-velocity components increased significantly in the condition where the participants read aloud reach, and the upward peak velocity also increased significantly in the condition where participants read aloud lift. Kinematic parameters in the other speech conditions were not significantly different compared to the control condition, and there were no significant differences between the read aloud (RA) and read silently (RS) conditions of the five presented words.

**Lift Segment**

Table 3 shows the effects of the 10 task-related words and the control (no speech) condition on the mean values of the lift/place parameters. The one-way ANOVA results showed a significant effect of speech factors on the lift/place time (LIFT/PLACE _Time) and the upward peak-velocity component (PV [Z]), but no significant effect of speech was shown on the transverse peak-velocity component (PV [X]). Post hoc pair-wise comparison revealed that compared to control condition, the time taken to complete the lift/place component of the motor task was significantly decreased in the condition where the participants read aloud and read silently the words reach, lift, and place presented on the laptop monitor. In addition, compared to the control condition, the upward (PV [Z]) peak velocity component increased significantly in the condition where participants read aloud reach, lift, and place presented on the monitor. Kinematic parameters in the other speech conditions

<table>
<thead>
<tr>
<th>TASK CONDITION</th>
<th>REACH_TIME</th>
<th>PV (Y)</th>
<th>PV (Z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROL</td>
<td>0.903 (0.185)</td>
<td>1.165 (0.187)</td>
<td>0.650 (0.133)</td>
</tr>
<tr>
<td>RS_REACH</td>
<td>0.860 (0.162)</td>
<td>1.216 (0.161)</td>
<td>0.654 (0.178)</td>
</tr>
<tr>
<td>RA_REACH</td>
<td>0.784 (0.140)*</td>
<td>1.375 (0.144)*</td>
<td>0.694 (0.154)*</td>
</tr>
<tr>
<td>RS_LIFT</td>
<td>0.909 (0.174)</td>
<td>1.154 (0.171)</td>
<td>0.646 (0.160)</td>
</tr>
<tr>
<td>RA_LIFT</td>
<td>0.910 (0.272)</td>
<td>1.162 (0.193)</td>
<td>0.705 (0.196)*</td>
</tr>
<tr>
<td>RS_PLACE</td>
<td>0.909 (0.167)</td>
<td>1.156 (0.178)</td>
<td>0.642 (0.168)</td>
</tr>
<tr>
<td>RA_PLACE</td>
<td>0.864 (0.1200)</td>
<td>1.167 (0.202)</td>
<td>0.684 (0.173)</td>
</tr>
<tr>
<td>RS_RETURN</td>
<td>0.884 (0.169)</td>
<td>1.136 (0.194)</td>
<td>0.646 (0.148)</td>
</tr>
<tr>
<td>RA_RETURN</td>
<td>0.877 (0.138)</td>
<td>1.186 (0.172)</td>
<td>0.665 (0.150)</td>
</tr>
<tr>
<td>RS_GRASP</td>
<td>0.885 (0.180)</td>
<td>1.171 (0.190)</td>
<td>0.644 (0.144)</td>
</tr>
<tr>
<td>RA_GRASP</td>
<td>0.845 (0.158)</td>
<td>1.162 (0.189)</td>
<td>0.688 (0.195)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TASK CONDITION</th>
<th>LIFT/PLACE_TIME</th>
<th>PV (X)</th>
<th>PV (Z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROL</td>
<td>1.151 (0.299)</td>
<td>-1.028 (0.169)</td>
<td>1.051 (0.213)</td>
</tr>
<tr>
<td>RS_REACH</td>
<td>1.085 (0.208)*</td>
<td>-1.007 (0.173)</td>
<td>1.067 (0.207)</td>
</tr>
<tr>
<td>RA_REACH</td>
<td>0.981 (0.190)*</td>
<td>-1.038 (0.180)</td>
<td>1.107 (0.181)*</td>
</tr>
<tr>
<td>RS_LIFT</td>
<td>1.057 (0.202)*</td>
<td>-1.020 (0.177)</td>
<td>1.048 (0.179)</td>
</tr>
<tr>
<td>RA_LIFT</td>
<td>0.957 (0.211)*</td>
<td>-1.048 (0.195)</td>
<td>1.138 (0.233)*</td>
</tr>
<tr>
<td>RS_PLACE</td>
<td>1.041 (0.174)*</td>
<td>-1.029 (0.181)</td>
<td>1.073 (0.167)</td>
</tr>
<tr>
<td>RA_PLACE</td>
<td>1.011 (0.180)*</td>
<td>-1.041 (0.183)</td>
<td>1.113 (0.186)*</td>
</tr>
<tr>
<td>RS_RETURN</td>
<td>1.095 (0.200)</td>
<td>-1.039 (0.165)</td>
<td>1.054 (0.174)</td>
</tr>
<tr>
<td>RA_RETURN</td>
<td>1.040 (0.188)</td>
<td>-1.042 (0.186)</td>
<td>1.103 (0.186)</td>
</tr>
<tr>
<td>RS_GRASP</td>
<td>1.088 (0.190)</td>
<td>-0.999 (0.128)</td>
<td>1.050 (0.149)</td>
</tr>
<tr>
<td>RA_GRASP</td>
<td>1.093 (0.243)</td>
<td>-1.053 (0.175)</td>
<td>1.094 (0.196)</td>
</tr>
</tbody>
</table>

Note: df = degree of freedom (10, 230). In pair-wise comparisons, means within columns are significantly different from CONTROL at least p = .05. Control = no speech condition; RS_ = read silently condition; RA_ = read aloud condition; effect size; Lift/Place Time = time taken to complete lift/place component; PV (Y) = peak reach velocity in forward direction; PV (Z) = peak reach velocity in upward direction; m/s = meters per second; F = ANOVA statistic.
were not significantly different compared to the control condition. Furthermore, there were no significant differences between the RA and RS conditions of the five presented words.

**Return Segment**

Table 4 shows the effects of the 10 task-related words and the control (no speech) condition on the mean values of return time (RETURN_TIME) and peak velocity for the return component. The one-way ANOVA results showed no significant effect of speech factors on return time, transverse peak-velocity components (PV [X]), forward peak-velocity components (PV [Y]), or upward peak-velocity components (PV [Z]). There also was no significant difference between the RA and RS conditions of the word return.

**Grasp Segment**

Table 5 shows the effects of the 10 task-related words and the control (no speech) condition on the mean values of the grasp parameters. The one-way ANOVA results showed a significant effect of speech factors on both the maximum grasp aperture (MAX_GRASP_APERTURE) and the transverse peak velocity (PV [X]). Post hoc pair-wise comparison revealed that, compared to control condition, the maximum grasp aperture for participants was significantly increased in the conditions where participants read aloud the words place and grasp. In addition, compared to the control condition, the transverse (PV [X]) component of peak velocity increased significantly in the condition where the participants read aloud the word grasp. Kinematic parameters in the other speech conditions were not significantly different compared to the control condition. Also, there were no significant differences between the RA and RS conditions of the five presented words.

**Discussion**

The present study was guided by two purposes: first, to investigate whether performance during a specific segment of a motor task is influenced by reading aloud or silently a segment-specific action word, and second, if such an influence on performance exists, to determine whether reading aloud a printed segment-specific word influences performance differently than silently reading the same word. The hypotheses were formed on the basis of these two purposes. The first two hypotheses addressed the transport components (reach, place, return), and the third and fourth hypotheses addressed the grasp components of the reach-grasp motor task.

The first hypothesis is supported in part: The movement times were shorter compared to the control conditions for both the reach and lift/place segments of the reach–grasp motor task when participants read aloud and silently task-specific words. The movement time of the reach segment in particular was influenced only when participants read aloud the word reach; however, the lift/place segment was influenced not only when participants read aloud and silently the words lift and place, but also when they read aloud and silently other task-related words. In addition, the forward peak-velocity component (PV [Y]) for the reach segment and the upward peak-velocity components (PV [Z]) for both the reach and lift/place segments were higher only when participants read aloud task-specific words. Movement time and peak velocities for the return

| Table 4. Results for Return Components Separated by Speech Factors |
|---------------------------------|----------------|----------------|----------------|----------------|
| **TASK CONDITION**             | RETURN_TIME  | PV (X) (m/s)  | PV (Y) (m/s)  | PV (Z) (m/s)  |
| CONTROL                        | 1.143 (0.234) | 1.245 (0.221) | -1.261 (0.213) | -1.002 (0.226) |
| RS_REACH                       | 1.127 (0.261) | 1.243 (0.247) | -1.234 (0.193) | -0.996 (0.289) |
| RA_REACH                       | 1.105 (0.227) | 1.225 (0.233) | -1.253 (0.232) | -1.028 (0.265) |
| RS_LIFT                        | 1.187 (0.180) | 1.289 (0.191) | -1.291 (0.180) | -0.984 (0.189) |
| RA_LIFT                        | 1.124 (0.185) | 1.311 (0.248) | -1.266 (0.194) | -1.058 (0.262) |
| RS_PLACE                       | 1.154 (0.203) | 1.265 (0.174) | -1.262 (0.187) | -0.992 (0.185) |
| RA_PLACE                       | 1.132 (0.197) | 1.263 (0.167) | -1.234 (0.206) | -1.018 (0.220) |
| RS_RETURN                      | 1.160 (0.202) | 1.223 (0.210) | -1.224 (0.194) | -0.944 (0.211) |
| RA_RETURN                      | 1.144 (0.190) | 1.290 (0.199) | -1.282 (0.199) | -1.010 (0.210) |
| RS_GRASP                       | 1.115 (0.227) | 1.221 (0.173) | -1.230 (0.219) | -0.940 (0.171) |
| RA_GRASP                       | 1.122 (0.253) | 1.237 (0.208) | -1.214 (0.244) | -0.954 (0.243) |

*p = 0.381*  
*p = 0.178*  
*p = 0.777*  
*p = 1.166*  

*Denotes significance.

Note. df = degree of freedom (10, 230). In pair-wise comparisons, means within columns are significantly different from CONTROL at least p < 0.05. Control = no speech condition; RS_ = read silently condition; RA_ = read aloud condition; r = effect size; RETURN_TIME = time taken to complete return component; PV (X) = peak return velocity in the transverse direction; PV (Y) = peak return velocity in the backward direction; PV (Z) = peak return velocity in upward direction; m/s = meters per second; F = ANOVA statistic.
The second hypothesis was supported in that the greatest effect was focused on the main purpose of the motor performance—the lift/place segment. The other components that preceded and followed could be considered adjunct components necessary only to allow the person to complete the entire motor performance. Such findings indicate that if one wants to affect performance through language, one must use words that are related to the main purpose of the performance.

In addition to the language-based effect on a specific task segment, the findings of the present study suggest that there is also an overall semantic effect on performance. For most of the segments, with the exception of the return segment, the segment-related words read by participants significantly influenced one or more of the kinematic variables, which signifies that meaningful (i.e., performance-congruent) speech can be used to facilitate performance.

Pulvermuller (1999) proposed that words are represented in the brain by a distributed interactive functional neuronal network (or cell assemblies) that connects the neural map representing a word’s meaning (sensory perception) and the neural map representing a word’s content (motor action). In these regards, action words (or verbs) are especially important because they form the semantic links between the motor programs and language elements (Glover & Dixon, 2002; Pulvermuller, 2005). Action words are learned in the context of actions; for example, a mother tells her child “eat,” and often performs the action. The child listens to the action word, observes the action, and eventually eats or performs the action of eating. In other words, “neurons related to a word form become active together with neurons related to perceptions and actions reflecting aspects of its meaning” (Pulvermuller, 1999, p. 260). Repeated activation of this kind of language–perception–action cell assembly leads to permanent higher order assembly, which can be stimulated by any sufficient part of the cell assembly. Thus, for example, visually seeing the word reach (perception) or saying the word reach would ignite cell assembly governing “reach” action. Major support for this theory comes from a recent fMRI study (Hauk, Johnsrude, & Pulvermuller, 2004). In
this study, researchers first recorded the fMRI of the somatotopic activation area in the cortex of participants following tongue, finger, and foot movements. Then the same participants silently read action words that related to the face, arm, and leg. Similar patterns of category-specific somatotopic activation close to and overlapping with the motor and premotor representations of the tongue, fingers, and feet, respectively, were observed. Theoretically, then, these cell assemblies have strong internal word perception–action networks, and once stimulated they can produce action automatically without much dependence on attention (Pulvermuller, 2005). The results of the present study support this theory.

**Implications for Occupational Therapy**

Occupational therapists use unique and creative tasks to treat people with physical or cognitive decline. The tasks often are designed by altering the context to make the task meaningful to the client. The underlying assumption is that enhanced meaningfulness will motivate the client to perform the task and will lead to more functional and satisfying performance of the daily task. Overall, this study established that reading task-related words positively influences upper-extremity task performance, possibly by enhancing the meaningfulness of the task. The results of the present study suggest that using action-specific words may enhance one’s movement. Thus, using action words to cognitively cue or prime tasks during treatment with people with various disabilities, such as stroke, may enhance the patient’s relearning abilities. Rizzolatti and Arbib (1998) stated that Broca’s area becomes active in clients who have recovered from subcortical infarctions when they are asked to use their paralyzed hand. Thus, displaying action words such as *reach, grasp*, or *lift* on a paper or simply on the object during practicing a reaching or grasping task not only will force the patients to read these words to cognitively cue them to move, but also will cognitively focus them to the task. Standard outcome measures such as the Assessment of Motor and Process Skills (Fisher, 2003a, 2003b) could then be used to assess the improvement of the motor skill. In the line of cell assembly hypothesis, it also is important to remember that repeated incorporation of language may eventually produce permanent changes in the brain in the form of plasticity, which will be reflected in the occupational behavior, a goal of rehabilitation process.

**Limitations**

Multiple limitations may have influenced the results of the present study. The task was performed in a laboratory environment, which is an unnatural context/occupational form. A more naturalistic environment may have elicited a more meaningful experience for participants. In addition, this study consisted of a fairly small sample size, which if increased could have increased the validity of the findings. Furthermore, although it was unavoidable, the upper-extremity performance might have been influenced by external attachments, such as reflective markers. Another limitation is the indirect evidence on motor planning. Because the current study did not measure fMRI or PET studies of brain activity, the inference on the motor planning was drawn from behavioral results; therefore, this inference is only speculative. Also, the results of this study cannot be generalized to all populations across ages, ethnicities, and geographical locations because the participant pool used in the current study was age-specific and drawn from the northwest Ohio area. Finally, the large number of trials may have produced a learning effect. This is unlikely, however, because the trials were counterbalanced and randomized.

**Recommendations for Future Research**

The current study shows that an action word related to a specific action during a task could be used to prime the action. Because the profession of occupational therapy focuses on active doing and how meaning enhances such performance, findings of the present research should be explored in more depth in different contexts pertaining to occupational therapy. Future findings also may establish more options for treatment strategies for people with impairments or disabilities requiring movement priming. For these reasons, it is vital that the present study be extended to investigate various related questions that stem from this research. These include the following:

- **Whether a priming effect exists when the action word is embedded in a sentence.** For example, it is important to find out whether the phrases *reach for the mug or reach for the pencil* have the same effect on performance.
- **Whether a pseudo-word such as *dreach* or *treach* has a similar priming effect as the word reach**
- **Whether a priming effect on motor performance of general action words such as *view or wake* is possible**
- **Whether the priming effect that a word has on an action is possible with people with degenerative diseases such as Parkinson’s disease or arthritis**
- **Whether words should be displayed continuously or at a frequency**
- **Relative to clinical population, whether factors such as impact of motivation, different sizes and weights of the objects, placement accuracy, and ability to generalize to other tasks could be investigated.**
Thus, the present research leads to various alternative possibilities that need confirmation by further research to establish a rehabilitative strategy involving language and action.

Results of the current study suggest that when words pertaining to a specific motor performance are presented visually just before the performance, the performance can be influenced. For instance, when participants in the current study read aloud the word reach, both the movement time and peak velocity for the reach segment of the motor performance were significantly faster and higher, respectively, than when no word was read. However, when the word return was read aloud, the performance was not altered significantly during the return segment. In addition, the lift/place segment of the reach–grasp motor task was influenced by the reading aloud and silently of more than just the segment-specific words lift and place. Therefore, it can be concluded that the participants in this study did perceive the lift/place component of the reach–place task to be the core segment. It also can be assumed that the semantic influence of the visually presented, action-related words remained throughout most of the movement sequence because the participants were young and likely had adequate or above-adequate sensory–perceptual processing capabilities. It would be interesting to see whether such a semantic effect is present throughout the movement in a population of older adults; such findings could be applied during occupational therapy interventions. Occupational therapists could use words that are both task related and semantically congruent to enhance the meaning of the occupational performance for each client. ▲

Acknowledgments

This work is part of the first author’s scholarly project. The authors sincerely thank the School of Nursing/School of Allied Health at the Medical University of Ohio (now the University of Toledo) for the 2003 Research Support Award to the first author.

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