Semantic Modulation in a Daily Occupational Performance

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Abstract: Occupational therapy practice places extra emphasis in finding a way to influence the meaning of an object to a person, because many of our daily occupations are object related. Meaning is an interpretive cognitive process that a person undergoes when deciding on an occupational interaction with an object or form. Within the past few years, a series of studies by Gentilucci have found a priming effect of object related words on the motor performance. The purpose of the present study was to extend Gentilucci's (2003) study by adding a speech component to investigate whether the language induced effect of motor performance is further enhanced by speech production of the action congruent words. Twenty-eight adult participants either read aloud or read silently four object related words ('far', 'near', 'large', and 'small') written on a water bottle while reaching, grasping, and placing the bottle on a second spot. A movement recording and analysis system measured movements of the fingers and arm. A counterbalanced repeated measures analysis of variance, results showed a) no significant differences between reading aloud and reading silently conditions b) grasping aperture was significantly larger when participants read 'large' and reaching was significantly faster when participants read 'far' on the bottle. No other significance was found. The results indicated that it is possible to cognitively prime an occupational performance by using object or action congruent words in a specific manner. Occupational therapists might incorporate action congruent words as a priming cue to enhance performance of their clients.

Introduction

Occupational therapists are interested in finding a way to influence the meaning of an object, because the majority of our daily occupations are object related. These objects are a major part of our occupational form. An occupational form is defined as the set of physical and sociocultural circumstances, external to the person, at a particular time. The occupational form guides, structures, or suggests how a person should interact with an object [1].

For example, drinking tea from a cup that is used everyday would be different than drinking tea from fine china. A person drinking tea from an everyday cup may not show care towards how they pick up the cup to take a drink. However, when a person uses fine china, they will probably show much care in how they move to pick up the cup to take a drink. The tea in the cup may be the same, but the person extracts meaning from the fine china cup (it's breakable, it's a family heirloom) and may show more caution in their movements when drinking from the cup. Thus, before interacting with an object, a person extracts meaning and purpose for the upcoming occupation. Meaning is an interpretive cognitive process that a person undergoes when deciding on an occupation [1]. Our cognitive interpretation of object characteristics is language based [2]. We assign words to interpret objects or object's characteristics. For example, window, floor and fan are all labels given to objects in the environment. White window or round fan describes the object's characteristics. Through studying the way in which people interpret the meaning of an object, not only could it help us to understand the action they take toward the object but also it could help us to influence an action made by the person towards that object. The object properties can be extrinsic or intrinsic. The intrinsic properties would be the temperature, shape, or texture of an object. The extrinsic properties would be where the object is in relation to the person or the environment. For example, is the book on a desk, on a shelf, within arms reach, or is it across the room? When reaching for an object, these properties of the object influence the action.

Neurological and motor control researchers have shown that the central nervous system (CNS) goes through cognitive programming before making an action or a movement. Within the past few years a series of studies by Gentilucci and other group [3,4,5] have found priming of this cognitive programming is possible. Priming is a way in which the meaning and movement planning before the movement is made can be influenced, which is then reflected in the movement (occupational performance). Gentilucci (2000) showed that language (words) could be used to prime cognitive programming by manipulating the properties of an object (occupational form) without physically changing the object [4]. In his studies, participants completed a reaching/grasping task with a block while they read silently words like 'near', 'far', 'small', and 'large'. Results of the study were that subjects had reached faster in the presence of a block with the word 'far' on it, than in the presence of a block with the word 'near'. Also, peak velocity of finger aperture and maximal finger aperture (grasp) increased in the presence of the word 'large' compared to the word 'small'.

In another study by Gentilucci (2003), participants were given an object with a word or a non-word visible to the participant [4]. The words given were "high", "low" (adjectives), or "place", "lift" (verbs). Participants were instructed to reach out and grasp the object, and move it to the opposite side of the table as fast as they could. This movement was to be done quickly, but without compromising accuracy. For the reach, peak velocity was found to significantly increase when the word "place" was the word on the target object, as compared to "lift" or the non-word was on the target. The movement in the placing component of the task was found to be more efficient if the word "lift" was printed on the target compared to the word "place" or the non-word. In a neurophysiological level, it was found that the premotor cortex (area for planning movement) and Broca's area (area for language production) are activated simultaneously during hand movement [3]. Studies using PET scans have also shown that Broca's area becomes activated during both execution and observation of hand and arm movements [5, 6]. Broca's area is a part of the brain, usually in the left hemisphere that plans the movement of the mouth for speaking [7] or speech production. With the findings in these studies, it could be thought that speech production might also affect motor performance. Along with speech production, another part of speech is speech comprehension. This part of speech could include comprehending other's speech in spoken or written form, or understanding gestures. Wernike's area is responsible for the language component of speech comprehension. A research study done by Floel et al. (2003) assessed the effects of language in gestures and the areas of the brain that were excited, especially those of the hand muscle representation by transcranial magnetic stimulation [8]. They found that the hand motor system was activated by language tasks. Maitra and his group recently conducted a series of study to measure the effects of linguistic and nonlinguistic words that were either silently read or read aloud before a sequential reach-grasp-lift task in young and older adults [9, 10]. Two sets of experiments were conducted each with two age groups. In one set of experiments, five action words (reach, grasp, place, lift, and return) and a control condition (blank screen) appeared on a display monitor following an instruction of either read aloud or read silently. This created 11 word conditions. After either reading the word aloud or silently, the participants had to perform a sequential motor task that consisted of reaching for a water filled bottle, grasping and lifting it, placing it on a simulated cabinet, then returning to the initial position. Results showed that pre-reading of the word 'reach' was the only condition that increased the reaching velocity and reduced the reaching time. Only the action words reach, lift, and place influenced the lift components positively. Return components were not affected by any words. Similar experiments with older adults revealed an effect of only the word 'reach' on reach components. The effects of words on lift and return components were not seen. As expected from literature, older adults were slower in overall performances as compared to younger adults. In a second set of experiments, a separate group of young and older adults performed the same task after pre-reading silently or reading aloud the non-linguistic word "GA". No movement priming effects were seen from this non-word in either the young or older adults (tables not shown). Also, in all conditions no significant differences ($p < 0.05$) were found between silently reading and reading aloud conditions [11]. Thus, these results suggest that action words indeed influence the specific action congruent with the word meaning. And the action word 'reach' influences only the 'reach component' in young as well as older adults. Further, the effect of reading action words seems to have a temporal limit. Thus, reading 'lift' influenced the specific action of lifting which is occurring as a second element in a movement sequence ~1 sec after uttering the word. However, reading the 'return' did not influence the 'return' component which the third action in the sequence and happened approximately 2-2.5 seconds after uttering the word. Interestingly, in older adults this temporal limit was reduced to the first segment only. The first line of research in neurology and motor control shows that language used in cognitive programming can be used to change properties of an occupational form. The second line of studies in brain research shows that the language and motor areas of the brain are in some way connected. This leads to the possibility that the speech and language and motor center might be functionally connected. So if we can use language to change properties of an occupational form, and language and motor areas are connected then can we use language and properties of the occupational form to facilitate occupational performance during therapy?

Hypotheses: It is hypothesized that a) there will be significant mean differences in reaching and grasping parameters for different levels of read aloud and read silently speech conditions, b) there will be significant mean differences in reaching parameters between Near and Far speech condition, and c) there will be significant mean differences in grasping parameters between Large and Small speech condition The results are expected to formulate a line of therapeutic strategies to increase meaning via speech and language mechanisms in affecting occupational performance.

Method

Study design

One way within subject repeated measure ANOVA design was used. Participants were randomly assigned to either the "read aloud" or "read silently" group for the first half of the experiment. Once assigned to a group, the participant was then randomly assigned to one of the following conditions: ABCD, BCDA, CDAB, or DABC. A, B, C, and D represent the four words: "far" "near" "large" and "small" respectively.

Participants

In this study, twenty-eight healthy young adults (18-26 years of age), without disabilities, were voluntarily recruited from the local Toledo area. The group consisted of 10 males and 18 females. Inclusion criteria for participation was that the participants report that they have 20/20 vision with or without corrective lenses, are right hand dominant, and are without physical or cognitive impairment. To test for cognitive status, the adults completed the Mini Mental Status Examination (MMSE) prior to participation in the study. The participants had to score within the range of 26-30 on the MMSE to ensure that they were cognitively sound [12]. Right-handedness was assessed through the Edinburgh Inventory. Also, prior to participating in the study, each participant signed an informed consent form approved by the Medical University of Ohio-Institutional Review Board for human participant research. The participant was blind to the purpose and experimental hypotheses of the experiment. When requested, a debriefing was done after the experiment.

Task and Apparatus

This experiment was completed in the motion analysis laboratory in the occupational therapy department at the Medical University of Ohio. The laboratory staging area included a table, a chair for the participant, a coaster, a shelf, a bottle, and a red disc switch (DS).

Three motion sensors were used to track the reaching and grasping movements. The first two were placed on the fingernail of the thumb and index finger of the participant's right hand. The third sensor was placed about 1 centimeter proximal to the wrist on the radial side of the right forearm. The index and thumb markers were used to measure grasping movements. The wrist marker was used to measure the reaching movement.Participants sat on a chair facing the table, with their hips and knees flexed at 90 degrees and their trunks in neutral position. They started by placing their index finger and thumb of their right hand on a red disc switch that will represent the start position (DS-SP). The disc was 15 cm from the edge of the table closest to the participant, in the sagittal axis of the participant . 4 kg bottle filled with water was placed on a coaster 12cm from DS-SP. An 11.7 cm by 13.2 cm shelf was on the table. The shelf was elevated 30 degrees from the table and 20 cm to the left of the coaster. The place where the water bottle was moved to (the ending position) is 20 cm from the bottle's starting location on the opposite side of the participant's sagittal axis. The measurements of the starting location, placement of the object, and ending location of the object were adapted from Gentilluci [4]. Figure 1 is a picture of the experimental set-up. The words 'far', 'near', 'large', and 'small' were displayed in a counterbalanced randomized manner on the water bottle. The letters were written with black marker on the side of the bottle with each letter in the word approximately 1.0"tall, and 0.75" wide in all lowercase letters. In a series of trials, the participant was asked to move the water bottle from its initial position to a final location. A picture of the bottles used in this experiment is provided in Figure 2. A 3-D movement recording system (Qualisys Version 3.0) was used to record the participant's arm, hand, and finger movements. Four cameras read and detected infrared reflecting motion sensors.

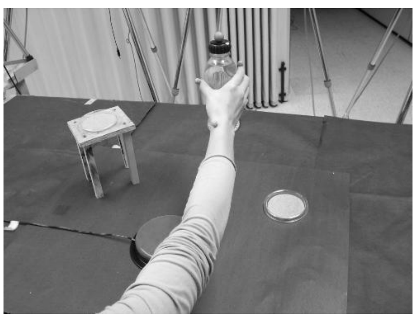

Figure 1. The figure shows the task of reaching, coaster to a simulated table on the left. The red disc switch is the initial position where participants rested their hands as the initial positions.

Figure 2. The picture showing 4 different bottles with words written on them and one bottle without any word that served as a control.

Procedure

Participants used their right arm to perform the reaching-grasping task in this study. Their left arm remained in their lap. When the researchers said "begin," the participant was asked to move their right hand from the start position to the object, grasp the water bottle, move the bottle to the ending position, then return their hand to the DS-SP (Fig 1). The participants were asked to perform the task in one action. The participant was asked to either read aloud (speech production) or read silently (speech comprehension) the object related word written on the water bottle while reaching grasping, and placing the bottle on a second spot for the first half of the experiment. The participant was then asked to complete the second half of the experiment with the read aloud or read silently variable opposite to the variable that was used for the first half.

Data Processing

The sensor data was digitized at a rate of 120 Hz through the Qualisys Track Manager (QTM Version 3.0). The research on this system has found it to be reliable and accurate for recording motion measurements within 1 mm. During the acquisition, the QTM took 2D camera information and processed and converted it into 3D using advanced algorithms. Data was stored for off-line analysis using Visual 3D Origin analytical software Version 7.0 (OriginLab Corporation, One Roundhouse Plaza, Northampton, MA 01060).

Data Analysis

For reaching, the kinematic variables of reach time, peak velocity of the reaching movement, and percentage of time to achieve peak velocity were analyzed in this study. These kinematic variables were analyzed to determine the efficiency and quality of the transport. Reach time was calculated as the time the hand leaves the DS-SP to the time that the hand touches the bottle. Peak velocity was the maximum height of velocity profile.

For grasping, maximal grasp aperture, maximal speed of opening the grasp aperture, and time to achieve maximal grasp aperture were calculated. Grasp aperture was calculated by subtracting the index signal from the thumb signal. The resultant signal was named as grasp aperture signal. The kinematics variables were extracted from this grasp aperture signal.

Results

Overall One Way within subjects repeated measures ANOVA did not differ significantly in any of the reaching and grasping parameters between read aloud and read silently conditions. Thus the hypothesis 1 was not supported. Therefore, read aloud and read silently data were pooled and five factors of speech condition were created for one way repeated measure ANOVA to assess the hypothesis 2 and 3. These five task- related conditions are control, far, near, large, and small.

Reach segment

Table 1 shows the effects of the four task-related words and the control (no speech) condition on the mean values of the reach parameters. The one-way within subject repeated measure ANOVA results showed a significant effect of speech factors on the peak velocity of reach $F(4,56)=9.129$, $p=0.0001$, $\eta^2=0.39$, but not on reach time $F(4,56)=0.271$, $p=0.895$, $\eta^2=0.01$or on the percentage of time to achieve peak velocity $F(4,56)=0.782$, $p=0.542$, $\eta^2=0.05$. Post hoc pair wise comparison revealed that, peak velocity of reach was significantly increased ($p<0.05$) in ‘FAR’ (i.e., participants reached after reading ‘FAR’) condition compared to other conditions.

Table 1.Means, and Standard Deviation for REACH Segments Separated by *SPEECH facto*

	REACH_TIME (sec)	PV_RCH (m/s)	%TPV_RCH (%)
CONTROL	0.446 (0.07)	0.906 (0.109)	0.470 (0.030)
FAR	0.456 (0.07)	**0.997 (0.137)***	0.479 (0.037)
NEAR	0.455 (0.07)	0.900 (0.091)	0.467 (0.031)
LARGE	0.445 (0.07)	0.910 (0.121)	0.483 (0.050)
SMALL	0.446 (0.08)	0.928 (0.122)	0.475 (0.052)

Note: (* denotes significance). In pairwise comparisons means within columns are significantly different from CONTROL at least $p \leq .05$. Standard Deviations appear in parenthesis beside means. Control = no speech condition, Reach Time= Time taken to complete reach component, PV_RCH = Peak reach velocity, and %TPV_RCH = Percentage of movement time

Grasp Segment

Table 2 shows the effects of the ten 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 maximum grasp aperture $F(4,56)=4.837$, $p=0.002$, $\eta^2=0.25$ but not on the velocity of grasp $F(4,56)=0.118$, $p=0.976$, $\eta^2=0.008$ or time to reach maximum grasp velocity $F(4,56)=0.477$, $p=0.753$, $\eta^2=0.03$. Post hoc pair wise comparison revealed that, Maximum grasp aperture was significantly larger ($p<0.05$) in 'LARGE' (i.e., participants reached and grasped after reading 'LARGE') condition compared to other conditions.

Table 2. Means, and Standard Deviation for GRASP Segments Separated by *SPEECH factors*

	MAX_GRASP (m)	MAX_GR_SPD (m/s)	TPV_GRASP (s)
CONTROL	0.096 (0.01)	0.906 (0.114)	0.091 (0.040)
FAR	0.095 (0.01)	0.913 (0.173)	0.099 (0.038)
NEAR	0.091 (0.02)	0.925 (0.147)	0.098 (0.041)
LARGE	**0.108 (0.02)***	0.920 (0.228)	0.104 (0.037)
SMALL	0.097 (0.01)	0.896 (0.179)	0.108 (0.045)

Note:(*denotes significance). In pairwise comparisons means within columns are significantly different from CONTROL at least $p \leq .05$. Standard Deviations appear in parenthesis beside means. Control = no speech condition, Max_Grasp= Maximum Grasp Aperture, MAX_GR_SPD = Peak

Discussion

The first hypothesis that there would be significant mean differences in reaching and grasping parameters for different levels of read aloud and read silently speech conditions was not supported by this research. It was thought there would be a difference in the read aloud and read silently conditions because of the results of earlier studies done at the Medical University of Ohio by Maitra and his group. During the previous studies, participants were asked to move a bottle while reading action words, such as "reach," "grasp," and "lift". They found an equivocal difference between read aloud and read silently conditions in their studies [9, 10, 11]. An explanation of this difference may be that the action words (used in the previous studies) are more important than the adjectives used in this study. The adjectives may have had a milder effect on reading aloud vs. reading silently conditions.

The second hypothesis stated that there will be significant mean differences in reaching parameters between 'Near' and 'Far' speech conditions. This hypothesis was supported in that there was statistical significance in the reach time when the word far was read before reaching for the bottle. And the third hypothesis stated that there would be significant mean differences in grasping parameters between Large and Small speech condition. This hypothesis was supported in that the maximum reach aperture was greatest when the word far was read before reaching for the bottle.

Thus the present study essentially produced two important observations that the participants had larger grasp aperture after reading words 'large' that signifies large objects and reaching speed was higher after reading words 'Far' that signifies a distantly placed object. These results are consistent with the proposed idea that motor tendencies or priming of motor planning are interfered with action congruent words [13]. These results also further suggest that planning of an action depends on the perception about the context and certainly semantics can be used to alter such perception [4, 13]. The present study also supported the results of a similar study by Gentilucci [3]. Like our results, Gentilucci also found that the reach time was the fastest when the word far was presented and maximum finger grasp aperature was the greatest when the word large was presented. As suggested by Glover et al [13], that semantic effects on motor action can be explained by an extension of the idea of affordances proposed by Gibson (1979). Thus, possibly, the action congruent words may activate perceptual affordances as can be assumed to be activated by seeing a 'large' object or an object placed at a 'far' distance. Therefore, an extension of the present study might suggest that not only the word, but also other congruent sensory influence through audition, olfaction, vision, or combined semantic multi-sensory influence could also activate motor affordances. Such a hypothesis from motor control literature along with the present study can provide evidential support to the notion of 'meaning' in occupational therapy. Thus multi-sensory aspects of ‘meaning’ perceiving from an occupational form can elicit affordances or motor tendencies related to the form, thereby can enhance occupational performance [1].

Thus in summary, this study adds to growing body of literature that suggests that motor planning can be influenced by perceptual and cognitive variables and contextual word can be used to influence these variables.

Limitations

We recognize that there are limitations to the study. One limitation is the generalizability of the results to other populations. Because subjects were recruited from a small geographic area that is homogeneously populated, the results cannot be generalized to other geographic locations and ethnicities. Similarly, the results cannot be generalized to all ages, because the subjects were from the ages of 18-26. Another limitation is the non-naturalistic environment that was used for this study. This study was conducted in the Motion Analysis lab in the basement of the Collier Building on the campus of the Medical University of Ohio. Also, sensors were used which may have affected how the person reached and grasped the bottles. The research subjects participated in this study at various times during the day. Since the study was not completed at the same time for each participant, the results might have been affected. A third limitation to this study was the bottles for each condition of the task were presented for three consecutive times. If the participant realized this during the study, they were no longer blind to the word on the next bottle.

Implications

A central aspect of occupational therapy treatment is to enhance the ‘meaning’ of occupations to the client so that they can be engaged in the occupation with interest and motivation. The present research indicates that ‘meaning’ is made up of a set of perceptual and cognitive variables that can affect the occupational performance. Performance congruent words can be used to influence the meaning associated with the performance. A practical implication of this study into the therapy would be to label different objects with their properties including the actions to be performed with those objects. This will provide cognitive priming or cueing to the participants to enable them to interact with the object. This approach might be especially helpful with a client population having cognitive decline or difficulty.

Acknowledgements

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 University of Toledo for the Research Support Award to KL. Authors also wish to thank the participants for their support.

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