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Abstract

The present study's purpose was to examine the effects of semantic priming in persons who stutter (PWS) and persons who do not stutter (PWNS) upon the aperture motor performance of the thumb and index finger during a reach and grasp task. Seven PWS and seven PWNS were recruited and matched on age, gender, and handedness. Participants reached for, grasped, and lifted a water bottle to place it on a shelf before returning their hand to the initial position under three conditions: reading a task-related word aloud prior to movement, reading a task-related word silently prior to movement, or not reading a word. Task-related words (i.e., *reach, grasp, lift*, *place*, *return*) were randomized and counterbalanced such that each participant experienced a total of 33 trials. Overall, results were not statistically significant (p<.05). Neither peak grasp aperture velocity nor maximum grasp aperture was significantly different from control in read aloud or read silently conditions of the word *grasp*. Additionally, these measures were not significantly different when comparing read aloud and read silently *grasp* conditions to one another. However, there were significant differences when comparing PWS to PWNS on maximum grasp aperture, but not peak grasp aperture velocity, in the read aloud *reach* and read silently *place* conditions. Statistically nonsignificant results should be considered within the body of preceding research. Previous findings suggest positive effects of semantic priming; the inconsistency of the present study's results to prior research justifies further exploration of semantic priming and its utility in occupational therapy.

Semantic Priming of Motor Performance in Persons Who Stutter:

Effects on Grasp Aperture in a Reaching Occupation

Introduction

Occupational therapists help people live fuller lives through enhanced engagement in occupations perceived as being meaningful and purposeful. To facilitate greater engagement and function, occupational therapists analyze the process of occupational performance, including how a client interprets the occupational form and finds meaning. Many occupations involve the upper-extremity; consequently, upper-extremity motor performance is crucial to functioning and is of great interest to occupational therapists (Hill, Dunn, Dunning, & Page, 2011; Houwink, Roorda, Smits, Molenaar, & Geurts, 2011; Rice, Alaimo, & Cook, 1999; Tebben & Thomas, 2004). If an occupational therapist finds ways to make an upper-extremity occupation more meaningful to a client, it is believed that motor performance can be enhanced. In the Conceptual Framework of Occupational Therapy, meaning is a person's subjective attempt to make sense of the occupational form perceptually, symbolically, and affectively (Nelson, 1997). By changing the physical and sociocultural dimensions of an occupational form, changes may occur in the meanings the form elicits. For example, if a person is reaching for and lifting an object, an increase in the size of that object may influence the person's discernment of perceptual meaning such that his or her neurological system may recruit more muscle fibers to perform the lift.

Enhanced Meaning through Occupational Embeddedness

Since the profession's beginning, occupational therapists have been synthesizing meaningful occupations for their clients. Instead of using simple rote exercise to strengthen upper extremities, early occupational therapists provided more meaning to patients by engaging them in curative shops (Wish-Baratz, 1989). Here, clients were provided with tangible products, useful industrial occupations, and social interactions, all of which enriched clients' experiences and increased the purpose perceived in therapy. Today, occupational therapists still use occupationally embedded exercise to elicit greater meanings and improve clients' engagement in therapy and participation in life.

Sometimes, clients experience reluctance to initiate therapy. In these cases, occupational therapists implement creative methods to introduce opportunities for clients to find enhanced meaning and therefore greater purpose to participate. In a sample of 52 elderly nursing home residents, 36 of them chose to unilaterally dunk a small ball into a basketball hoop instead of choosing to unilaterally flex the shoulder in rote exercise (Zimmerer-Branum & Nelson, 1995). The familiarity and enhanced meaning the residents found in dunking a basketball provided greater motivation to take part in therapy.

In addition to increased initiation of therapy, occupationally embedded exercise can lead to greater exercise repetitions and performances during therapy (Hsieh, Nelson, Smith, & Peterson, 1996). People with hemiplegia performed significantly more exercise repetitions when bending down, picking up a ball, and tossing the ball into a cut-out face target than when they performed these rote motions without instructions to imagine the ball or the target (Hsieh et al., 1996). Perhaps the ball and target helped participants recall enjoyable memories or simply provided a distraction from exercise, giving them more motivation to complete the task. Regardless of the exact cause, the addition of the ball and target allowed subjects to elicit more meaning and purpose from the occupation, leading to superior performances.

Semantic Priming

A newer line of research involving meaning in occupational therapy involves using contextually relevant words to alter symbolic meaning, which in turn alters motor performance

(Gentilucci, Benuzzi, Bertolani, Daprati, & Gangitano, 2000; Gentilucci & Gangitano, 1998; Glover, Rosenbaum, Graham, & Dixon, 2004; Grossi, Maitra, & Rice, 2007). This practice is called semantic priming and is closely related to semantic priming in linguistics, an effect which allows a person to recognize a word more quickly when a semantically related primer word precedes it (Friederici, Steinhauer, & Frisch, 1999).

For instance, during a reach-grasp occupation, motor performances of young adults vary according to the size-related meaning of nouns presented at the start of the occupation (Glover et al., 2004). Glover et al. (2004) found that words representing larger objects (e.g., *apple*) led to larger grasp apertures than words representing smaller objects (e.g., *grape*).

Similarly, in a study done by Gentilucci et al. (2000), which made use of Italian adjectives, Italian young adults' reaches were faster and grasp aperture velocities greater in the presence of the word *far* while reaches were slower and grasp aperture velocities smaller in the presence of the word *near*. In addition, peak velocities and accelerations were greater in the presence of the word *high* than in the presence of the word *low* (Gentilucci et al., 2000). The authors surmised that the printed adjectives activated appropriate motor planning because of the subconscious meaning participants assigned to those words. Interestingly, motor planning was less directly influenced by adjectives, (i.e., *low* or *high*) than by their semantically equivalent adverbs (i.e., *down* or *up*) (Gentilucci et al., 2000). When asked in a questionnaire, participants were more likely to respond that they associated the presented adjectives, rather than the presented adverbs, with object properties (Gentilucci et al., 2000). This is likely because in language, adjectives describe nouns. In contrast, adverbs describe verbs, which are often motor actions. Therefore, reading adverbs over adjectives elicits meanings that more directly affect motor planning (Gentilucci et al., 2000).

More recent studies have looked at the effects of semantic priming using task-related verbs. One of these is a study by Grossi et al. (2007), which analyzed the effects of reading aloud and silent task-related verbs (i.e., *reach, grasp, lift, place, return*) prior to initiation of a reach-grasp motor performance. Reach, lift, and return times and velocities were compared between aloud and silent reading conditions, as were measurements of grasp aperture velocity and magnitude. Semantic priming conditions, which were expected to elicit more meaning, were also compared to a rote reach-grasp control condition. Due to an expected elicitation of greater meaning, Grossi et al. hypothesized that reading task-specific words aloud would cause greater performances than reading silently, and that reading either aloud or silently would cause greater performances than control conditions. Specifically, Grossi et al. hypothesized that reading the words *reach, lift, place,* and *return* would decrease movement times and increase peak velocity within these respective segments of the occupation. Grossi et al. also hypothesized that reading the word *grasp* would lead to greater grasp aperture velocities.

Results from this study partially supported the two hypotheses dealing with the grasp segment of the occupation. In comparison to control conditions, participants had higher grasp aperture velocities and larger maximum grasp apertures when they read aloud the word *grasp*. However, no performance differences existed in comparison to control conditions when participants read silently the word *grasp*. When comparing aloud and silent semantic priming conditions, the hypothesis was fully supported: maximum grasp aperture was larger and grasp aperture velocity was higher when reading aloud the word *grasp* versus reading it silently. In an unexpected finding, differences in aperture performance also existed when participants read aloud the word *place.* Overall, results do support previous semantic priming findings that suggest language can be used as a cognitive cue to increase motor performance, probably because of the increased meaning language elicits. Language, specifically the meaning action words elicit, can semantically influence motor programs and facilitate enhanced performance (Grossi et al., 2007).

Speech and Motor Production

Adding to the effects of speech-related meaning on movement, speech and motor production areas functionally overlap in the brain; language production and motor performance mutually, directly affect one another (Cappa & Pulvermuller, 2012; Gentilucci & Dalla Volta, 2008). Broca's and Wernicke's areas have traditionally been considered the neurological centers responsible for speech production and comprehension, respectively (Benson, 1979; Mohr, 1976). Recently, however, research has discovered that additional brain regions beyond Broca's and Wernicke's areas are active during speech and that conversely, Broca's and Wernicke's areas play a role in motor performance, not just speech performance (Hauk, Johnsrude, & Pulvermuller, 2004). Cortical activation, as studied by positron emission tomography during speech production, suggests that motor processes are also involved in the comprehension of speech, and therefore in the formation of subjective meanings of speech (Wise et al., 1991).

Moreover, event-related functional magnetic resonance imaging (fMRI) has shown that simply reading upper-extremity action words activates the cortical motor strip that is normally associated with upper-extremity movement, demonstrating that the interpretation of action words appears to correlate somatotopically to motor and premotor areas (Hauk et al., 2004). Further demonstrating the somatotopic correlation between motor and language brain regions, transcranial magnetic stimulation (TMS) applied to arm and leg motor areas influences the processing of arm and leg action words differentially. For example, stimulation on the motor area associated with the arm leads to faster cortical responses to arm-associated action words compared to leg-associated action words (Pulvermuller, Hauk, Nikulin, & Ilmoniemi, 2005).

The results of another TMS study shed light on the influence of timing and hand dominance on the language-motor connection. Meister et al. (2003) found that the activity of the primary motor hand area in the language dominant-hemisphere is increased during a reading aloud task but not directly before or after, suggesting meaning elicited by language has a time component (Meister et al., 2003). When TMS was applied to the primary motor hand area in the language non-dominant hemisphere, the same hemisphere containing the motor control center of the non-dominant hand, cortical activity remained unchanged (Meister et al., 2003).

Speech and Motor Production in Persons Who Stutter

Both structurally and functionally, it has been found that speech and motor areas of the brain are different in PWS than in PWNS (Chang, Kenney, Loucks, & Ludlow, 2009; Watkins, Smith, Davis, & Howell, 2008; Xuan et al., 2012). For instance, during perception of speech, fMRI has shown that compared to PWNS, PWS consistently show less blood oxygen level-dependent responses in the bilateral superior temporal gyrus, where Wernicke's area is located, and in the bilateral precentral motor gyrus (Chang et al., 2009). Amplitude of low-frequency fluctuation, another measure of brain activity, is decreased in the supplementary motor areas and precentral gyrus of PWS, again suggesting that stuttering is a speech disorder that is involved in non-speech motor function (Xuan et al., 2012). These differences in brain activity are accompanied by differences in structure. Using diffusion tensor imaging, structural reductions in the white matter connections underlying both speech and non-speech motor areas have been detected in PWS (Watkins et al., 2008).

Likely because of these functional and structural differences, motor performances in PWS are qualitatively different than in PWNS. Reproducing varying rhythmic patterns is more difficult for PWS, as is reproducing unpredictable digit sequences (Hunsley, 1937; Webster, 1986). For example, during a digit key-tapping task requiring imitation of rapid sequences presented on a visual display, male PWS perform fewer correct sequences and make more errors than male PWNS (Webster, 1986). Additionally, PWS exhibit slower motor initiation and slower manual reaction times (Webster, 1986; Webster & Ryan, 1991; Smits-Bandstra, De Nil, & Saint-Cyr, 2006). This likelihood of poorer sequential performance as well as slower motor initiation times in PWS suggests that stuttering is not a simple motor problem but rather a higher level organizational problem (Webster, 1986).

As such, it is conceivable that PWS may experience motor planning and motor control issues with volitional movement of the upper extremities, such as a reach-grasp occupation. In PWNS, semantically appropriate word verbalization is associated with more successful motor performances in terms of acceleration, velocities, grasp apertures, and duration, probably because more meaning is elicited and appropriate motor programs are activated during semantic retrieval (Grossi et al., 2007; Fargier, Menoret, Boulenger, Nazir, & Paulignan, 2012). If occupational therapists can encourage similar elicitation of greater meaning in PWS during motor tasks, performances may be enhanced. It is probable, as suggested by research in PWNS, that increased meaning may be elicited in PWS through the use of semantic priming.

Purpose

This study examined the effects of semantic priming in PWS and PWNS during the grasp portion of a reach, lift, place, and return occupation. It was built upon the study conducted by Grossi et al. (2007). The following hypotheses were explored:

a. In PWS and PWNS, peak grasp aperture velocity and grasp aperture magnitude will be greater when participants read either aloud or silently the word *grasp* prior to grasping for a bottle.

b. In PWS and PWNS, peak grasp aperture velocity and grasp aperture magnitude will be greater when participants read aloud the word *grasp* prior to grasping for the bottle as compared to silently reading *grasp*.

c. PWS will demonstrate different movement strategies from PWNS.

Method

Participants

The Biomedical Institutional Review Board of The University of Toledo approved this study prior to recruitment and experimentation. The general inclusion criteria included participants between the ages of 12 and 35 years and negative history of orthopedic or neurological conditions that interfere with the ability to perform a reach motor task. Individuals attending the summer Stuttering Clinic at the sponsoring university were invited to participate in the study via advertisement fliers and word of mouth. In addition, age, gender, and handedness matched fluent-speaking participants were recruited to volunteer through advertisement fliers, word of mouth, and email from the northwest Ohio and southeast Michigan areas. Based on the Grossi et al. (2007) results for peak velocity using the standard deviation of 0.144 m/s, α of 0.05, and β of 0.8, an *n* of 5 pairs was assumed to generate enough statistical power to reach a significant mean difference of approximately 0.21 m/s. Therefore, it was planned that 15 PWS and 15 PWNS would be recruited.

Task and Apparatus

The Motor Control Laboratory of the Occupational Therapy program at The University of Toledo served as the setting for the experiment. Initial laboratory setup consisted of an adjustable height table, standard height chair, coaster, water-filled bottle (approximate dimensions: 25 cm height, 5 cm circumference, 0.3 kg), circular shelf (12 cm height), Big Red Switch®, and laptop monitor for delivering the independent variable conditions.

Eight Owl Motion Analysis cameras (Motion Analysis Corporation, 3617 Westwind Blvd., Santa Rosa, CA 95403) recorded data from seven motion sensors using Cortex (version 4.0.0.1387) data acquisition software.

Procedure

This study obtained approval from the Biomedical Institutional Review Board at The University of Toledo. Furthermore, informed consent was obtained prior to any data collection. Data collection occurred from July 2013 to February 2014. While semantic priming practice may be included in speech therapy, the following procedures are wholly for research purposes.

Reflective motion sensors were placed on the participant's upper extremity and upper body. Specifically, grasp was monitored by two sensors placed at the base of the thumbnail and index fingernail of the dominant hand. The third sensor was placed on the second metacarpal bone of the dominant hand approximately 3 cm proximal to the metacarpal joint of the index finger to monitor wrist movement. Distal reach was monitored by the fourth sensor positioned approximately 1 cm proximal to the radial styloid process of the dominant wrist. The fifth sensor placed on the distal end of the humerus of the dominant upper extremity approximately 5 cm proximal to both the elbow and lateral epicondyle of the humerus monitored upper extremity movement. The sixth sensor monitored shoulder stability via placement on the acromioclavicular joint on the dominant side. The seventh sensor placed on top of the bottle monitored bottle movement.

The task took place with the participants seated at the table with feet flat on the floor and knees at approximately 90°. Participants assumed the disc-switch starting position (DS-SP) by approximating the thumb and index finger to form a two-point pinch while resting the hand in the middle of the Big Red Switch® about 4 cm from the edge of the table. The water-filled bottle was centered on a coaster approximately 12 cm from the DS-SP, and the circular shelf was located 13 cm left of the coaster at 30° of elevation.

A television positioned on the wall in front of the participant presented an instruction slide (*Read aloud* or *Read silently*) followed by a slide containing one of five task-related words for each trial. A control condition was prompted by the presentation of a white screen with a solid black box in the middle. The following 11 conditions were presented to each participant three times for a total of 33 trials: (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*, and (k) control. Randomized, counterbalanced sequences for condition presentation were generated by RAPB software (version 1.0, The University of Toledo University, 2801 W. Bancroft St., Toledo, OH 43606).

To ensure participants did not bend forward at the waist while completing the procedure, each participant was instructed to sit at a comfortable distance from the table. They were instructed to sit with their backs always touching the seat back, not moving their upper bodies during the motor task. All participants used their dominant hand to complete the motor task.

Participants were given specific procedural instructions to perform the motor task properly. They were instructed to place the ulnar side of their dominant hand on the Big Red Switch®, making sure to depress the switch, and place their thumb and index finger in a pinch position prior to initiating each trial (DS-SP). The non-dominant hand remained resting in the lap. Participants were informed that presentation slides would appear before them in sets of three on a laptop monitor positioned just behind the coaster. An instruction slide read, “Read aloud”

(RA) or “Read silently” (RS), or a white screen with a black rectangular box (control condition) appeared. The instruction slide appeared for only a few seconds and will then dissolved into a second slide. The second slide either displayed the task-related word to be read in bold black print or a blank white screen appeared during the control condition. Participants were instructed to read the task-related word slide, initiate the motor task as soon as reading was finished, and return their hand to the DS-SP at the conclusion of the motor task. A speech-recording microphone was used to ensure participant adherence to the research RA/RS protocol and to account for the fluency of speech.

After receiving instructions, participants were given one practice trial of each condition. They were told that the word *hi* would appear on the second slide during the practice trial but that different words would appear during the actual experiment. For each condition, participants were required to reach and grasp the bottle and then lift, transport, and place it onto the shelf at a comfortable pace. They were then required to return their dominant hand to the DS-SP. The task-related word was displayed on the television until the participant completed the movement.

Data Processing and Analysis

Motion was captured at 120 Hz, using the Owl Digital RealTime System. The system was calibrated and checked for accuracy prior to each experiment session in accordance with the system manual. A custom routine build by Visual3D software version 4.96.10 (C-Motion, Inc., 20030 Century Blvd, Suite 104A, Germantown, MD 20874) filtered the data using a second-order Butterworth filter with dual passes at a low-pass cutoff frequency of 6 Hz. The reduced data was analyzed by IBM SPSS statistical software version 19.

Movement data were allocated into three segments (reach, lift-place, return) by analyzing movement velocity profiles. A segment was defined from the magnitude of the resolved vector of the movement based on wrist velocity. Transverse (X), forward (Y), and upward (Z) components were extracted from each segment. If data were missing, a linear spline was applied to interpolate the missing data up to 10 points. Trials missing more than 10 points of data were not analyzed.

The following components were analyzed for the indicated segment: Y and Z axes for reach; X and Z axes for lift; and X and Z axes for return. Maximum grasp aperture and peak grasp aperture velocity will be considered the primary dependent variables.

Hypotheses were tested using a one-way repeated measure analysis of variance (ANOVA) to determine the significance of kinematic parameters among the 11 conditions, and follow-up simple contrast with reference to control will be used to investigate further. Additionally, post hoc least squares differences multiple comparisons after significant findings from the ANOVA were used to compare the read aloud and read silently conditions and determine the significance of differences for all parameters between PWS and PWNS.

Results

Grasp Segment

The overall repeated measures ANOVA revealed no statistically significant results for peak grasp aperture velocity or for maximum grasp aperture (Table 1). Additionally, planned follow-up simple contrasts show there were no statistically significant differences on peak grasp aperture velocity or maximum grasp aperture in any of the conditions compared with the control condition except for the maximum grasp aperture comparison of read aloud *reach* (Table 2). Furthermore, there were no statistically significant interactions for peak grasp aperture velocity or maximum grasp aperture between condition and group (i.e., PWS or PWNS) when compared to control except for in the peak grasp aperture velocity read silently *grasp* condition (Table 2). Based on these results, the first hypothesis (a) was not supported.

The overall ANOVA revealed no statistically significant results when comparing the read aloud versus the read silent conditions and group for peak grasp aperture velocity (Table 3). While there was a statistically significant difference in the overall ANOVA when comparing the read aloud versus the read silent conditions and group for maximum grasp aperture (Table 3), post hoc analyses revealed no statistically significant differences on maximum grasp aperture for any of the conditions when comparing read aloud to read silently for both PWS and PWNS (Table 4). Therefore, the second hypothesis (b) was not supported. Furthermore, post hoc analyses revealed no statistically significant differences when comparing PWS to PWNS on maximum grasp aperture across all conditions except for read aloud *reach* and read silently *place* (Table 5) providing only partial support for the final hypothesis (c). Figures 1 and 2 depict the peak grasp aperture velocity means and the maximum grasp aperture means, respectively.

Discussion

The purpose of this study was to explore semantic priming as it relates to occupational performance in PWS and PWNS, building on a study conducted by Grossi et al. (2007). Specifically, this study aimed to investigate whether aperture motor performance of the thumb and index finger performance during the grasp segment of a reach task is influenced by reading the word *grasp*, to determine whether reading aloud influences performance differently than reading silently, and to investigate whether PWS demonstrate different movement strategies from PWNS.

The first hypothesis (a) was not supported: compared to control conditions, there were no significant differences on peak grasp aperture velocity or maximum grasp aperture when the word *grasp* was read aloud or silently prior to grasping for a bottle. However, maximum grasp aperture was significantly greater in the read aloud *reach* condition compared to the control condition. The second hypothesis (b) was also not supported in that there were no significant differences on peak grasp aperture velocity or maximum grasp aperture when comparing the read aloud *grasp* condition to the read silently *grasp* condition for both PWS and PWNS. The third and final hypothesis (c) was partially supported in that there were significant differences when comparing PWS to PWNS on maximum grasp aperture, but not peak grasp aperture velocity, in the read aloud *reach* and read silently *place* conditions.

Semantic Priming of Aperture Motor Performance

Findings regarding the first and second hypotheses are somewhat inconsistent with previous research in semantic priming that suggest the addition of contextually relevant words alters motor performance, most likely through an alteration in symbolic meaning (Gentilucci et al., 2000; Gentilucci & Gangitano, 1998; Glover et al., 2004; Grossi et al., 2007). In particular, the findings of this study do not correspond to the outcomes of the very similar Grossi et al. (2007) study.

In the present study, peak grasp aperture velocity and maximum grasp aperture were not significantly different in the read aloud *grasp* conditions whereas the Grossi et al. (2007) study found both dependent variables to be greater when participants read the word *grasp* aloud. It is unclear why the present study, which used guiding principles and a procedure very similar to that the Grossi et al. study, did not find significant differences in read aloud *grasp* conditions. However, inconsistency in findings can perhaps be explained by the small sample size of the present study, which may not have allowed for true semantic effects to reach significance, or by slight divergences from the Grossi et al. protocol.

These protocol divergences involved an alteration of the position of the priming words and the inclusion of PWS and left-handed participants. The Grossi et al. (2007) study placed priming words on a laptop at the same level as and directly behind the bottle and shelf while the present study placed priming words on a TV screen hanging on a wall above and farther away from the bottle and shelf. By removing priming words farther from the key aspects of the occupational form (i.e., the bottle and shelf), it is possible participants perceived the words as less important and found decreased meaning, thereby limiting effects of semantic priming.

A second variation in study protocol involved the inclusion of PWS. Compared to PWNS, PWS have developmental structure differences that may impact their motor performances (Chang et al., 2009; De Nil, Kroll, Kapur, & Houle, 2000; Sato et al., 2011; Watkins et al., 2008; Xuan et al., 2012). These potential motor performance differences may have created a more heterogeneous mixture of participants than the Grossi et al. (2007) study, again restricting semantic priming effects from reaching statistically significant levels.

Similarly, inclusion of left-handed participants increased the heterogeneity of the sample. In the present study, six of the 14 participants were left-handed, a proportion much higher than that of the population at large. Left-handed individuals, like PWS, have developmental structure differences that affect motor performance. For example, left-handed individuals are more likely to have right hemisphere lateralization or bilateral cerebral involvement than right-handed individuals in both language and grasping tasks (Martin, Jacobs, & Frey, 2011; Pujol, Deus, Losilla, & Capdevila, 1999). Moreover, recent research has demonstrated that motor planning may be a specialized function of the left hemisphere in that the right hand, regardless of handedness, has advantages during motor planning (Hughes, Reissig, & Seegelke, 2011). Thus, it is possible the inclusion of left-handed individuals diversified results to further inhibit the ability of the effects of semantic priming to reach significance.

However, in accordance with the Grossi et al. (2007) study, the present study did not find differences in aperture performance when participants read the word *grasp* silently compared to control conditions. It is possible both studies revealed no significant differences because silent reading of the word *grasp* truly elicited meanings that were not great enough to impact performances. However, it is also possible the present study did not find significance due to the size and heterogeneous nature of the sample as discussed above.

In a second consistent finding, both the Grossi et al. (2007) study and the present study found maximum grasp aperture to be greater in read aloud conditions of words other than *grasp* (i.e., *place* and *reach*, respectively). Perhaps greater maximum grasp apertures during the read aloud *reach* conditions of the present study can be explained by the fact that the grasp and reach segments of the motor task occurred simultaneously (i.e., participants initiated the reach as they opened their hand to grasp the bottle). Because of this overlap in time and performance, a possible semantic overlap may exist; the meaning elicited by the word *reach* may correspond very closely to the meaning elicited by the word *grasp.* That is, when participants were thinking about reaching for the bottle, they were also thinking about opening their hand to grasp the bottle, creating a strong semantic relationship between the words *reach* and *grasp.* Therefore, the word *reach* may have effectively semantically primed participants for the grasp segment of the motor task, causing maximum grasp aperture to be greater.

Differential Aperture Motor Performances of PWS and PWNS

The final hypothesis (c) was partially supported in that some significant differences were found between PWS and PWNS. Specifically, maximum grasp aperture was significantly greater in PWS in read aloud *reach* and read silently *place* conditions.

Differences in motor performance were expected between PWS and PWNS; PWS have been found to have poorer performance on rapid sequence motor tasks, such as rapid sequential key-tapping, as well as slower initiation and reaction times than PWNS (Webster, 1986; Webster et al., 1991; Smits-Banstra et al., 2006). Such variations in motor performance are likely due to structural and functional differences that exist in brain speech and motor regions between these populations (e.g., increased language lateralization to the right hemisphere in PWS, less oxygen level-dependent responses in Wernicke's area, and decreased white matter connections and brain activity in speech and non-speech motor areas) (Chang et al., 2009; De Nil, Kroll, Kapur, & Houle, 2000; Sato et al., 2011; Watkins et al., 2008; Xuan et al., 2012). Lateralization of language processing to the right hemisphere, which commonly occurs in PWS, is correlated with a difficulty in motor planning (Hughes et al., 2011; Knecht et al., 2000; Martin et al., 2011). Moreover, decreased white matter connection in non-speech motor areas may negatively impact motor planning and subsequent motor performance.

In the present study, PWS had greater maximum grasp apertures in all conditions but differences were only significant in the read aloud *reach* and read silently *place* conditions. It is possible that due to difficulties with motor planning, PWS inaccurately judged how wide they needed to separate their thumb and index finger to grasp the bottle. Therefore, this poor planning may have resulted in inefficient motor performances and larger apertures than necessary for the occupation at hand. These postulates, regarding inefficient motor performance by PWS, are supported by anecdotal observations of participants: PWS were generally observed to have less efficient motor patterns than PWNS. Perhaps significance was revealed in only the read aloud *reach* and read silently *place* because of the sample size and heterogeneity. Effect sizes across all conditions were relatively similar within the moderate range (Table 5), suggesting that the robustness of differences was similar across conditions.

In addition to investigation of hypotheses, a significant interaction was found between the factors of group and condition on the condition of read silent. It is interesting to note that for all of the conditions, peak grasp aperture velocity is greater within the PWS group than the PWNS group except for the read silent condition of the word *grasp* (Figure 1). It is unclear as to why this was the case, but is likely the reason the interaction was statistically significant. Specifically, it is unclear why reading the word silently would differentially affect the two groups. However, a closer look at the differential performance of the two groups, specifically when the word *grasp* is read, reveals the possibility that the meaning associated with this word had a differential influence. While the peak grasp aperture velocity is uniquely greater for PWNS, the opposite is true when the word was read aloud. Nonetheless, the difference in this condition between the two populations appears to be much less than the other conditions. It is possible that reading the word *grasp* may have a greater influence on the peak grasp aperture velocity performance more so than reading the other words. Regardless, any possible influence is small and is most likely not robust.

As mentioned earlier, statistically nonsignificant findings of the first and second hypotheses and only partial support of the third hypothesis may be explained by small sample size. A power analysis conducted prior to data collection based on data from the Grossi et al. (2007) study revealed enough statistical power would likely exist if five pairs of participants were recruited. In this study, seven pairs of participants were ultimately recruited. This small sample size, only slightly larger than the sample size called for by the power analysis, may have not been sufficient to avoid Type II error. Moreover, in post hoc comparisons of PWS to PWNS on maximum grasp aperture across all conditions, medium effect sizes existed in many of the conditions in which statistical significance was not found (i.e., $.5 \leq d \leq .8$) (Sullivan & Feinn, 2012). These medium effect sizes may point to a possible Type II error. However, effect sizes in post hoc comparisons of read aloud to read silently conditions for both PWS and PWNS were all small (i.e., $d < .2$), supporting the statistically nonsignificant *p* values and suggesting that a very small magnitude of difference exists between the groups.

Further explaining statistically nonsignificant findings of the first and second hypotheses, previous studies have found that the most profound effects of semantic priming are exhibited during the main component of motor performance (Grossi et al., 2007; Maitra et al., 2003). In an occupation that requires a participant to lift a bottle onto a shelf, the main component of motor performance is just that: lifting the bottle. In contrast, grasping the bottle simply precedes the lift and can be considered an accessory component. The grasp portion of movement may be perceived as less meaningful and priming effects of the word *grasp* may not be strong enough to reach significance. Therefore, differences in aperture and aperture velocity within read aloud and read silently *grasp* conditions may not be revealed.

Illustrating this principle, the Grossi et al. (2007) study found that during the lift/place segment of movement, upward peak-velocity was greater in read aloud conditions of the words *reach, lift*, and *place* and movement time was shorter in both read aloud and read silent conditions of these same words. This segment of movement had significant differences on more dependent variables and in more appropriate conditions than both the reach/grasp or return segments. Additionally, in the Maitra et al. (2003) study, more pronounced priming effects on movement time, peak velocity, and time to peak velocity were found during the segment of movement that required participants to place the bottle on a shelf than during the reach/grasp or return segments. In the grasp portion of movement in the present study, few consistencies with previous findings were revealed. In one of these few consistencies, movement time during the lift/place segment was statistically shorter when reading silently *reach* as compared to not reading.

This replicated finding reinforces the proposal that the main component of movement, in this case the lift/place segment, is most affected by semantic priming. Statistically significant findings during the lift/place segment, as opposed to the grasp segment, may be explained by the differential meaning participants find during these segments. The grasp segment may be considered an adjunct component that is only necessary in assisting participants in completing the motor task; the most purposeful portion of movement is to lift and place the bottle. Consequently, more meaning may be found during the lift/place segment and semantic priming of the grasp portion of the task may not be as effective as priming of the most purposeful segment.

Implications for Occupational Therapy

Through the use of occupations that are personally meaningful for their clients, occupational therapists help clients more successfully engage in life. The theory that drives therapists to alter occupational forms posits that a client will perceive greater purpose and will therefore have greater performances if they find enhanced meaning. Overall, the statistically nonsignificant results of the present study suggest that reading words related to portions of a reach, grasp, lift, place, and return task do not effectively enhance meaning to therefore improve the quality of the associated motor control. However, these findings are contrary to previous evidence suggesting that semantic priming is an effective way to improve motor performance. Therefore, occupational therapists in the field should use detailed documentation as well as strong clinical reasoning skills to determine if semantic priming is a beneficial practice method for the population they work with. Displaying action words and asking clients to say action words prior to a reaching or grasping occupation may or may not cognitively cue clients to perform the movement efficiently and may focus them to the goal of the treatment session. As mentioned above, the influence of semantic priming will most likely be highly unique to individual clients; sound clinical reasoning should be employed to determine the appropriateness of semantic priming given the unique circumstances that each treatment session provides.

Limitations

Results of the present study may have been influenced by several limitations. First, the occupation was performed in a laboratory environment that was atypical of a natural occupational form. Therefore, the environment may have elicited meanings that were not typical. Second, reflective markers used for data collection were attached to participants' upper extremities and may have influenced motor performance. Additionally, it was assumed that participants had adequate sensory-perceptual processing capabilities such that the semantic influence of reading visually presented words prior to movement initiation remained throughout the entire movement sequence. Moreover, the large number of trials may have produced a learning effect. However, a randomized, counterbalanced design likely accounted for any potential influence of learning. Perhaps the largest factor limiting results was the study's small sample size, perhaps leading to Type II errors. Finally, the results cannot be generalized to all populations as the participants in this study were largely Caucasian, young-adult males from the northwest Ohio area and were much more likely to be left-handed than the population at large.

Recommendations for Future Research

The purpose of the present study was to determine if reading the word *grasp* prior to a reach-grasp motor performance would prime a person's grasp quality and to determine if a difference existed in priming and performance between PWS and PWNS. While statistical nonsignificance was found, there were a number of comparisons with medium effect sizes suggesting that Type II errors may be present. In light of this, future research should involve a larger sample size of PWNS and PWS along with age, gender, and hand dominance matching. The profession of occupational therapy is built upon using meaningful occupations as a means and an end to therapy; the present study should be extended to investigate related questions about the elicitation of meaning and effects on performance through semantic priming in both PWS and PWNS. These questions include the following:

- Whether the priming effect that a word has on an action exists if the word is embedded within a descriptive sentence (e.g., *Grasp the bottle.*)
- Whether the priming effect that a word has on an action exists if the word is said by someone other than the individual performing the action (e.g., an occupational therapist)
- Whether the priming effect that a word has on an action exists if word to be read is displayed at a frequency or continuously
- Whether the priming effect that a word has on an action exists for other actions (e.g., stand, sit, step, button, eat)
- Whether the findings of the above questions differ between PWS and PWNS

- Whether the priming effect that a word has on an action exists in people with degenerative diseases (e.g., Parkinson's disease, arthritis, multiple sclerosis) or other disabilities that affect motor control such as cerebral vascular accident

Conclusion

The purpose of this study was to explore semantic priming as it relates to occupational performance in PWS and PWNS. Specifically, this study explored the grasp component of a reaching occupation. PWS were matched to PWNS on age, gender, and handedness. In a randomized, counterbalanced design, participants engaged in an occupation that required them to reach for, lift, and place a bottle onto a shelf before returning their hand to an initial starting position under three primary conditions: reading aloud a task-related word prior to movement, reading silently a task-related word prior to movement, and reading no word prior to movement. Results were not statistically significant ($p<.05$) but medium effect sizes were noted, possibly suggesting a Type II error. These results were inconsistent with evidence that supports the influence of semantic priming on occupational performance, possibly because the present study's small sample size limited strength of results. Positive effects of semantic priming may truly exist in the population of PWS and PWNS, but the small, heterogeneous sample recruited for the present study did not express these effects. Thus, further investigation of semantic priming, its effects across populations, and its utilization within occupational therapy practice is warranted.

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Table 1.

2x11 Repeated Analyses of Variance for Peak Grasp Aperture Velocity and Maximum Grasp Aperture

Dependent Variable Source	*df*	*SS*	MS	*F*	*P*
Peak Aperture Velocity					
Within					
Condition	10	0.020	0.002	1.048	0.408
Condition*Group	10	0.035	0.004	1.827	0.063
Error	120	0.231	0.002		
Between					
Group	1	0.006	0.006	1.318	0.273
Error	12	0.052	0.004		
Maximum Grasp Aperture					
Within					
Condition	10	5.838E-05	5.838E-06	1.538	0.134
Condition*Group	10	2.089E-05	2.089E-06	0.550	0.851
Error	120	0.000	3.796E-06		
Between					
Group	1	0.000	0.000	1.318	0.273
Error	12	0.001	7.854E-05		

Notes: Alpha was set at .05

Table 2.

Follow-up Simple Contrast With the Reference to the Control Condition

Dependent Variable	*df*	*SS*	MS	*F*	*p*
Peak Aperture Velocity					
Condition					
RS_GRASP vs. CONT	1	0.000	0.000	0.156	0.700
RA_GRASP vs. CONT	1	0.012	0.012	3.256	0.096
Condition*Group					
RS_GRASP vs. CONT	1	0.015	0.015	6.283	**0.028**
RA_GRASP vs. CONT	1	0.003	0.003	0.868	0.370
Error					
RS_GRASP vs. CONT	1	0.029	0.002		
RA_GRASP vs. CONT	1	0.043	0.004		
Maximum Grasp Aperture					
Condition					
RS_REACH vs. CONT	1	7.990E-06	7.990E-06	1.010	0.335
RA_REACH vs. CONT	1	3.740E-06	3.742E-05	5.201	**0.042**
Condition*Group					
RS_REACH vs. CONT	1	3.639E-07	3.639E-07	0.046	0.834
RA_REACH vs. CONT	1	4.373E-06	4.373E-07	0.608	0.451
Error					
RS_REACH vs. CONT	1	9.492E-05	7.910E-06		
RA_REACH vs. CONT	1	8.633E-05	7.194E-06		

Notes: Alpha was set at .05; RS_ = read silently condition; RA_ = read aloud condition

Table 3.

2x11 Repeated Analysis of Variance Among Condition and Group for All Conditions

Dependent Variable Source	*df*	*SS*	MS	*F*	*p*
Peak Aperture Velocity					
Between					
Group and Condition	19	0.109	0.006	0.978	0.492
Error	120	0.703	0.006		
Total	140	17.663			
Maximum Grasp Aperture					
Between					
Group and Condition	19	0.003	0.000	1.982	**0.014**
Error	120	0.010	0.000		
Total	140	2.356			
Reach Peak Velocity X					
Between					
Group and Condition	19	0.031	0.002	0.534	0.942
Error	120	0.373	0.003		
Total	140	21.412			
Reach Peak Velocity Z					
Between					
Group and Condition	19	0.046	0.002	1.972	**0.015**
Error	120	0.148	0.001		
Total	140	6.851			
Lift Peak Velocity Y					
Between					
Group and Condition	19	0.016	0.001	0.559	0.928
Error	120	0.182	0.002		
Total	140	26.736			

Lift Peak Velocity Z					
Between					
Group and Condition	19	0.018	0.001	0.557	0.929
Error	120	0.209	0.002		
Total	140	21.656			
Return Peak Velocity X					
Between					
Group and Condition	19	0.075	0.004	0.580	0.914
Error	120	0.812	0.007		
Total	140	23.087			
Return Peak Velocity Z					
Between					
Group and Condition	19	0.021	0.001	0.196	1.000
Error	120	0.662	0.006		
Total	140	22.114			
Reach Time					
Between					
Group and Condition	19	0.120	0.006	0.217	1.000
Error	120	3.492	0.029		
Total	140	121.893			

Lift Time					
Between					
Group and Condition	19	0.115	0.006	0.217	1.000
Error	120	1.770	0.015		
Total	140	117.471			
Return Time					
Between					
Group and Condition	19	0.281	0.015	0.217	1.000
Error	120	8.174	0.068		
Total	140	193.909			

Notes: Alpha was set at .05

Table 4.

Post hoc Least Squares Differences Multiple Comparisons for Maximum Grasp Aperture

Group, Conditions	MD	SE	*p*	d
PWS, RS_REACH vs. RA_REACH	-0.002	0.005	0.744	-0.088
PWS, RS_LIFT vs. RA_LIFT	-0.001	0.005	0.890	-0.037
PWS, RS_PLACE vs. RA_PLACE	0.000	0.005	0.931	0.023
PWS, RS_RETURN vs. RA_RETURN	-0.002	0.005	0.749	-0.086
PWS, RS_GRASP vs. RA_GRASP	-0.000	0.005	0.974	-0.009
PWNS, RS_REACH vs. RA_REACH	-0.000	0.005	0.974	-0.009
PWNS, RS_LIFT vs. RA_LIFT	0.001	0.005	0.882	0.040
PWNS, RS_PLACE vs. RA_PLACE	-0.002	0.005	0.717	-0.097
PWNS, RS_RETURN vs. RA_RETURN	-0.001	0.005	0.807	-0.065
PWNS, RS_GRASP vs. RA_GRASP	-0.000	0.005	0.976	-0.008

Notes: Alpha was set at .05; PWS = Persons who stutter; PWNS = Persons who do not stutter; RS_ = read silently condition; RA_ = read aloud condition; d = effect size, Cohen's d (Piasta & Justice, 2010).

Table 5.

Post hoc Least Squares Differences Multiple Comparisons for Maximum Grasp Aperture for PWS and PWNS

Group, Condition; Group, Condition	MD	SE	*p*	d
PWS RS_REACH; PWNS RS_REACH	0.009	0.005	0.058	0.511
PWS RA_REACH; PWNS RA_REACH	0.011	0.005	**0.029**	0.602
PWS RS_LIFT; PWNS RS_LIFT	0.008	0.005	0.093	0.453
PWS RA_LIFT; PWNS RA_LIFT	0.010	0.005	0.050	0.548
PWS RS_PLACE; PWNS RS_PLACE	0.011	0.005	**0.033**	0.602
PWS RA_PLACE; PWNS RA_PLACE	0.008	0.005	0.091	0.455
PWS RS_RETURN; PWNS RS_RETURN	0.009	0.005	0.067	0.494
PWS RA_RETURN; PWNS RA_RETURN	0.009	0.005	0.057	0.515
PWS RS_GRASP; PWNS RS_GRASP	0.009	0.005	0.064	0.500
PWS RA_GRASP vs. PWNS RA_GRASP	0.009	0.005	0.063	0.501

Notes: Alpha was set at .05; PWS = Persons who stutter; PWNS = Persons who do not stutter; RS_ = read silently condition; RA_ = read aloud condition; d = effect size, Cohen's d (Piasta &Justice, 2010).

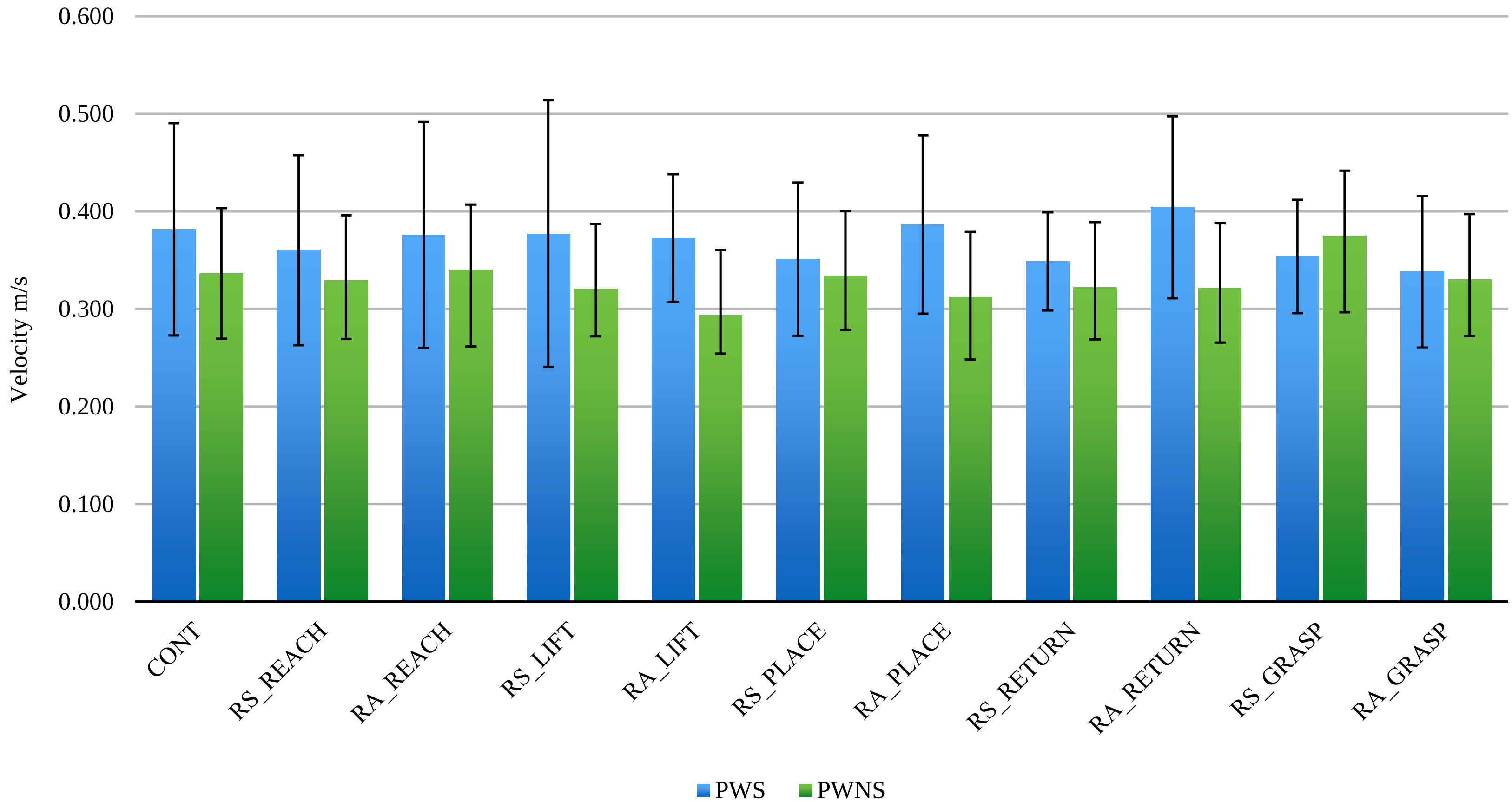

Figure 1. Peak Grasp Aperture Velocity Means; Velocity in m/s; PWS = Persons who stutter; PWNS = Persons who do not stutter; RS_ = read silently condition; RA_ = read aloud condition

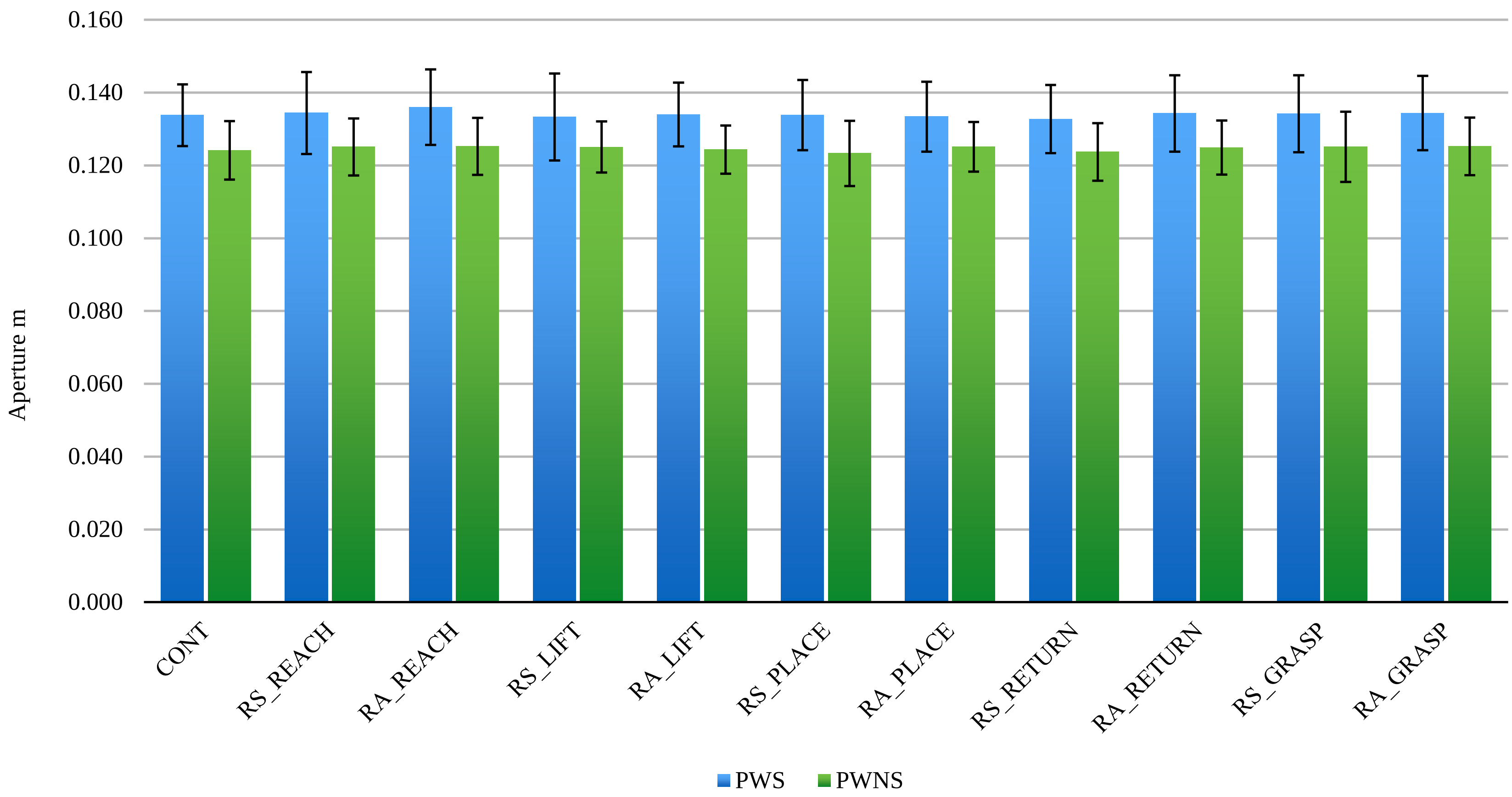

Figure 2. Maximum Grasp Aperture Means; Aperture in m; PWS = Persons who stutter; PWNS = Persons who do not stutter; RS_ = read silently condition; RA_ = read aloud condition