THE PENNSYLVANIA STATE UNIVERSITY
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DEPARTMENT OF PSYCHOLOGY

WORD GENERATION AFFECTS HAND MOVEMENTS BUT NOT THE REVERSE

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ABSTRACT

Past research has shown that cognitive and perceptual-motor activities affect one another, but progress in this area has been hampered by the lack of continuous measures of perceptual-motor activity. To address this need, I compared performance on a word generation task and a continuous hand movement task. I studied each task on its own and combined with the other. The word generation task was to generate words for categories that were either superordinate (e.g., animals) or subordinate (e.g., reptiles). The hand movement task was to move a small cart back and forth on a track. Participants (N=10) performed 5 trials of each task on its own and in combination. Trials took 1 minute and were tested in a random order per participant. The results revealed that the word generation task significantly interfered with the hand movement task, but not vice versa. Participants generated more words in the superordinate (broad) categories than the subordinate (narrow) categories, but this effect was uninfluenced by moving the hand or not. By contrast, moving the hand showed different patterns depending on whether or not the word generation task was carried out at the same time. This study shows the power of the approach taken here, which could apply to the analysis of neurodegenerative diseases, among other practical concerns.

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INTRODUCTION

General Background

Past research has found evidence that when two tasks are performed concurrently, an impairment in performance is present. Researchers have come to identify such an impairment as dual-task interference. This interference has been hypothesized to result from a competition among the different brain areas used in the tasks for common attention resources or information processing mechanisms (Klingberg & Roland, 1997). Through this competition and “cross-talk,” researchers believe that the different brain regions interact with each other when multiple tasks are being performed simultaneously. However, the exact mechanisms underlying these interactions remain unclear.

Cognitive and motor performances are two tasks that are commonly studied in the dual-task interference field (Bridenbaugh, Monsch, & Kressig, 2012; Hall, Echt, Wolf, & Rogers, 2011). Often, simple cognitive tasks such as counting numbers or reciting the alphabet are paired together with walking tasks. The task of walking is one of the most popular gross motor tasks used besides a full body balance task (Rodriguez, McCabe, Nocera, & Reilly, 2012). In the walking task, gait is studied in terms of stride pattern, length, and speed. To the best of my knowledge, much research has been conducted on gross motor performances in dual-task studies, with less focus on fine motor performances. Experiments that have been conducted with finer motor movement tasks commonly involved individual finger motions such as those present in finger tapping and peg moving tests (Bishop, 2002; Hermes et al., 2012; Rodriguez et al., 2012).

Fine motor performances are of great importance due to the wide array of activities that people’s hands and arms engage in on a daily basis. Due to such activities, the previously mentioned finger motion tasks are not adequate to provide knowledge of how fine motor movements that involve the entire hand, as well as forearms, behave in multitask situations. Therefore, an adaptation of the common walking procedure to an analogous hand movement task was of great interest in the present research to further challenge the perceptual-motor system in dual-task studies. I reasoned that with suitable recording equipment, it might be possible to obtain more refined, and so more sensitive, measures of performance than are possible with larger scaled gait studies. In addition, finer motor tasks are not restricted to individuals who can walk or researchers with access to gait labs, but essentially, can be performed by any person with functioning upper body movement capabilities who may or may not be fully ambulatory.

Purpose

To obtain a better understanding of the interactions among different brain regions during the concurrent execution of multiple tasks, the present research used a dual-task set up in which a cognitive task was combined with a perceptual-motor task. In the word generation (cognitive) task, participants were asked to generate words of superordinate (broad) and subordinate (narrow) categories. In the hand movement (perceptual-motor) task, participants were asked to move a small cart back and forth on a linear track. Each task was studied on its own and with the other.

The question of interest was whether the cognitive task would be affected by the motor task, whether the motor task would be affected by the cognitive task, both, or neither. The overarching hypothesis was that if interferences are present upon the simultaneous execution of a word generation task and hand movement task, then cognitive and motor functions use common resources. Interferences were coded as any differences in the number of words generated and/or motor movement performances that were present in the combined task but not in the individual tasks.

If cognitive and motor functions rely on similar resources, performance in the individual tasks should be worse or better when each is performed simultaneously with the other than when each is performed independently. This is because in the combined task, it is hypothesized that the two tasks are competing for the same limited resources and thus each task receives less resources in the presence of another task than when it is performed by itself, when essentially, all resources are available to that individual task. This idea reflects the general resources accounts theory, which states that most tasks draw upon a general pool of similar cognitive resources (Kail & Salthouse, 1994; Salthouse, 1996). Therefore, interferences that may be present during the combined task condition could reflect a shortage of available cognitive resources (Kahneman, 1973). Since the availability of the resources is altered in the combined task condition, performance in this task should vary, either in a positive or negative manner, from the performance in the respective individual tasks. Furthermore, even if the resources required by multiple tasks are available in the brain, they may or may not be able to meet the needs of concurrent demands when necessary. This idea is often referred to as the task coordination accounts, which may explain interferences in the combined task condition to reflect an inability of proper resource allocation and delivery to the concurrent tasks at hand (Kramer, Larish, Weber, & Bardell, 1999).

Conversely, if cognitive and motor functions do not rely on the same resources, the individual tasks' performance should be no worse or better when each is performed together with the other than when each is performed independently.

METHOD

Participants

The participants were 10 Penn State undergraduates (7 female, 3 male, 8 right-handers), all of whom signed a consent form for this study, which was approved by the university's Institutional Review Board.

Procedure

Participants performed three tasks: pure word generation (G), pure motor (M), and combined word generation and motor (GM) in 5 trials per task in a random order per participant. Each task's trials were randomized among other tasks' trials, providing a mix of all three tasks throughout the entirety of the experiment per participant.

Pure Word Generation (G) Task

The pure word generation task took the form of a verbal fluency test. This test is a cognitive test in which participants are asked to say as many words as possible corresponding to a given category in a specific amount of time (Rohrer et al., 1995). The categories used here were at the superordinate level (animals, activities, countries, food), and at the associated subordinate level (reptiles, water activities, US state capitals, fruits). All participants were assigned the same 4 superordinate categories and their 4 associated subordinate categories. The superordinate and subordinate categories were not split among participants to prevent the effect of individual differences from skewing the results. By having each participant generate words in all the superordinate and their corresponding subordinate categories, differences that arise would be attributable to the two different category levels themselves and not to external factors that may vary among participants.

Each trial lasted 1 minute. Participants carried out the word generation task with their hands folded on their lap while sitting at the apparatus used in the M task and GM task, described below.

Pure Motor (M) Task

In the pure motor task, participants sat at a table and moved a small, low-friction cart on a linear track back and forth past two wooden dowels located behind the track and separated, end to end, by a distance of 20 cm (Figure 1). Participants could use whichever hand they preferred (the same one throughout the experiment) and could move at whatever speed they wished. Each trial lasted 1 minute.

Combined Word Generation and Motor (GM) Task

Here, participants performed the pure motor and pure word generation tasks simultaneously. Each trial lasted 1 minute.

For all three tasks, a 12 second pre-recording time period, in which the motion sensor was turned on, but no data were being recorded, was given per trial to each participant. During this initial time period, respective task type and word category directions were read to the participants. For trials that involved motor movement, participants were reminded at the start of each trial to move back and forth in a continuous manner while making sure to clear the wooden dowel at each end. For trials that involved word generation, participants were reminded at the start of each trial to generate as many words as they could that correspond to the given category. At the end of the pre-recording period, participants were verbally told to start the trial. The pre-recording time period was incorporated into the experiment to standardize the data recording and collection procedures, making sure that each participant started at the same time per trial. The recording timer was programmed to record for 1 minute, after the 12 second pre-recording time period, and then stop. All of the data recording and timing procedures were controlled via the DataStudio Software on a computer, as described below.

Apparatus and Data Collection

The linear track was one used in physics classes. The linear track used here was the 2.2 meter PAScar Dynamics System ME-6956 aluminum track. The cart that rode the track was the nearly frictionless Collision Cart ME-9454. The Motion Sensor II Cl-6742A was used to record the cart's position on the air track. The motion sensor's recorded data was collected and transmitted to a computer via the ScienceWorkshop 500 Interface Cl-6400. The DataStudio Software was used to display and analyze the collected data on the computer in addition to controlling the data recording and timing procedures. All experimental equipment was purchased from PASCO® (Roseville, California).

The motion sensor was attached to the left end of the air track and data were recorded at a rate of 100 Hz. The electrostatic transducer in the sensor transmitted a burst of ultrasonic pulses (16 pulses in a burst) at a frequency of 49 kHz. The sensor was set on the "Narrow Beam" setting to record distances from 15 cm to 2 m. The recorded position data were differentiated once with respect to time to give velocity data and twice with respect to time to give acceleration data. This was done with the DataStudio Software provided by PASCO®.

Performance in all conditions was recorded with a webcam and a microphone. The webcam was mounted on the wall behind the track, directly in front of the participant. Audio and video data were recorded for all trials.

Data Analyses

For the kinematic (movement) data, basic parameters including range of motion, average velocity, and duration of movement were used to test for differences between the M and GM conditions. Differences were studied in terms of the collected raw data as well as additional mathematical manipulations of these data. Performance analyses, in terms of movement smoothness, were studied via jerk integral calculations. Variance ratio analyses were used to study the morphologies of kinematic waveforms. To study the time variability among movement cycles, coefficients of variation were analyzed.

For the word generation data, the number of words generated in the verbal fluency tests was analyzed for differences between the G and GM conditions as well as between the superordinate and subordinate categories.

All data in the experiment were analyzed for statistical significance. Measures of statistical analyses included paired t-tests, 3-way ANOVA, and repeated measures ANOVA, in which $p < .05$ was designated as being significant. For the basic movement parameters as well as the jerk integral calculations, the average of all 5 trials was calculated separately for the M and GM conditions for each participant. The average of all participants' averages in each task condition was then used to perform the test of statistical significance. The difference in time between movement cycles in all the trials corresponding to each of the M and GM conditions was independently averaged to one value for each condition per participant. The average of all participants' averages in each task condition was used to perform the paired t-test in the analysis of coefficient of variation.

For the word generation data, the sum of the number of words generated in each of the G and GM conditions was calculated. Similarly, the sum of the number of words generated in each of the superordinate and subordinate categories was calculated. These sums were then used in the repeated measures ANOVA analysis.

RESULTS

Word Generation

The word generation data are summarized in Tables 1 (unfiltered) and 2 (filtered). No significant differences in word generation performance between the G and GM conditions were observed. As shown in Figures 2 and 3 (unfiltered data), participants generated similar number of words in G and GM conditions, $p=.215$ unfiltered, $p=.403$ filtered. Due to two participants, participants 1 and 2, interpreting two different categories incorrectly and thus generating words out of the regular context, an unfiltered and filtered repeated measures ANOVA was performed, with the filtered analysis excluding these noted participants.

Among the different categories of the verbal fluency tests, a significant difference was present in the number of words generated in the superordinate and subordinate categories in both G and GM conditions. As presented in Figures 2 and 3 (unfiltered data), participants generated more words in the superordinate categories than in the subordinate categories for both task conditions, $p < .001$ unfiltered, $p < .001$ filtered. Two exceptions include participants 5 and 6 who generated more words in the subordinate category of fruits than the superordinate category of food in the GM condition (Figure 3). These two participants, however, were not the participants who were taken out in the filtered analyses; as noted previously, the two filtered participants were participants 1 and 2.

Kinematics

The movement data results are summarized in Tables 3 (unfiltered) and 4 (filtered). There was a 6% increase in movement range, $p < .0001$, and a higher velocity, $p < .001$, in the GM task compared to the M task; Figures 4 and 5 (unfiltered data), respectively. There was also an increase in the duration of the GM-condition movements, which were also significantly longer than the M-condition movements, with a 6% increase (Figure 6, unfiltered data), $p < .001$.

GM-condition movements were also found to be significantly less proficient than M-condition movements in terms of movement smoothness, as characterized by the integral of jerk, a standard performance index in motor-control research (Hogan, 1984). Data from all trials were combined into a single within-participant-within task average. A paired t-test was performed to compare the smoothness of movement in the M and GM conditions. As shown in Figure 7 (unfiltered data), greater variation, in terms of a greater average jerk, was observed in the GM condition than in the M condition, $p < .0001$.

Additional variance ratio measurements from waveform variability analyses further confirmed that GM-condition movements were significantly more varied than M-condition movements, $p < .01$. The variance ratio measured cycle-to-cycle waveform variability of position versus time plots. Statistical significance in the difference between M and GM conditions were assessed via a 3-way ANOVA using the group factors: participant ID, trial number (1 through 5), and task condition. Furthermore, the morphologies of the kinematic waveforms were different between the GM and M conditions, although the difference did not reach statistical significance: in the M-condition trials, faster acceleration was during the initial movements.

Coefficient of variation analyses were performed to study the time variability among individual cycles of movement. The median value of each movement cycle was used in this calculation. As Figure 8 (unfiltered data) presents, greater coefficient of variation was present in the GM condition than the M condition, $p < .05$.

DISCUSSION

Past research has shown that cognitive and perceptual-motor activities affect one another. However, the exact mechanisms underlying the interactions remain unclear. To shed light on this topic, I compared performance on a word generation (cognitive) task and a continuous hand movement (perceptual-motor) task. I studied each task on its own and combined with the other. The word generation task was to generate words of superordinate or subordinate categories. The hand movement task was to move a small cart continuously back and forth on a linear track.

Word Generation

The results revealed that more words were generated in the superordinate (broad) categories than in the subordinate (narrow) categories. This result accords with previous research showing that people produce significantly more exemplars of large categories than of small categories (Rohrer et al., 1995). On the other hand, there were no significant differences in the number of words generated in the G and GM conditions (Figures 2 and 3).

Kinematics

Whereas word generation was not affected by the addition of a secondary task (hand movement), the movement task was affected by the addition of a secondary task (word generation). Significant differences were found in the movement data between the M and GM conditions. The results revealed 6% larger movement ranges (Figure 4) and higher velocities (Figure 5) in the GM condition than the M condition. The duration of the movements was also significantly longer in the GM condition than in the M condition (Figure 6).

Significant differences were also found in several analyses of movement proficiency between the M and GM conditions. Greater proficiency was defined as less variable and smoother performance, while less proficiency was defined as more variable and less smooth performance. In general, the M-condition movements were more proficient than the GM-condition movements, the M-condition movements were smoother than the GM-condition movements (Figure 7), the M-condition movements were less variable than the GM-condition movements in terms of waveform variability, and the times of individual cycles of movements in the M condition were less varied than in the GM condition (Figure 8).

General Discussion

These results indicate that, in the present tasks, cognitive functions interfered with motor functions but not vice versa. This result supports the original hypothesis that predicted, if interferences are present upon the simultaneous execution of a word generation task and hand movement task, then cognitive and motor functions use common resources. The addition of the cognitive task required the common resources allotted to the two interacting brain regions to be partially shunted from the motor task to the cognitive task. Therefore, decreased resources were present for the motor task, resulting in the difference in motor movement performance and poorer movement proficiency in the GM condition compared to the M condition.

This result supports previous work that showed that the addition of cognitive activities, by means of mind wandering, disengages executive control resources from motor performance, as shown in a tapping task (Seli et al., 2012). If the regions of the brain that controlled cognitive tasks and motor tasks did not utilize the same resources, then the addition of the cognitive task to the motor task should have had no impact on the motor performance and thus the results of the M and GM conditions should have been the same or significantly non-different.

The presence of only the unidirectional relationship observed between the cognitive and motor areas of the brain eliminates the hypothesis that a bidirectional relationship connects the two regions. Furthermore, the nature of the unidirectional relationship implies that the brain gives priority to cognitive performances over motor performances when both are being performed together. Due to the cognitive task's influence on the motor task's performance, the results of this study ultimately eliminate the hypothesis that no relationship, and thus no interference, exists between the cognitive and motor regions of the brain.

Future Work

The present research, like any other, incorporated several limitations. These limitations include a limited sample population and the absence of word generation and motor movement data synchronization. Additional future work to count for the limitations will be beneficial to the present project and the overall line of research.

The sample in the present study was comprised of all college aged students. To obtain a more representative sample, the current general testing framework could be used to test populations of different age groups. These groups could include toddlers, adolescents, and senior citizens. It would be interesting to see if individuals of different ages display more, less, or no interference compared to each other. Since the brain is at different maturity levels and functioning states at different ages, perhaps the elderly population will display more interference in the dual-task condition since their brains are less active and in less optimal functioning levels. Young children may display less interference due to their brains being more plastic and easily adaptable to multiple stimuli.

Due to the absence of synchronization equipment for the word generation and motor movement data, the exact moment that each participant generated a word was not matched up with the hand movement and location at the same time. In the future, it would be very interesting to utilize synchronization equipment or a computer program that combines the two different data in order to study the relationship between the brain areas that control the two tasks in greater depth.

In regards to the participants emphasizing word generation more than movement production, as seen in the M and GM data analyses, perhaps this was due to the difficulty levels of the two tasks. Perhaps the cognitive task was easier to perform than the motor task in the present experiment and thus the participants had more motivation to focus the common resources in their brain to the simpler word generation task. This may have been possible since the motor movement task involved multiple muscle groups and their synchronization. Therefore, different difficulty levels and demands of the tasks present in multitasking situations could influence how the brain allocates its resources rather than "hard-wired" differences in the brain in terms of physical structures. To further study how malleable the interactions are, the tasks to be performed should be calibrated to be of similar difficulty levels. In regards to the present research, perhaps the motor movement task could be further simplified to encompass fewer synchronous muscle activity and coordination or the cognitive task could be altered to be more challenging by changing the word generation task to different mathematical calculation or visual spatial tasks. Interesting results could occur when the brain has to execute tasks that equally require the same resources.

Finally, the fact that simple back and forth hand movements suffered in performance when a cognitive task was added parallels similar effects that have been found in past research regarding gross motor movements. The results of this research show, therefore, that it is possible to extend the general gross motor approach to the coordination of finer manual behavior and cognition tasks. This will make it possible to extend the approach to individuals who have difficulty with walking actions. In addition, it will also make it possible to pursue this approach and overall line of research outside of gait-analysis labs, potentially, in labs that have nothing more than a standard computer and mouse or digitizing tablet (a flat surface on which a stylus can be moved back and forth). The newly found diversity of the basic gross motor dual-task approach paves the way for increased opportunities to research dual-task interferences in the presence of multitasking.

Applications

Knowledge gained from the current study could afford many beneficial applications in clinical settings. The results could provide a better understanding of various neurodegenerative diseases such as Alzheimer’s, Parkinson’s, and Huntington’s in terms of learning more about how decline in different cognitive performances such as reasoning, decision-making, memory, and learning mental functions influence and relate to the loss of various motor control and actions. These understandings will help build the foundation to better and more accurate diagnostic techniques as well as treatment methods of such diseases.

Appendix A

Tables

Table 1. Mean ± 1 Standard Deviation Of Number of Words Generated in The Verbal Fluency Tests In Task Context G and GM For All 10 Participants

	Task Context	
Category Level	**G**	**GM**
Superordinate	213.0 ± 21.21	213.5 ± 7.78
Subordinate	101.5 ± 30.41	120.5 ± 72.83

Mean value and standard deviation were calculated based upon the sum of generated words among all 10 participants in respective superordinate and subordinate levels in the G and GM conditions.

Table 2. Mean ± 1 Standard Deviation Of Number of Words Generated in The Verbal Fluency Tests In Task Context G and GM For The 8 Participants Who Performed as Instructed

	Task Context	
Category Level	**G**	**GM**
Superordinate	181.0 ± 19.80	175.0 ± 4.24
Subordinate	82.5 ± 26.16	101.5 ± 70.00

Mean value and standard deviation were calculated based upon the sum of generated words among all 8 participants who performed as instructed in respective superordinate and subordinate levels in the G and GM conditions.

Table 3. Raw and Analyzed Motor Movement Parameters in M and GM Conditions for All 10 Participants

Parameter	**M**	**GM**	**Significance**
Movement Range (m)	0.461 ± 0.002	0.487 ± 0.008	$p < .0001$
Average Velocity (m/s)	0.732 ± 0.109	0.745 ± 0.103	$p < .001$
Movement Duration (s)	72.26 ± 13.84	76.87 ± 15.85	$p < .001$
Average Jerk (m/s^3)	2311.09 ± 96.43	2571.85 ± 85.92	$p < .0001$
Waveform Variability	0.0088 ± 0.0009	0.0102 ± 0.0022	$p < .01$
Coefficient of Variation	0.04563 ± 0.0098	0.08403 ± 0.0558	$p < .05$

Mean ± 1 standard deviation shown; Statistical significance $p < .05$

Table 4. Raw and Analyzed Motor Movement Parameters in M and GM Conditions for the 8 Participants Who Performed as Instructed

Parameter	**M**	**GM**	**Significance**
Movement Range (m)	0.461 ± 0.002	0.487 ± 0.005	p <.0001
Average Velocity (m/s)	0.691 ± 0.075	0.705 ± 0.069	p <.001
Movement Duration (s)	77.35 ± 9.89	82.53 ± 11.81	p <.001
Average Jerk (m/s^3)	2303.65 ± 101.18	2582.39 ± 79.00	p <.0001
Waveform Variability	0.0088 ± 0.0009	0.0108 ± 0.0020	p <.01
Coefficient of Variation	0.0448 ± 0.0104	0.0925 ± 0.0598	p <.05

Mean ± 1 standard deviation shown; Statistical significance p <.05

Appendix B

Figures

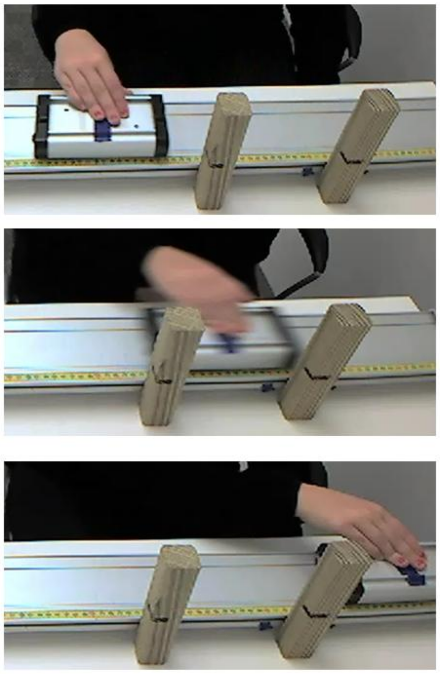

Figure 1. Movement task used in the pure motor (M) and generation-plus-movement (GM) conditions. A single move from right to left from the perspective of the participant is shown.

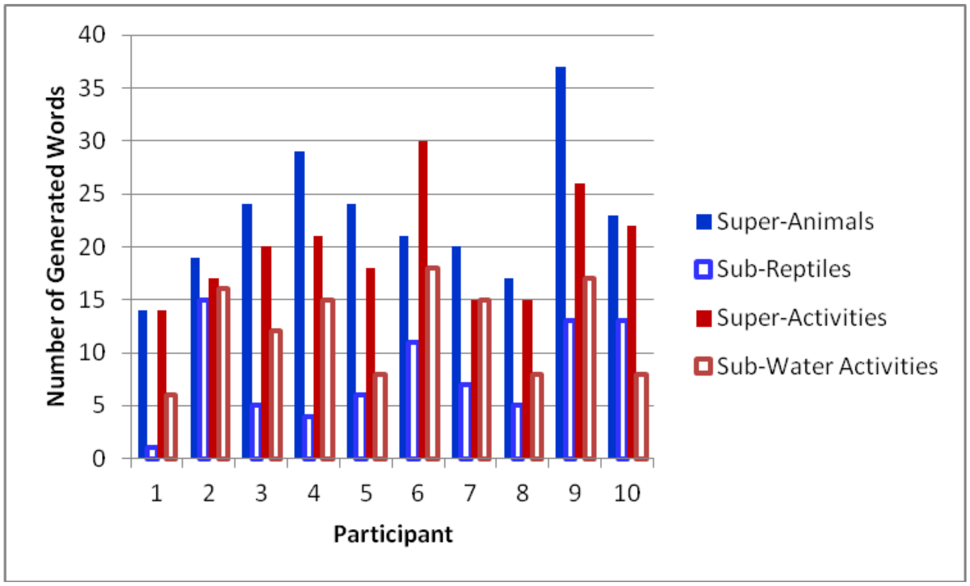

Figure 2. Number of words generated in verbal fluency tests in G condition. “Super” refers to a superordinate category (solid bar) and “sub” refers to a subordinate category (lined bar).

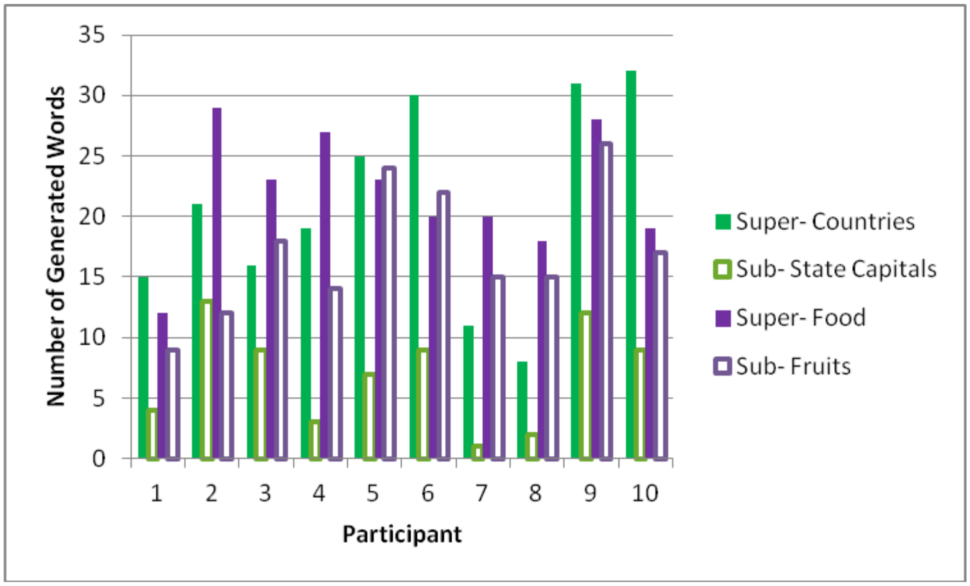

Figure 3. Number of words generated in verbal fluency tests in GM condition. "Super" refers to a superordinate category (solid bar) and "sub" refers to a subordinate category (lined bar).

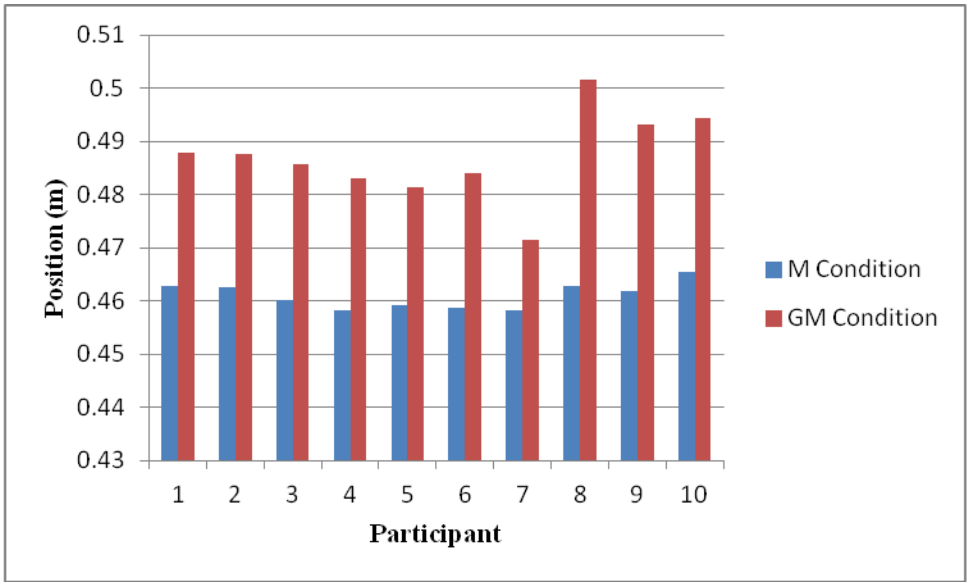

Figure 4. Range of motor movements in M and GM conditions.

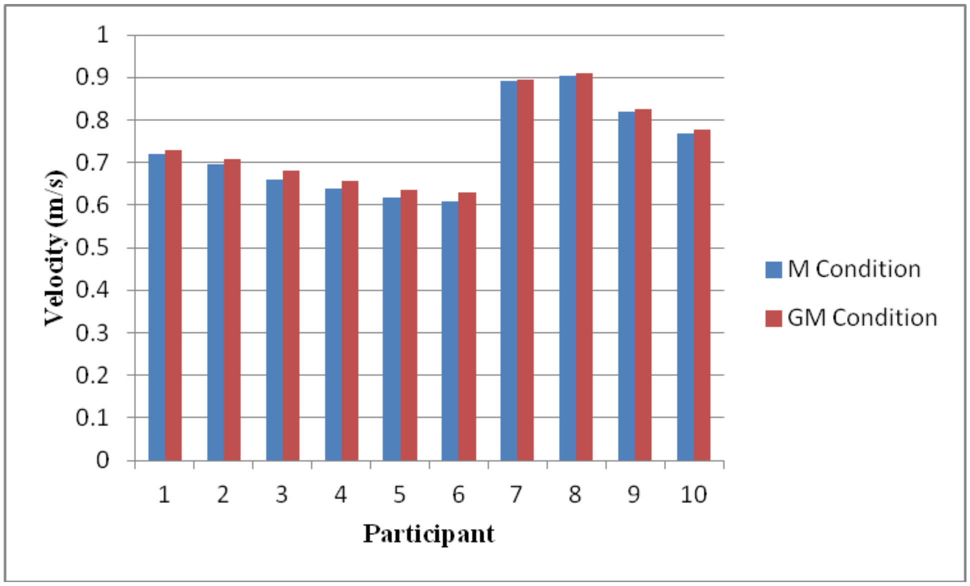

Figure 5. Average velocity of motor movements in M and GM conditions.

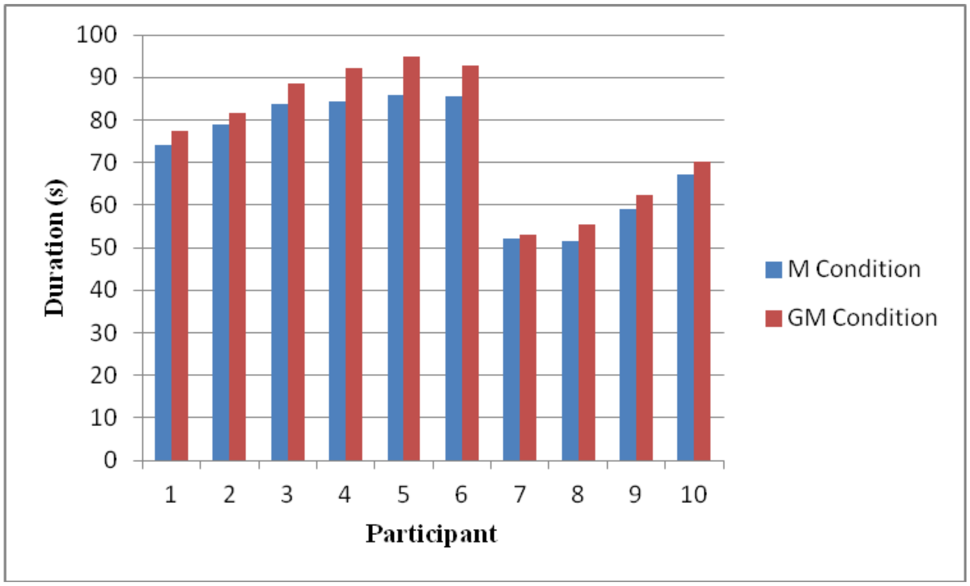

Figure 6. Movement duration in M and GM conditions.

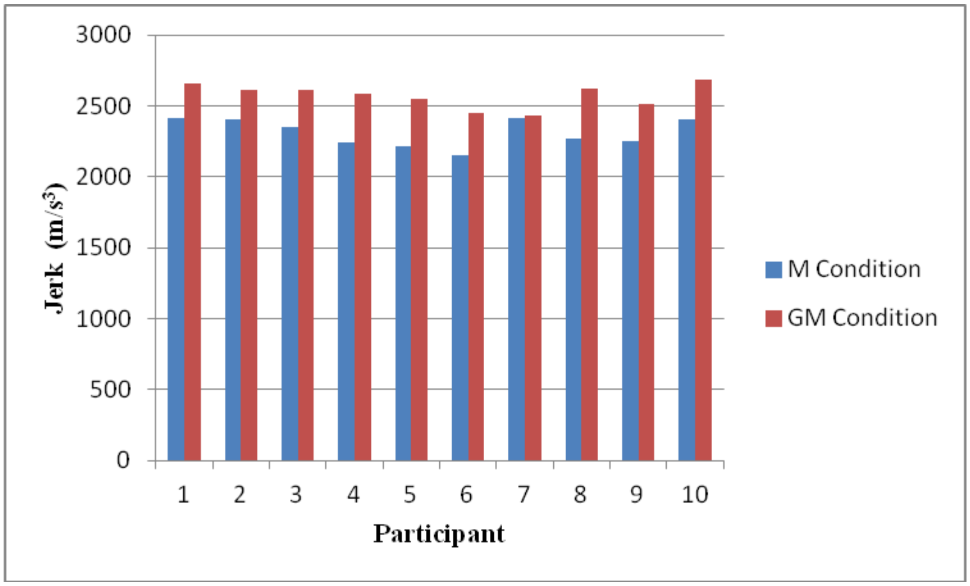

Figure 7. Average jerk of motor movements in M and GM conditions.

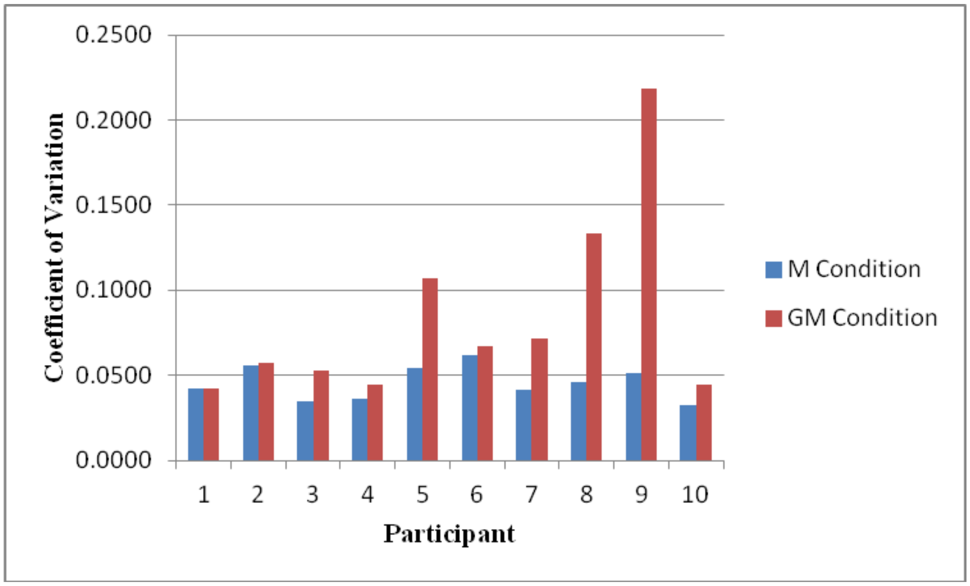

Figure 8. Coefficient of variation in time variability among movement cycles in M and GM conditions.

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Honors Advisor – James H. Marden, Ph.D.

Research Experience

The Laboratory for Cognition and Action, State College, PA **January 2011 – May 2013**
Penn State University
Dr. David Rosenbaum, Distinguished Professor of Psychology

- Design, implement, and analyze Honors Thesis project that studies the interaction between cognitive and perceptual motor control
- Assisted in design, conduction, and data collection pertaining to the study of the relationship between walking and reaching
- Co-authored, "Picking up a close bucket at the cost of transporting it a longer distance: A study of walking and reaching" research presented at New England Sequencing and Timing conference, March 2012

Movement Neuroscience Laboratory, State College, PA **January 2010 – May 2010**
Penn State University
Dr. Bob Sainburg, Professor of Kinesiology
NASA Women in Science and Engineering Research Program

- Assisted in implementation and data collection to study the neural foundations and influences of handedness
- Assisted with psychophysical experiments and biochemical simulations to study interlimb differences in multijoint reaching

Pennsylvania Governor's School for the Sciences, Pittsburgh, PA **June 2008 – August 2008**

- Designed and conducted team experiment, "A Comparative Survey of 16S Ribosomal RNA Diversity in Soil Bacteria under Various Environmental Conditions"
- Presented research experiment at the final project symposium
- Published results of experiment in *The Journal of the Pennsylvania Governor's School for the Sciences*

Clinical Experience

Penn State University Health Services Clinic Intern, State College, PA **August 2011 – May 2012**

- Prepared patients to see clinicians by performing intakes, determining reason for visit, providing health education, and conducting visual acuity exams
- Observed and assisted nurses and doctors during operations

Activities and Leadership

Penn State Pre-Medical Society, State College, PA **August 2010 – May 2013**

- Secretary for the 2012 – 2013 school year
- Organize Alex's Lemonade Stand fundraisers, structure meetings, write meeting summaries, maintain membership activities
- Volunteer in health related service events, including the American Red Cross

The National Society of Collegiate Scholars, State College, PA **August 2010 – May 2013**

- Participate in community service events, leadership opportunities, and club socials
- Received scholarship for designing and making a brochure for Penn State's chapter

Science LionPride, State College, PA **August 2009 – May 2013**

- Serve as ambassador to Penn State University's Eberly College of Science
- Represent the college of science at alumni events and open houses, participate in student panels, give science and campus tours to prospective students and their families

Private Piano Lessons, State College, PA **January 2010 – May 2011**

- Practiced skills and played classical, baroque, and modern pieces with instructors form Penn State School of Music

Work Experience

Chemistry Proctor, State College, PA **September 2012 – May 2013**

- Hired by Penn State University's Chemistry Department
- Proctor Chem 110 (Chemical Principles 1), Chem 210 (Organic Chemistry I), Chem 212 (Organic Chemistry II) courses

Honors and Awards

- Dean's List, all semesters **August 2009 – May 2013**
- Schreyer Honors College Academic Excellence Scholarship **August 2009 – May 2013**
- Class of 1916 Memorial Scholarship Fund **August 2009 – May 2013**
- NASA Women in Science and Engineering Research Program **January 2010 – May 2010**
- GE STAR Awards **August 2009**
- Penn State University Eberly College of Science Scholarship **May 2008**
- SPARKS Hall of Flame Award in Science, Millcreek School Foundation **May 2007**