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The Effects of Creative and Cognitive Exercises on Body Balance

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The Effects of Creative and Cognitive Exercises on Body Balance

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Master of Science Thesis

The Effects of Creative and Cognitive Exercises on Body Balance

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1.0 Introduction
1.1 Background
1.1.1 Motivation

Currently, there is an incredible disparity between certain components of STEM education and the practical skills needed to successfully influence new, innovative ideas in industry. Most of the exercises a STEM degree contains are purely analytical and systematic, which rarely leave room for creative problem solving. This however, is certainly not the case post-graduation, where employees are faced with finding novel solutions to society’s problems. Creativity is needed for these real-life situations, and should be an integral part of any STEM curriculum as it is the key influence of innovation in new technologies and research.

The purpose of this study is to research the efficacy of artistic, creative exercises on participant’s problem-solving skills revealed in quantitative changes of body balance, in the hopes of underlining the importance of creative exercise for critical thinking. This is especially important for engineering fields, as it pertains to the novel creation of new technologies to improve our daily lives at the beginning stages of conceptual thought. Throughout the experiment, participants are exposed to different ways of thinking and are encouraged to apply creative thought to problem solving techniques. The experiment hopes to impart creativity to the participants where it can then be practically applied, mirroring the ability of creative thinking in the design process when used by those trying to create novel solutions.

1.1.2 Creativity in Engineering Education

A Consensus Study Report of the NASEM (National Academies of Sciences, Engineering, and Medicine) published in May 2018 clearly states “the evidence behind the assertion that educational programs that mutually integrate learning experiences in the humanities and arts with science, technology, engineering, mathematics, and medicine
(STEMM) lead to improved educational and career outcomes for undergraduate and graduate students. It explores evidence regarding the value of integrating more STEMM curricula and labs into the academic programs of students majoring in the humanities and arts and evidence regarding the value of integrating curricula and experiences in the arts and humanities into college and university STEMM education programs,” [NASEM, 2018]. Creativity is needed for well-rounded growth, and should be an integral part of any STEM curriculum as it is the key influence of innovation in new technologies and research. As well, creative thinking is an integral part of the design process for any medium, which of course extends to engineering design. However, creativity usually falls out of consideration behind the more rigid and structured components involved in STEM education.

Incorporating creative activities for students, especially in STEM curricula, would have a great benefit when coupled with more analytical coursework. In addition to the boost in cognitive activity, a creative outlet for students engaged in STEM education, which is usually perceived as demanding and stressful in nature, would provide much needed emotional relief and meditation, as well as create more attractive coursework that allows students greater freedom of thought. This implementation of an integrated education would then produce a stronger workforce capable of creating novel solutions to tough problems.

1.1.3 Existing Methods and Tools
1.1.3a. KEEN Module

The inspiration for this investigation comes from a review of a KEEN (Kern Entrepreneurial Engineering Network) Program learning resource that was designed to foster creative thinking in engineers. The Keen Program’s resource, a module selectively available to students through the University’s primary online course content site, was written as a tool to help foster a creative attitude of idea generation in students involved in a design process. The module
focuses on bringing awareness to the processes that an engineer will typically go through to solve a problem with a novel solution; seeking out a creative approach, integrating previous and newfound knowledge and discoveries, and applying these skills to a market in need. The module is presented as a series of small written pieces, and gives a multiple-choice test at the end to evaluate student engagement. It also encourages students to implement certain exercises presented throughout the module in their own time.

This module was examined by the investigator, and was given to a small focus group of 5 engineering seniors to be completed over the course of 3 weeks. The focus group was involved in their own Senior Design project (a year-long capstone project that has teams of engineering students solve a design problem using the education they’ve received while at the University), and was asked to use the module as a tool to help them generate design ideas for this project. The following is an excerpt from one of the focus group’s project reports, where they evaluated the efficacy of the module:

“Our group was exposed to the KEEN E-Module before coming up with alternative designs. The KEEN module essentially consisted of about 50 slides, a few thinking activities, and a lot of information regarding the creative thinking process. Exposure to this creativity...
module made our team more aware of creative design thinking, but the module’s activity itself did not have any major influence on our strategy. A few critiques we had on the KEEN Module include:

1. The module was very wordy and quite dry. There was a lot of lecture-like material but not a lot of advice as to how to implement or examples of how these activities were to be used. We felt it was overall a bit hypocritical and counterintuitive to be describing creative processes in just words.

2. It should overall be more interactive, and should require the physical presence of all members. We felt that a big part of creativity in this project relied on our ability to bounce ideas back and forth, so doing the module independently was not as helpful to our thought process.

3. Some of the brainstorming activities were helpful, and some of the examples of previous inventors were educational. However, these activities (such as Mind Mapping, and highlighting the heterogeneity of our thought processes) would have been performed regardless.

4. Our project may not have been the best example for creative design thinking. Because our model involves really accurate simulation of tissue and bony landmarks, we’re actually limited in some areas because we must maintain a degree of realism and adhere to the Pelvimetry process.

In summary, because we were told to be aware of our creative thinking process, we were. But, the KEEN module did little to aid us in creative thinking or the engineering design process. This module could be improved extensively with more group activities, interactivity, videos, etc.”
The focus group, although they were aware that the ideas the module incorporated were important in the design process, were not actively engaged while performing the reading and activities the module presented. When doing the module, the student investigator as well found the material to be unengaging and did not make the user feel creative, inspired or excited to apply the new ideas. This element of voluntary engagement, or interest in the material and willingness to incorporate learned concepts, is what is primarily missing from the module. Students are not convinced to listen to what the material has to offer, because it is presented in an unengaging way, and therefore do not retain as much information as they possibly could. The procedures for increasing creative thinking put forth by the following study are mainly motivated by the idea that student engagement and genuine interest in generating original ideas are the primary factors that should be evaluated and increased by any activity that seeks to boost student creativity.

This study aims in part to improve on the ideas this module wants to impart, but make them more easily consumable and interactive by the user. Imparting creative thinking is a difficult but very important idea in STEM education because it allows the thinker to create novel solutions and ideas to apply to the world’s problems, however it is difficult to create these ideas unwillingly. Art and hands-on creation are an engaging, enjoyable experience the student will more willingly take part in and in turn learn more about creative thinking from than simply studying “how to be creative” like the module suggests. If a student’s creative drive can be expanded, then they are better able to make novel solutions and ideas in the design process. This is the motivation which drives the current experiment.
1.1.3b. Potential Evaluation Methods

Four major methods of evaluating cognitive changes were considered for this experiment. The first, postural sway, was considered because of its ease of use, availability and low levels of invasiveness towards the participants. Eye movement tracking was also considered as there have been studies that link certain movement patterns to cognitive processes. Verbal expression and facial movement using electromyography was also considered as there are minute changes in facial expression that occur with cognitive changes. However, these methods were not used due to potential large-scale data corruption due to the need for verbally given answers to stimulus during the experimental protocol. Finally, electroencephalography was also considered for this experiment, and was initially recorded, however it was subject to the same levels of corruption and was ultimately not a viable method for reliable data collection.

1.2 Measures of Cognitive Changes
1.2.1 Postural Sway

There has been some previous work that links postural sway with cognition. The following section describes key publications that represent the “state of the art” of the research into postural sway and cognition.

The first study is entitled “Postural sway increases with attentional demands of concurrent cognitive task” by Geraldine L. Pellecchia, and was published in 2003. This study examined the effects of tasks of varying difficulty on participant’s postural sway, and found that as the tasks got more difficult, their postural sway increased. One key takeaway this work mentioned is that while previous research has shown that cognitive tasks do affect postural sway, to show that harder tasks affected sway more was difficult due to the uncertainty in quantifying how difficult a task was [Dault, 2001]. The study devised a novel way to quantify how difficult their tasks were by evaluating the “processing power” necessary to complete them, or how many
steps of equal increment of difficulty the participant would need to take in order to complete the
task. For instance, one of their tasks was to count backwards by threes. By this measure,
counting backwards from 21 would require 7 steps, however counting backwards from 15 would
only require 5. This quantifies the former tasks as more difficult than the latter, according to this
study. By this process, the study found that as the difficulty of the tasks increased, so too did the
postural sway of the participants [Pelleccia 2003]. For the present research, the takeaway from
this is that if the tasks presented are not able to be absolutely quantifiable in difficulty, some way
of randomizing the difficulty of the tasks would be necessary to account for confounding. This is
why the RPM task is randomized, as the difficulty of each question is impossible to state
objectively. The main reason for this is to ensure that the two RPM tasks are as close to the same
difficulty as possible, without repeating any questions.

To support the claim that cognitive tasks influence postural sway, a paper by Yvette
Blanchard et. al. examined this effect in children. This research also confirmed that cognitive
tasks affected the sway of the children, and as the tasks got more difficult, the sway increased.
This research also used randomization in the cognitive tasks given to ensure that there was no
confounding due to the order of presentation of the tasks, however the tasks themselves were
described with a quantifiable difficulty [Blanchard 2005]. The reasoning for the randomization
of tasks was adopted in the present research, as well.

To partially model the procedure of the present study, a paper by M. Zok et. al. was used.
This study, entitled “Should the instructions issued to the subject in traditional static
posturography be standardized?” examined the effects of instructions to either “stand as still as
possible” or “stand quietly” given to participants standing on a force platform. The results
suggest that instructions given to subjects strongly influence the outcomes of posturography, and
“stand as still as possible” subjects offered greater stability and less variance to the task assigned. This was the instruction given to the participants in the present study. In addition, a baseline recording was taken prior to the experimental task to compare the tasks to, which was also done in the present research. This was done to account for individual variances in posture unique to each participant, as this can be influenced by a number of factors, making sway during a task non-absolute and instead a variation from a norm. In addition, this study used a 100 Hz acquisition rate, had the participants stand without shoes on the platform, and prescreened participants for self-reported musculoskeletal or neurological disorders [Zok 2008]. These measures were also used in the present research.

An additional study that was consulted was “Generalizability of center of pressure measures of quiet standing.” By RJ Doyle et.al. This study examined how long a posturography reading of quiet standing must be in order to achieve accepted levels of reliability utilizing Generalizability Theory. The study had participants complete 10 90 second trials of quiet standing, with eyes open and closed, and measured the X and Y displacements, velocity, and 95% ellipse area of the first 30, 60, and 90 seconds of each trial. They found that COP measures of at least five 60 second trials were needed to achieve reliability [Doyle 2007]. This is used in the present research by making the baseline and both RPM tasks five minutes long, and taking the average of the 95% ellipse area, velocity, and X and Y displacements over this time period.

One interesting study to note is by JA Raymakers et. al. entitled “The assessment of body sway and the choice of the stability parameter(s).” In this study, participants of varying ages with stability problems were measured on a force platform during standing tasks on various surfaces. One task involved doing a cognitive task, and the aim of the paper was to see what parameters were the most informative in terms of loss of balance. They concluded that for most tasks, the
mean displacement velocity was the best metric for most situations, however the cognitive task results yielded mixed results. They resolved that there needs to be more research into the effects of cognitive tasks on balance, and so the present research will use the 95% ellipse area and X/Y displacement in conjunction with the velocity parameter to measure stability [Raymakers 2005].

Because attentional resources are necessary in retaining postural control, there is a distinct loss of this control when attentional resources are directed elsewhere. This increase in sway has been measured using a variety of cognitive tasks. The present experiment aims to use sway as a measure of cognitive activity by using a force platform to quantify the loss of balance experienced by the participants during problem-solving tasks.

1.2.2 Eye Movement

Eye tracking has become a popular method of biometric research, and is used extensively to measure attentional responses to stimulus, especially in non-verbal participants such as young children. Eye tracking can consist of data related to where the gaze is directed, blink frequency and changes in pupil diameter. In addition, eye tracking data can be analyzed for cognitive workload of the user, as well, and had been applied to several studies evaluating this type of measurement [EyeTracking 2011]. This type of measurement was considered to measure the cognitive load on the participants in the present study.

One such work that evaluates the efficacy of eye tracking for cognition is a 2009 paper by van Gog et. al.’ “Uncovering cognitive processes: Different techniques that can contribute to cognitive load research and instruction.” In this review, eye tracking metrics of gaze fixation (where the participant is looking, and for how long) and pupil dilation are said to increase with increasing processing demands, while the length of eye movements between fixed gazes (saccades) becomes shorter. However, the paper goes on to say that gaze fixation may actually
be situational based on the process of mental loading, fluctuating with the different steps involved with solving a problem (a similar effect is seen in EEG, where different mental states experienced by the participant during the solving of a problem have their own biometric signatures [Sandkühler, 2008]) [Gog 2009].

A second study that focuses on saccadic eye movements during cognitive load is by Stuyven et. al. entitled “The effect of cognitive load on saccadic eye movements.” In this series of studies, various mental tasks were given to participants and their ability to look (prosaccades) or avoid looking (antisaccades) in certain areas was measured. They found that increased cognitive load led to increased latencies in both the prosaccade and antisaccade cases, making these metrics a possible measure of cognitive load effects [Stuyven 2000].

Finally, pupil dilation has been a known effect of cognitive load since the early 1900’s. A 1982 paper by Jackson Beatty gives entitled “Task-Evoked Pupillary Responses, Processing Load, and the Structure of Processing Resources” gives an overview of the exact responses seen in pupils due to cognitive load. He writes that they are a good metric for measuring cognitive load because “they occur at short latencies following the onset of processing and subside quickly once processing is terminated.” He reports that, similar to the sway response, pupil dilation is due to changes in central nervous system (CNS) activity related to cognitive processing, which in turn affect the pupils that are also subject to changes in the CNS. He cites several cases where this is seen in mental arithmetic tasks, where more difficult tasks evoke a stronger pupillary response [Beatty, 1982].

Ultimately, these methods of cognitive workload assessment were not used as they were easily able to be confounded by the type of stimulus presented, namely the Raven’s Progressive Matrices test that served as the cognitive load (see section 2.2 and appendix 7.1 for more
information). In this type of test, there are several competing images shown at once that the participant must choose from. The presence of multiple images at once may have different effects on the eye movement and saccade metrics than other types of tests that use only one image, with one or otherwise restricted areas of gaze. In addition, other stimuli include a series of photographic images with different levels of brightness and color, which may affect the pupil dilation by way of varying levels of light. Because of these, this measurement was deemed to be prone to too much interference by artifacts to be considered viable.

1.2.3 Verbal Expression and Muscle Face Movement

Another metric for evaluating cognitive workload is gained from electromyography (EMG) readings of various facial and face surrounding muscle. This involves reading the muscle activation of various muscles around the face and neck during cognitive loading. Though this method is more commonly used to gauge emotional responses or sub-vocal (or other non-audible) verbal movement, there are recent works that suggest there may be links to certain muscle activities when engaging in cognitive loads. This method was also considered for the present research.

One study that uses this approach is entitled “Workload Assessment Using Speech-Related Neck Surface Electromyography” by Novstrup et. al. This work is one of the few available studies on the effects of cognitive load on facial muscle metrics due to the relatively new introduction of non-invasive fine EMG sensors that can pick up signals from muscles as small as those in the face and neck. In this evaluation of collected EMG data during cognitive loading, researched studied the inter-muscular coherence of two anterior neck locations above neck strap muscles during cognitive loading. They found that in cases of greater cognitive loading, this coherence would decrease significantly, and could be measured in real-time using
EMG hardware and software. However, this work stresses the fact that the findings are strictly ad hoc, and the original experiment was concerned with finding speech-related patterns in neck muscle coherence. Direct cognitive manipulations would be necessary to solidify these claims. In addition, the task the participants did was based on arithmetic, and thus is not necessarily representative of all types of cognitive load. Other artifacts produced by the nature of the data evaluated were also mentioned, such as peaks of muscle movement due to laughter or other speech-related actions [Novstrup 2019].

Ultimately, this method of measuring cognitive load was not used primarily due to the lack of empirical evidence and previous studied that used it as a viable method. Because non-invasive EMG hardware has only just recently become widely available, there is not a large body of work surrounding it concerning cognitive load. In addition, EMG is prone to many different sources of interference, especially when on the face and neck while the participant is speaking.

1.2.4 Electroencephalography

Electroencephalography is the measurement of the voltage potentials that escape the brain through the skull, measured at the scalp by electrodes. This measurement’s repetitive voltage drops and rises can be analyzed to find the power of specific frequencies of the voltages at each electrode (see Figure 2), and then averaged over a particular cortical region. Although all of these frequencies may be happening simultaneously to the output signal, a Fourier Transform can be used to parse the underlying frequencies and gauge their intensities.
Figure 2: Standard 10-20 placement system for EEG caps.

There are several intervals of frequency, or “bands”, that have been identified and studied in cognitive function, however EEG frequency bands are a somewhat debated topic on what they actually represent. Several papers studying similar effects to the present research suggest that increases in the power of the alpha band in the frontal lobe region may represent increased attentional demands [Belkofer 2014] [Ray 1985]. This is the frequency that will be studied in the present research. Following the protocol of previous studies, the alpha band has been split in this study into upper (10-12 Hz) and lower (8-10 Hz) halves (see Figure 10). The other bands are reported for completion and to see any significant trends should they be present. Common interpretations of the other bands are as follows: 1) beta activity is linked to emotional stress, especially anxiety [Ray, 1985], 2) theta activity is also linked to creative thinking, intuition, and recollection, although usually during a drowsy state of alertness, and 3) delta waves are associated with lethargy and non-attentive states, and are usually always present in normal cognitive function [Stevenson, 2019]. In addition to the postural sway parameters, this experiment was originally going to apply data collected from electroencephalography (EEG) equipment, and this data was indeed taken from the majority of the participants of the study.
Studies of note are a pair of studies conducted by Christopher M. Belkofer et. al. that looks specifically at the EEG data associated with participants immediately after they spend time drawing. Two studies, one conducted in 2008 and the other in 2014, had participants take an EEG recording during quiet sitting, then spend twenty minutes drawing and immediately took EEG recordings of them afterwards, while not engaging in any further activity. The results of the studies found that the alpha frequency recorded after the drawing period had significantly increased, and artists responded more strongly than non-artists in terms of the frequency’s power [Belkofer 2008] [Belkofer 2014]. Though EEG was ultimately not indicative of any significant results in the present work, this series of experiments helped to shape the current experimental method. The present research, as will be seen in later sections, uses the 20 minute drawing exercise as part of the creative thinking stimulus.

Another study of note was done by Andreas Fink et. al. and examines cortical activity during problem solving as measured by EEG and fMRI. In this study, the EEG alpha band was recorded and analyzed during original idea generation in verbal tasks. Alpha synchronization in various brain regions, although strongest in the frontal lobe, was observed, with stronger alpha activity corresponding to more original ideas. This suggests that the EEG alpha band during
creative thinking can be interpreted as a sign of active cognitive process, and is a metric for measuring creative engagement. Additionally, this evidence was found to be stronger in more creative individuals, and also leads the current experiment to perform a similar analysis where more creative and less creative individuals are examined both together and separately.

1.3 Goals, Specific Aims and Hypothesis

From informal observations during the past few years, both the student investigator and the primary investigator have noted that students that exhibit artistic interests (such as painting, drawing, dance or music creation) have found interesting, effective and novel solutions to coursework presented in STEM curricula. This has led to the idea that difficult concepts can be made more interesting and easier to understand by presenting them in a visual, interactive way, rather than by a classic textual representation. This idea, in conjunction with the KEEN module’s vision of boosting creativity, has led to the creating of an experiment in which creativity and learning is driven by a series of interactive activities that take a different approach to presenting educational material. The purpose of this study is to research the quantitative efficacy of artistic, creative exercises on STEM student’s problem-solving skills via body balance. It is also to determine what measurement equipment, if either, is the best solution for measuring the quantitative engagement of students. The goal of this experiment is to apply these findings to support the theory that creative exercise is helpful in the STEM curriculum. The following specific aims and hypotheses are derived from this goal:

Specific Aim 1: To compare the engagement of engineering students during problem-solving tasks before and after artistic exercise, as measured by postural sway (balance).

Hypothesis: There will be significant increased instability in the center of pressure (CoP) X/Y displacement, 95% ellipse area, and velocity parameters observed in students
during the problem-solving task given after the artistic exercise, compared to the tasks given before the exercise.

2.0 Methods
2.1 Apparatus

![Figure 4: Example of the AMTI AccuSway force platform used in the study.](image)

The equipment used in this portion of the study is the AMTI AccuSway force platform (Advanced Mechanical Technology, Inc., Watertown, MA, USA), a sturdy metal plate on which participants stand to measure their center of pressure (CoP) over time (see Figure 4). The center of pressure is defined as the single point on the force platform where a resultant vector force can be calculated to act from the participant standing upon it [Benda, 1994]. Because this can be represented differently on the participant depending on how their force is being applied (ie. the vector force during stepping shifts from the heel to the toe), the participants are told to stand with their feet flat on the platform and with their hands at their sides to keep the CoP consistent. The force platform works by measuring the ground reaction forces and moments in three dimensions of the participants standing on top. This information is then recorded by AMTI’s NetForce program, and analyzed in AMTI’s BioAnalysis program to deliver a variety of analyses. This equipment operates at 100 Hz, or 100 data samples per second.
The parameters that this experiment will focus on are the participant’s CoP displacements in the X (medial/lateral) and Y (ventral/dorsal) directions, the 95% ellipse area created by the 2D movement of these displacements, and the average velocity of these displacements. Other parameters are calculated by the BioAnalysis program, however previous literature focuses on these parameters as the main tools for quantifying loss of balance [Pellecchia 2003].

This experiment was also originally built to evaluate electroencephalographic (EEG) data as well, and Brain Vision products were used to measure their scalp electrical potentials over time as they completed the various activities that will be outlined in the following sections. Brain Vision’s Pycorder software was used to record the EEG data, and MATLAB with EEGLAB and ERPLAB toolboxes was used to analyze the EEG data. Microsoft Excel was used for statistical analysis. The EEG system used in the present study is comprised of the Brain Vision head cap ActiCAP (Brain Vision LLC, Morrisville, NC, USA) and amplifier ActiCHamp. 32 channels in a standard 10-20 arrangement are used to record scalp voltages, and this recording is synchronized with the stimulus presentation via custom MATLAB code (see appendix section 7.2 for complete code). The recorded data is then output to MATLAB, where the frequency band powers are calculated for each participant, activity and channel in the 32-channel system. The data is then averaged over brain regions such as the frontal lobe. This equipment operates at 500 Hz, or 500 data samples per second.

The Brain Vision system was supplemented by the use of a response timing box that sent an analog voltage spike to the recording software PyCorder according to the custom MATLAB presentation code. These “trigger codes” were used to determine when certain stimulus was showing.
2.2 Stimulus

Stimulus was presented to the participants via a computer screen. MATLAB with the PsychToolbox toolbox was used to run the stimulus presentation. Code for this presentation can be found in appendix section 7.2.

2.2.1 Raven’s Progressive Matrices

As mentioned in section 1.2, several behavioral tasks can be used to elicit cognitive responses in participants that would in turn induce postural sway. In addition, increased cognitive activity, primarily in the frontal lobe, has been observed in individuals during certain creative problem-solving activities commonly used in behavioral cognitive tasks [Fink 2009]. These problem-solving activities can include the Alternate Uses Task, where participants are told to create unique uses for everyday objects (for example, using a brick as a paperweight), or the Remote Associates Task, where participants must link three words together that seem to be unrelated. In previous work, tests like these seem to elicit specific EEG responses linked to alpha frequencies [Martindale, 1975]. The present research aims to use a well-tested task to elicit a similar response for sway recording.

To measure cognitive activity before and after the artistic activities, a randomized version of the Raven Progressive Matrices (RPM) test was given to participants. This test is widely used in psychology as a tool to evaluate a participant’s “educative ability” (or general cognitive ability to learn new material) [Raven, 2003]. The tests are a series of images presented with one section of each image missing, and a potential answer to each missing portion presented alongside the main image. These questions range from very easy to very hard.
Figure 5: Example of an image presented as part of the Raven Progressive Matrices test. Here, the answer would be 4.

The RPM test was used because it is a standard in evaluating cognitive activity, incorporates many trials that are easy to administer in a timely manner (this is important for EEG based experimentation), and because it is visual, minimizes the experimental inconsistencies associated with language-based activities (such as with the Remote Associate or Alternate Uses Tasks).

The test was not evaluated in the standard manner it usually is, where test scores are comprised of the number of correct and incorrect answers. Instead, cognitive activity was measured by postural sway and EEG, with the correctness of answers virtually ignored (they were, however, recorded and are reported in the Results section). This was because this study is interested in the engagement and cognitive activity of the participants, as opposed to their performance on the test. In other words, the RPM test was simply administered to elicit a response from the participants.

Two sets of 15 images each of the RPM test were administered to each participant, one before the artistic activities, and one after. The difficulty of each image was randomized, as well (as in, they were not presented in an ascending or descending difficulty level order).
Randomization was done to eliminate confounding for image order. More examples of the images presented can be found in appendix section 7.1.

2.2.2 Sequences and Series Illustrations

Throughout the experimental procedure, participants were exposed to images that convey different mathematical sequences and series as artistic representations. Images were taken from the works Patterns of the Universe and Visions of the Universe [Bellos, 2015, 2016]. In these works, author Alex Bellos and illustrator Edmund Harriss explore different representations of mathematical concepts through unique graphical imaging and other artistic means (see Figure 6).

![Image of a unique representation of the well-known Recamán’s Sequence.](image)

These representations were chosen because of their visual simplicity and similarity in structure, and their availability in large numbers (about 60 images were used). The images were randomized to eliminate confounding for image order.
2.2.3 Photography by Richard Schulman

Another set of artistic material was presented, as well. Photographs taken by the artist Richard Schulman showcase abstracted views of architectural structures, mixing artistic and engineering design (see Figure 7). This gives the viewer an introduction to redefining common engineering ideas into an alternate view. These works were chosen to stay consistent with the theme of transforming classically “STEM” related concepts to more artistically driven ones, encouraging the viewer to alter their perspective. The images were randomized to eliminate confounding for image order.

Two sets of the sequence art pieces and one set of the Richard Schulman pieces were presented to each participant. Each set contained 15 randomized images without repeats. Randomization was done to eliminate confounding for image order. These works are considered as an artistic exercise that may influence an individual’s performance on the RPM activities.
2.3 Procedure

Figure 8: Flow chart of the experimental procedure.

Please note that this section includes the methods that were used to collect EEG data from participants, as well as postural sway data. The original intended goal of this data, and why it is not used in the rest of this report, is stated at the end of this section.

Before the actual study took place, participants were screened via an online Qualtrics survey (see appendix section 7.3 for full survey). The purpose of this pre-screening survey was to make sure participants:

1. Are 18 years of age or older
2. Are able to wear an EEG cap
3. Have never had a traumatic brain injury
4. Have normal or corrected-to-normal vision
5. Do not have severely impaired hearing
6. Are not currently taking any psychoactive medications
7. Are fluent in English
8. Are not left handed
9. Do not have any musculoskeletal or neurological disorders
10. Do not have trouble standing for periods of 10 minutes or longer

The purpose of this exclusion criteria was to be able to have participants eligible to give consent (items 1, 4-5, and 7), able to give accurate and consistent EEG readings (items 2-3, 8, and 9), and are able to give accurate postural sway readings comfortably (items 9-10). After being selected and notified via e-mail, participants were asked to come in for an approximately 2-hour experimental session and signed an IRB approved informed consent document. The testing consisted of the following steps (refer to Figure 8 for graphic explanation):

1. Participant comes in and is outfitted with the 32-lead EEG equipment. This includes measuring the participant’s head circumference and selecting an appropriate cap, and applying a saline gel to increase the conductance between the participant’s scalp and the electrodes. Participant is asked to step onto the force platform with socks on and with their hands at their sides. They are instructed to stand “as still as possible”. EEG recording software Pycorder and force platform recording software NetForce begins recording for a baseline reading of 5 minutes. This baseline records any predisposed variations in balance each individual might have, and is what the rest of the measurement are compared against during analysis for consistency.

2. Procedures for the RPM task are explained, and a short example given. This is done in the form of text presented on a screen, as well as verbally by the administrator so as to ensure the participant has a full understanding of the
activities, and has a chance to ask questions. The RPM task is presented, with 15 randomized images appearing on the screen for 20 seconds each. Participants give answers to each image verbally. This RPM task serves as the control task taken before any artistic material is viewed or created.

3. A slideshow of the Richard Schulman photographs will show up on the screen. The participant will be instructed to view each one carefully. 15 images show for 10 seconds each.

4. A slideshow of the sequence art pieces will show up on the screen. The participant will be instructed to view each one carefully. 15 images show for 10 seconds each.

5. Participant are asked to sit in a chair at a desk and draw using provided materials (pencil, eraser, drawing stimulation packet). They are given a drawing stimulation packet (found in appendix section 7.4) that consist of three mathematical sequences and a demonstration page. Participants are asked to draw visual representations of the mathematical sequences given.

6. Participant will be asked to immediately stand up and onto the force platform and view another slideshow of the sequence art pieces, with different randomized images.

7. The second RPM task, with a different randomized set of 15 images, is presented.

8. An end of study survey is given to document participant self-reported stress level, which may affect EEG recordings. This survey can be found in appendix section 7.5.
Afterwards, the participant was taken out of the EEG cap, and free to wash off any residual gel. A picture of this experimental setup can be found in Figure 9.

Control Group testing procedures were identical to the Test Group participants’, however they did not participate in EEG recordings, and they were allowed to take a break from the testing instead of completing the artistic activities for the same amount of time as it would take them to do the artistic activities (27.5 minutes).

![Experimental setup. Participant has on the EEG cap and is viewing artistic material.](image)

2.4 Subjects and Recruitment
This study was approved by the University of Connecticut Institutional Review Board (IRB) in Storrs, CT (H18-258). 21 participants were enrolled in this study, with 20 of them completing the testing procedure. One participant started the testing procedures but had to leave due to conflicting arrangements. Of the participants that completed the study, 9 participants were female, and 11 were male. In the prescreening survey, 10 participants indicated a self-reported regular art-creation time per week of over 4 hours, and 10 reported a time of under 4 hours. This
was done to alleviate confounding due to artistic inclination and experience, as this has been shown to have some effect on data recorded during artistic activity [Belkofer 2014]. All participants were recruited from the University of Connecticut, Storrs campus, and were tested in the Cognitive Sciences Shared Electrophysiology Resources Laboratory in Arjona, room 321. Recruitment was done through advertisements through the UConn Daily digest email burst and flyers in various campus buildings. The study began in February 2019 and ended in April 2019. Participants were given a $25 Amazon gift card for completing the study.

The Control Group consisted of 5 participants that completed the force platform analysis for the two RPM tasks. All participants were recruited from the University of Connecticut, Storrs campus, and were tested in Bronwell 215 on the Storrs Campus. The Control Group testing was held between June 4-10, 2019. Participants received no compensation. Artistic experience of the participants was not evaluated.

2.5 Data Analysis

CoP data was recorded in AMTI software NetForce and saved as a pair of .mrk and .bsf files for each participant’s baseline, art viewing and RPM activity. There was a total of 6 pairs of files for each participant. These files were loaded into AMTI software BioAnalysis for evaluation, where the X/Y CoP displacement was calculated for each data point (100 per second, or 100 Hz). These data points where then loaded into Excel for further analysis.

To compute all the parameters, the first and last 10 seconds of each recording was cut off to eliminate the noise caused by the participant stepping onto the platform and adjusting to standing. A visualization of this can be seen in Figure 10.
Next, to compute the average X and Y displacements for each participant, the average absolute value of the CoP from the origin on each axis was taken from the range specified above and averaged. The equation for this is:

\[
\text{Average Displacement} = \frac{\sum_{i=1}^{1000} x_i}{N} \tag{1}
\]

where \( t \) is the stopping point of the recording (data point 29000 for the baseline and RPM activities, which were 5 minutes long (300 seconds), and 14000 for the Art activities, which were 2.5 minutes long (150 seconds)), \( x \) is the \( i \)th value at each recording point (\( i \) is delayed by 10 seconds), and \( N \) is the number of data points.

The CoP velocity parameter was calculated using the following equation to get the instantaneous velocity at each data point:

\[
(\text{Instantaneous Velocity})_i = \frac{\sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2}}{0.01} \tag{2}
\]
where \( x \) is the \( i \)th CoP position on the X axis and \( y \) is the \( i \)th CoP position on the Y axis. This series of values was then averaged over the range specified earlier. This was done for each activity.

Finally, the 95% ellipse area was calculated first by finding the covariant matrix for each activity within the relevant data point range, its trace and its determinant. The eigenvalues were then calculated using the equations:

\[
e_1 = \frac{\text{tr}(\text{cov}) + \sqrt{\text{tr}(\text{cov})^2 - 4 \times \text{det}(\text{cov})}}{2}
\]

(3)

\[
e_2 = \text{tr}(\text{cov}) - e_1
\]

(4)

where \( \text{cov} \) is the covariant matrix. The standard deviations for these eigenvalues were then computed with the equation:

\[
SD_{1,2} = \frac{e_{1,2}}{\sqrt{N-1}}
\]

(5)

Finally, the area of the 95% ellipse was calculated using the equation:

\[
\text{Area} = 5.991 \pi SD_1 SD_2
\]

(6)

Visual output for the 95% ellipse area is given as well in Figure 11 to better understand the meaning of this parameter (Borg 2002) (Zaiontz, n.d.).
3.0 Results

Figure 11: Example of the graphical output for the 95% ellipse area parameter.

Figure 12: Bar graph showing the change from baseline of all postural sway parameters over each RPM activity (no artistic activities done for Control Group). Values are the average of all participants in the Control Group (5 participants).
The data collected was exported into Microsoft Excel for analysis. The first analysis, seen in Figure 12 and Figure 13, was a comparison of each parameter over the course of the experiment for the control and Test Group (“Test Group” refers to the group receiving the artistic exposure, i.e. all 20 participants not in the Control Group). The first notable difference, in Figure 12, is that the Control Group’s RPM balance parameters are all below the baseline measurements, denoting an increase in balance from baseline. The Test Group’s graph, Figure 13, shows that the first RPM activity yielded similar results, however the second RPM activity had all parameters (except for velocity) above those of the baseline, marking an increase in sway from baseline.

This data can also be broken down to see the evolution of each parameter for each group over the course of the experiment, as seen in Figures 14-17.
Figure 14: Average X displacement over the experimental activities for each group.

Figure 15: Average Y displacement over the experimental activities for each group.
Figure 16: Average 95% ellipse area over the experimental activities for each group.

Figure 17: Average CoP velocity over the experimental activities for each group.

Another notable observation is that the sway parameters for the Test Group are noticeably higher in each parameter than the Control Group during the first RPM activity, however are only higher than the Control Group in the Y displacement and 95% ellipse area parameters during the second RPM activity. This difference is explored further in sections 3.2 and 3.3.
3.1 Normality Analysis

The next analysis that was done was to evaluate the normality of each set of data. This was done to see what kind of comparison test to run to compare group means (parametric or non-parametric). This was done using a kurtosis and skewness evaluation, where kurtosis is defined as:

\[
K = \frac{n(n+1)}{(n-1)(n-2)(n-3)} \cdot \sum_{i=1}^{n} (x_i - \bar{x})^4 \cdot \frac{s^4}{s^4 - 3(n-1)^2(n-2)(n-3)}
\]

(7)

Where \( n \) is the number of measurements, and \( x_i \) is the \( i \)th measurement. \( K \) represents the “sharpness” of the peak of the data, and is 1 under perfect normality. Skewness is defined as:

\[
S = \frac{n}{(n-1)(n-2)} \sum \left( x_i - \bar{x} \right)^3
\]

(8)

and represents the degree of asymmetry of the distribution about its mean [Microsoft]. For both kurtosis and skewness, measurements are divided by their standard error and their ratio is evaluated. Values of the ratio above 2 or under -2 are considered out of the range of normality [Real Statistics]. The values of this analysis are in Tables 1-5.

<table>
<thead>
<tr>
<th>Test Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPM 1</td>
<td>RPM 2 Difference</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>-0.73</td>
</tr>
<tr>
<td>Std. Err.</td>
<td>0.55</td>
</tr>
<tr>
<td>Ratio</td>
<td>-1.34</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.80</td>
</tr>
<tr>
<td>Std. Err.</td>
<td>1.10</td>
</tr>
<tr>
<td>Ratio</td>
<td>0.73</td>
</tr>
<tr>
<td>Normal?</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 1: Normality of X displacement data. Red cells indicate non-normal identifiers.
### Table 2: Normality of Y displacement data. Red cells indicate non-normal identifiers.

<table>
<thead>
<tr>
<th></th>
<th>Test Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kurtosis</td>
<td>RPM 1: 4.37</td>
<td>RPM 1: -2.72</td>
</tr>
<tr>
<td></td>
<td>RPM 2: 3.01</td>
<td>RPM 2: 0.53</td>
</tr>
<tr>
<td></td>
<td>Difference: 0.67</td>
<td>Difference: 1.42</td>
</tr>
<tr>
<td>Std. Err.</td>
<td>RPM 1: 0.55</td>
<td>RPM 1: 1.10</td>
</tr>
<tr>
<td></td>
<td>RPM 2: 0.55</td>
<td>RPM 2: 1.10</td>
</tr>
<tr>
<td></td>
<td>Difference: 0.55</td>
<td>Difference: 1.22</td>
</tr>
<tr>
<td>Ratio</td>
<td>RPM 1: 7.97</td>
<td>RPM 1: -2.48</td>
</tr>
<tr>
<td></td>
<td>RPM 2: 5.49</td>
<td>RPM 2: 0.48</td>
</tr>
<tr>
<td></td>
<td>Difference: 1.22</td>
<td>Difference: 1.16</td>
</tr>
<tr>
<td>Skewness</td>
<td>RPM 1: 1.60</td>
<td>RPM 1: -0.53</td>
</tr>
<tr>
<td></td>
<td>RPM 2: 1.66</td>
<td>RPM 2: 1.11</td>
</tr>
<tr>
<td></td>
<td>Difference: 0.86</td>
<td>Difference: -0.52</td>
</tr>
<tr>
<td>Std. Err.</td>
<td>RPM 1: 1.10</td>
<td>RPM 1: 2.19</td>
</tr>
<tr>
<td></td>
<td>RPM 2: 1.10</td>
<td>RPM 2: 2.19</td>
</tr>
<tr>
<td></td>
<td>Difference: 1.10</td>
<td>Difference: 2.45</td>
</tr>
<tr>
<td>Ratio</td>
<td>RPM 1: 1.46</td>
<td>RPM 1: -0.24</td>
</tr>
<tr>
<td></td>
<td>RPM 2: 1.51</td>
<td>RPM 2: 0.51</td>
</tr>
<tr>
<td></td>
<td>Difference: 0.79</td>
<td>Difference: -0.21</td>
</tr>
<tr>
<td>Normal?</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### Table 3: Normality of 95% Ellipse area data. Red cells indicate non-normal identifiers.

<table>
<thead>
<tr>
<th></th>
<th>Test Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kurtosis</td>
<td>RPM 1: 2.84</td>
<td>RPM 1: -0.42</td>
</tr>
<tr>
<td></td>
<td>RPM 2: 3.33</td>
<td>RPM 2: -0.46</td>
</tr>
<tr>
<td></td>
<td>Difference: 11.18</td>
<td>Difference: -2.24</td>
</tr>
<tr>
<td>Std. Err.</td>
<td>RPM 1: 0.55</td>
<td>RPM 1: 1.10</td>
</tr>
<tr>
<td></td>
<td>RPM 2: 0.55</td>
<td>RPM 2: 1.10</td>
</tr>
<tr>
<td></td>
<td>Difference: 0.55</td>
<td>Difference: 1.22</td>
</tr>
<tr>
<td>Ratio</td>
<td>RPM 1: 5.19</td>
<td>RPM 1: -0.38</td>
</tr>
<tr>
<td></td>
<td>RPM 2: 6.08</td>
<td>RPM 2: -0.42</td>
</tr>
<tr>
<td></td>
<td>Difference: 20.41</td>
<td>Difference: -1.83</td>
</tr>
<tr>
<td>Skewness</td>
<td>RPM 1: 1.89</td>
<td>RPM 1: 0.25</td>
</tr>
<tr>
<td></td>
<td>RPM 2: 1.85</td>
<td>RPM 2: 1.01</td>
</tr>
<tr>
<td></td>
<td>Difference: 2.89</td>
<td>Difference: -0.13</td>
</tr>
<tr>
<td>Std. Err.</td>
<td>RPM 1: 1.10</td>
<td>RPM 1: 2.19</td>
</tr>
<tr>
<td></td>
<td>RPM 2: 1.10</td>
<td>RPM 2: 2.19</td>
</tr>
<tr>
<td></td>
<td>Difference: 1.10</td>
<td>Difference: 2.45</td>
</tr>
<tr>
<td>Ratio</td>
<td>RPM 1: 1.73</td>
<td>RPM 1: 0.11</td>
</tr>
<tr>
<td></td>
<td>RPM 2: 1.69</td>
<td>RPM 2: 0.46</td>
</tr>
<tr>
<td></td>
<td>Difference: 2.64</td>
<td>Difference: -0.05</td>
</tr>
<tr>
<td>Normal?</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
In the above tables, cells highlighted in red signify that the ratio between either the skewness or the kurtosis values over their standard errors was above 2 or less than -2. This means that analyses containing one or more of these values will be non-parametric, or do not have the assumption that the data is normal. The rest of the analyses (those that only include comparisons between two sets of normal data) will be analyzed with parametric tests.

3.2 Test Vs. Control Groups

The next set of analyses were done using the averaged values of each postural sway parameter across all of the experimental task participant groups, compared with the Control Group. The following values are the difference in RPM parameter measurements, or the second
RPM task measurement minus the first. Negative values indicate the group was more stable during the second RPM task than the first.

**Figure 18:** X displacement difference between the first RPM task and the second. Positive numbers indicate an increase in displacement, and therefore an increase in sway.

**Figure 19:** Y displacement difference between the first RPM task and the second. Positive numbers indicate an increase in displacement, and therefore an increase in sway.
Figure 20: 95% ellipse area difference between the first RPM task and the second. Positive numbers indicate an increase in area, and therefore an increase in sway.

Figure 21: Velocity difference between the first RPM task and the second. Positive numbers indicate an increase in velocity, and therefore an increase in sway.
In the above figures, the Test Group had a higher average score in the RPM score evaluation, when comparing the second RPM to the first, but mixed instability parameters (negative values indicating an increase in stability from the first RPM task to the second).

3.3 Significance Analysis

The next analysis that was done was to look for significant comparisons between the Test Group and the Control Group. This was done with measurement differences between RPM tasks, with negative values indicating that the group was more stable in that parameter during the second RPM task in comparison to the first.
Table 6: All test participant group average RPM difference (RPM 2 from RPM 1) in parameters, vs. control. Note the statistically significant difference in RPM scores.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average Displacement along X (cm.)</th>
<th>Average Displacement along Y (cm.)</th>
<th>95% Ellipse Area (cm..cm.)</th>
<th>Avg. RPM Score (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change from Baseline</td>
<td>RPM Diff. Sample Mean, Control</td>
<td>RPM Diff. Sample Mean, Test</td>
<td>RPM Diff. Sample Mean, Test</td>
<td>RPM Diff. Sample Mean, Test</td>
</tr>
<tr>
<td></td>
<td>1.13</td>
<td>-0.19</td>
<td>-1.32</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>-0.35</td>
<td>-0.37</td>
<td>-0.03</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>6.51</td>
<td>4.28</td>
<td>-2.22</td>
<td>10.30</td>
</tr>
<tr>
<td></td>
<td>0.02</td>
<td>-1.74</td>
<td>-1.76</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>-4</td>
<td>7</td>
<td>11.00</td>
<td>5.12</td>
</tr>
<tr>
<td>Type of Significance Test</td>
<td>Two-sided t-test</td>
<td>Two-sided t-test</td>
<td>Mann-Whitney</td>
<td>Fail</td>
</tr>
<tr>
<td></td>
<td>0.13</td>
<td>0.41</td>
<td>28.01</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>1.23</td>
<td>2.36</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.07</td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-value (t-test), reject/fail (MW)</td>
<td>0.13</td>
<td>0.41</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td>Pooled St. Dev.</td>
<td>1.32</td>
<td>2.36</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>Effect Size</td>
<td>1.23</td>
<td>2.36</td>
<td>0.08</td>
<td></td>
</tr>
</tbody>
</table>

The p-value for these tests, and subsequent statistical significance analyses, is done using a two-tailed Student’s t-test with unequal variances. A significance value of \( \alpha = 0.1 \) was chosen because this is a pilot study (however most significant statistics reached a significance value of \( \alpha = 0.05 \)), and there were limited numbers of participants, especially for the Control Group (5 participants). A one-way ANOVA was also done to verify each of the p-values. The effect size (how widespread the effect is in the population, otherwise known as Cohen’s \( d \)) is calculated using the pooled standard deviation (weighted for differences in sample mean, also called Cohen’s \( s \)) and is evaluated on the following criteria: “very small” for values of \( d \) near 0.01 and under, “small” for values near 0.2, “medium” for values near 0.5, “large” for values near 0.8, “very large” for values near 1.2, and “huge” for values near 2 and above [Sawilowsky 2009].

The Mann-Whitney test used as the non-parametric test for the non-normally distributed was done by ranking each of the measurements for each parameter, taking the sum of the rankings for each group and using the following equation to get the appropriate statistic:

\[
U = R - \frac{n(n+1)}{2}
\]
where $R$ is the sum of the ranks, and $n$ is the number of participants in the group. This was done for both groups (in this case, each of the Test Group and the Control Group), and the lower of the two statistics was compared against a Mann-Whitney critical value table. The null hypothesis (that the means were statistically the same) was rejected if this lower number was less than the test statistic, and would indicate that the means are significantly different [LaMorte 2016]. A full analysis of this data can be found in appendix section 7.6. The above tables show if the null hypothesis was rejected, or failed to be rejected.

The significant comparisons found in this analysis included the difference between the RPM scores of the Control Group and Test Group, with the Test Group scoring 11% higher than the Control Group. In addition, the Control Group scored overall worse during the second RPM test than the first, whereas the Test Group showed an improvement in scores (correct answers to the RPM questions). This observation had a “large” effect size according to the Cohen’s $d$ effect size calculation. The average CoP velocity across all Test Group in comparison to the Control Group was also found to be significant, with the Test Group scoring consistently more stable than the Control Groups when looking at the comparison between measurements taking during the RPM tasks. This fact, coupled with the improvement in RPM scores in the Test Group, leads to an interesting interpretation of the data. This may show that the Test Group needed less cognitive power to achieve higher results than the Control Group, leading to the decrease in sway. Further analysis into this idea is discussed in the Discussion section.

The other analyses did not produce significant results comparing the Test Group to the Control Group. This may have been a product of the small number of participants recruited, especially for the Control Group (5 participants). This was especially effective in the Mann-Whitney test, which relies heavily on the number of participants (and is previously determined to
be the type of test used if the data is non-normal, which is also affected by low participant numbers). As can be seen in appendix section 7.6, some of the Mann-Whitney evaluations approached the critical value, meaning they were almost significant but had not quite reached it. Regardless of this fact, an evaluation of the comparison within Test Group is given next.

A secondary analysis that was done was a comparison of the parameter means during the RPM tests given before and after the art viewing and drawing activities, for the Test Group and the Control Group. In other words, RPM 1’s mean was evaluated against RPM 2’s mean for each group. A summary of this analysis is in Tables 7-8.

<table>
<thead>
<tr>
<th>% Change from Baseline</th>
<th>RPM 1 Sample Mean</th>
<th>RPM 2 Sample Mean</th>
<th>Sample Mean Difference</th>
<th>90% Confidence Interval (+/-)</th>
<th>Type of Test</th>
<th>p-value (t-test), reject/fail (MW)</th>
<th>Pooled St. Dev.</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Displacement along X (cm.)</td>
<td>0.56</td>
<td>1.69</td>
<td>1.13</td>
<td>0.35</td>
<td>Mann-Whitney</td>
<td>Fail</td>
<td>0.96</td>
<td>1.17</td>
</tr>
<tr>
<td>Avg. Displacement along Y (cm.)</td>
<td>3.41</td>
<td>3.07</td>
<td>-0.35</td>
<td>0.99</td>
<td>t-test</td>
<td>0.84</td>
<td>2.69</td>
<td>0.13</td>
</tr>
<tr>
<td>95% Ellipse Area (cm..cm.)</td>
<td>25.27</td>
<td>31.78</td>
<td>6.51</td>
<td>9.29</td>
<td>Mann-Whitney</td>
<td>Fail</td>
<td>25.27</td>
<td>0.26</td>
</tr>
<tr>
<td>Avg Velocity (cm/sec)</td>
<td>1.77</td>
<td>1.79</td>
<td>0.02</td>
<td>0.13</td>
<td>Mann-Whitney</td>
<td>Fail</td>
<td>0.35</td>
<td>0.05</td>
</tr>
<tr>
<td>Avg. RPM Score</td>
<td>73.33</td>
<td>69.33</td>
<td>-4.00</td>
<td>5.43</td>
<td>t-test</td>
<td>0.68</td>
<td>14.76</td>
<td>0.27</td>
</tr>
</tbody>
</table>
Table 8: All test participant group RPM 1 parameters vs. RPM 2 parameters.

<table>
<thead>
<tr>
<th>% Change from Baseline</th>
<th>RPM 1 Sample Mean</th>
<th>RPM 2 Sample Mean</th>
<th>Sample Mean Difference</th>
<th>90% Confidence Interval (+/-)</th>
<th>Type of Test</th>
<th>p-value (t-test), reject/fail (MW)</th>
<th>Pooled St. Dev.</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Displacement along X (cm.)</td>
<td>1.22</td>
<td>1.03</td>
<td>-0.19</td>
<td>0.28</td>
<td>Two-sided t-test</td>
<td>0.43</td>
<td>0.75</td>
<td>0.25</td>
</tr>
<tr>
<td>Avg. Displacement along Y (cm.)</td>
<td>4.88</td>
<td>4.51</td>
<td>-0.37</td>
<td>1.04</td>
<td>Mann-Whitney</td>
<td>Fail</td>
<td>2.82</td>
<td>0.13</td>
</tr>
<tr>
<td>95% Ellipse Area (cm..cm.)</td>
<td>45.91</td>
<td>50.19</td>
<td>4.28</td>
<td>14.57</td>
<td>Mann-Whitney</td>
<td>Fail</td>
<td>39.61</td>
<td>0.11</td>
</tr>
<tr>
<td>Avg Velocity (cm/sec)</td>
<td>1.95</td>
<td>0.21</td>
<td>-1.74</td>
<td>0.07</td>
<td>Two-sided t-test</td>
<td>0.00</td>
<td>0.20</td>
<td>8.64</td>
</tr>
<tr>
<td>Avg. RPM Score</td>
<td>68</td>
<td>75</td>
<td>7.00</td>
<td>4.65</td>
<td>Mann-Whitney</td>
<td>Fail</td>
<td>12.66</td>
<td>0.55</td>
</tr>
</tbody>
</table>

The same criteria for evaluating the p-values, Mann-Whitney scores and effect size is used as when analyzing the statistical significance of the comparison between the testing groups and the Control Group. The populations consisted of the changes from the baseline of the first RPM activity, and those of the second RPM activity.

There were some statistically significant changes seen here. Of note, the CoP velocity difference between RPM tasks in the Test Group was found to be significant, and the measurement was also lower in the second RPM task than in the first, with an average mean difference of 1.74 cm/sec for the Test Group. This validates the significance of the increased stability (in the CoP velocity parameter) from the first RPM task to the second in the Test Group. The Control Group, however, did not share this significance, with none of the parameter differences reaching statistical significance. This may be a product of the low number of participants.

4.0 Discussion

There are some interesting observations that can be made from this data. First, the original hypothesis was not confirmed, as there was a significant decrease in sway parameters,
namely Cop velocity, in the group that received artistic exposure from the first RPM task to the second. This was supported by the fact that the Control Group showed a slight increase in sway in the velocity parameter, and though this increase itself was not significant, the comparison between the Control Group and the Test Group was significant. This means that the Control Group showed a greater cognitive effort during the second RPM activity as opposed to the first, while the Test Group showed the opposite.

Interestingly, another statistically significant parameter was the fact that the Test Group scored dramatically better than the Control Group when comparing the correct answers given during the RPM tasks, with the Test Group showing an increased score from 68% to 75% (7% increase, Table 8), and the Control Group showing a decrease from 73.3% to 69.3% (4% decrease, Table 7). This difference in behavioral scores indicates that the while the Test Group on average scored lower than the Control Group during the first RPM test, they had a greater improvement during the second RPM test and surpassed the Control Group in score averages. This indicates that the artistic material had a positive effect on the Test Group.

The combination of these observations creates an interesting hypothesis on the effect of the artistic material on the Test Group. If the correlation of cognitive workload to postural sway is to be believed (particularly in the CoP velocity parameter, which is referenced by Raymakers et. al. to be a particularly good measure of sway (Raymakers et.al. 2005)), then the Test Group showed decreased cognitive activity from the first RPM task to the second. This is echoed in other sway parameters, namely the X and Y displacement parameters, in the Test Group’s comparison of RPM tasks (Table 8) and the comparison between the Test Group and the Control Group (Table 6), however these comparisons were not statistically significant. However, given that the Test Group performed statistically significantly better than the Control Group, this may
point to the Test Group needing less cognitive power to achieve greater success in the RPM task. This may be due to a shift in thought process caused by the artistic material, conditioning the Test Group to view material in a visual manner, causing them to solve the RPM problems with greater accuracy.

4.1 Conclusions

Though the data presented may seem contradictory at first, there is an interesting interpretation that can come of it when considering the full implications. Because the Test Group scored objectively higher, and showed higher improvement on the RPM task given after the artistic exposure, it is at first difficult to see why their balance was affected by becoming better. This has been shown in previous studies to correlate with decreased amounts of cognition, and would indicate that the Test Group is giving less cognitive power to the second RPM task, yet achieving better results. This points to a hypothesis that the artistic material is conditioning them to view problem solving in a new way, solving the second set of RPM problems in a more creative manner than the first round. Though this does not agree with the originally stated hypothesis, it is interesting and may still align with the intended goal of the project; to promote the addition of artistic material in STEM curriculum. More experimentation would be necessary to validate the claims made here, however this is an interesting view into the interpretation of what it means for problem-solving to come naturally. Since the Test Group showed decreased sway parameters, both in the statistically significant and insignificant data, they may have become able to solve the RPM tasks with less cognitive effort and still achieve better results.

4.2 Limitations

During the study the most prominent limitation seen to affect the results was the size of the participant pool, particularly in the Control Group. For the total participant population, there was one statistically significant result with a sizable effect size, however this was not the case.
when dividing the population into two halves. Future studies should take into account the increased number of participants that would be needed for the Control Group to produce better results.

Another limitation to the study was the environment in which the EEG recordings were taken. First, there was constant line noise at 60 Hz due to the force platform and associated equipment. Second, there were a lot of movement artifacts generated by the verbal answers given by the participants during the RPM tasks, which had to be filtered out during analysis. This filtering was not perfect, however, and led to a loss of data in the long run. After the data had been measured and interpreted, it became clear that there was very little useful information gleaned from these analyses. The significance value of almost all of the measurements rendered them unusable (near \( p=1 \), or much larger than \( p=.1 \)), and the amount of data that had been lost due to artifact rejection was higher than originally thought. This means there was a significant amount of data corruption due to speaking, blinking and other movement from the participants. If the data had too much variance due to these factors, it had to be removed from the dataset. In the end, this data was not considered conclusive to the original aim.

Finally, the artistic material shown to the participants was limited. The point of the material was to have the participants think about a known subject in an artistic manner, however the material given could not possibly cover the scope of all that is possible to do in this way. The example used in this study may not be truly exemplary of the best way to introduce a topic in a new light, and further research into teaching methods would be necessary to meet this need.

4.3 Future Work

Future studies that could carry on the work presented here would benefit not only in improving the study, but also in growing the participant pool and data available for evaluation.
Future studies would be conducted in an environment that is able to best capture accurate EEG recordings, i.e. the participants would have a clicker or other hand-operated device to choose RPM answers with to reduce speech movement artifacts. Future work could also utilize a 64-channel EEG system instead of a 32-channel system to have a higher resolution and data output. Elimination of the EEG aspect could be done as well, focusing more on the balance portion of the study. A more sensitive force platform could also be used to better capture the minute changes in balance.

Different stimulus for the activities presented in this study could be used in future studies to supplement or challenge the material presented here, verifying the data presented. To induce creative thinking in individuals is a very varied and complex topic, and the best way to go about this task can be a work on its own.

Finally, the tiredness of the participants during the standing activities was not evaluated. This may have been consistent across the Test Group, as they spent time sitting down before testing began (about 20 minutes to sign the consent form, and have the EEG cap put on) and during the drawing period. However, the control group did not have this same time to sit before testing began, and may have started the experimentation tired. They were able to sit during the time they were not actively doing anything for the experiment, however. Future studies should allow the participants in the control group especially to be well rested to collect more accurate results.
5.0 References


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6.0  Appendices
6.1  Examples of Stimulus

RPM Stimulus
Art 1 Stimulus
[Schulman, 2019]
Art 2 and 3 Stimulus
[Bellos 2015] [Bellos 2016]
6.2 Stimulus Presentation Code

%% Intro (CHANGE PER PARTICIPANT)

Code by Gina DiGiacomo

% Before testing:
% Determine Participant number (P1, P4, etc.)
% randperm(60,60) for 60 items, print answer sheet, set array to 'rpm' variable
% Make sure timing section is correct
% Start recording on recording computer

% Code Checklist:
% Correct Paths
% (29) isfake=RTBox('fake', 0) (for EEG testing)
% (31) RTBox('ClockRatio') done at least once (for EEG testing)
% (38) Participant number is correct
% (40) RPM set is correct
% (42) rpm variable matches participant variable
% (53) timing is correct

% Clear the workspace and the screen
scs;
close all;
clearvars;

% RT Box Sync
addpath(genpath('C:Users\GPlab\Documents\STEM to STEAM\RTBoxMFILES'));

isfake=RTBox('fake', 0); % Turn this OFF (0) before actual EEG testing

RTBox('ClockRatio'); % Synchronize the computer and RT Box clocks at start of experiment

RTBox('TTLWidth', 0.01); % Sets width of the TTL pulse
RandRPM=[35,17,50,31,24,11,42,8,41,25,33,44,2,56,21,46,43,22,48,27,4,14,36,52,51,40,34,10,55,45,53,48,35,40,54,14,21,9,39,49,6,20,1,59,2,22,31,34,8,5,33,57,46,24,23,10,26,7,38,16,10,40,56,8,52,9,15,27,43,21,19,31,60,41,34,25,1,26,59,29,20,28,47,38,4,17,49,51;9,34,2,55,23,26,48,35,29,46,39,15,38,34,37,10,4,7,11,56,41,17,22,8,31,6,44,49,57,19,27,7,51,36,1,13,25,54,5,16;36,3,16,39,7,24,13,44,11,5,19,6,18,40,34,52,45,41,12,56,22,4,42,15,33,29,31,9,37,43;6,38,51,48,5,20,18,17,9,39,32,14,34,56,53,60,40,42,12,57,30,4,36,47,24,37,29,8,25,2;13,57,52,53,22,25,5,51,1,45,28,33,4,55,56,34,18,32,4,2,48,29,37,7,40,3,10,44,12,14,15;3,47,39,16,50,49,24,25,26,42,28,7,22,59,56,52,34,51,38,13,12,45,19,44,15,48,9,20,32,46;36,8,51,60,46,40,13,48,14,45,17,57,41,21,55,23,42,44,26,35,39,4,58,
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Art012=RandArt(12,:);
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Art014=RandArt(14,:);
Art015=RandArt(15,:);
Art016=RandArt(16,:);
Art017=RandArt(17,:);
Art018=RandArt(18,:);
Art019=RandArt(19,:);
Art020=RandArt(20,:);
Art021=RandArt(21,:);

rpmset='2'; % 1 or 2

rpm = RPM003;
MathOrder = Math003;
ArtOrder = Art003;

% Default timing parameters
% sec=10;
sec=10;

% Load RPM stimulus directory (choose 1 or 2)
addpath(genpath('C:\Users\GPlab\Documents\STEM to STEAM\ResizedRPM'));

%% PsychToolbox Stuff (DO NOT CHANGE)

% Here we call some default settings for setting up Psychtoolbox
PsychDefaultSetup(2);

% Get the screen numbers. This gives us a number for each of the screens
% attached to our computer.
screens = Screen('Screens');

% To draw we select the maximum of these numbers. So in a situation where we
% have two screens attached to our monitor we will draw to the external
% screen.
screenNumber = max(screens);

% Define black and white (white will be 1 and black 0). This is because
% in general luminance values are defined between 0 and 1 with 255 steps in
% between. All values in Psychtoolbox are defined between 0 and 1
white = WhiteIndex(screenNumber);
black = BlackIndex(screenNumber);
% Do a simply calculation to calculate the luminance value for grey. This
% will be half the luminance values for white
grey = white / 2;

% Open an on screen window using PsychImaging and color it grey.
[window, rect] = PsychImaging('OpenWindow', screenNumber, grey);

% Set the blend function for the screen
Screen('BlendFunction', window, 'GL_SRC_ALPHA', 'GL_ONE_MINUS_SRC_ALPHA');

% Get the size of the on screen window in pixels
% For help see: Screen WindowSize?
[screenXpixels, screenYpixels] = Screen('WindowSize', window);

% Get the centre coordinate of the window in pixels
% For help see: help RectCenter
[xCenter, yCenter] = RectCenter(rect);

% Measure the vertical refresh rate of the monitor
ifi = Screen('GetFlipInterval', window);

% Retrieve the maximum priority number and set max priority
topPriorityLevel = MaxPriority(window);
Priority(topPriorityLevel);

% Flip outside of the loop to get a time stamp
Screen('Flip', window);
nominalFrameRate = Screen('NominalFrameRate', window);

% Welcome and Baseline

texty=300;

Screen ('TextSize', window, 30);
Screen('TextFont', window, 'Arial');
Screen ('TextStyle', window, 0);
Screen ('DrawText', window, 'Welcome to our study on Creative Problem Solving!', 400, texty, white);

% Flip to the screen
Screen('Flip', window);

KbStrokeWait;

Screen ('TextSize', window, 30);
Screen ('TextFont', window, 'Arial');
Screen ('TextStyle', window, 0);
Screen ('DrawText', window, 'A baseline recording will now run for 5 minutes.', 400, texty, white);
Screen ('DrawText', window, 'Please stand as still as possible with your hands at your sides.', 400, texty+200, white);
Screen ('DrawText', window, 'If you have any questions please ask the administrator.', 400, texty+600, white);
Screen ('DrawText', window, 'Press any key to continue', 400, texty+500, white);

Screen('Flip', window);

KbStrokeWait;

%%%% Baseline recording marker
for k=1:30

    numberString = num2str(31-k);

    Screen ('TextSize', window, 50);
    Screen('TextFont', window, 'Arial');
    Screen ('TextStyle', window, 0);
    Screen ('DrawText', window, 'Recording...', 400, texty+200, white);
    Screen ('DrawText',window, numberString, 400, texty+400, white);

    Screen('Flip', window);

    for i=1:10
        RTBox('TTL', TriggerMe15(15));
        pause(sec/10)
    end

end

%%%% Example RPM

Screen ('TextSize', window, 30);
Screen ('TextFont', window, 'Arial');
Screen ('TextStyle', window, 0);
Screen ('DrawText', window, 'You are going to participate in a game called the Raven game.', 400, texty-200, white);
Screen ('DrawText', window, 'In each round, you will see some patterns appear on the screen.', 400, texty-100, white);
Screen ('DrawText', window, 'You must find the missing pattern from the list of available patterns.', 400, texty, white);
You may answer as many times as you want, but be thoughtful.

If you have any questions or would like to take a break, please ask the administrator.

Press any key to continue to an example.

In this case, the correct answer would be the one circled in red.

Possible answers will have a number next to them that you can use to answer.

You are now going to participate in the real Raven game.

Press any key to continue.

%%% First RPM Test (a)
a=1;

for k=1:15
    rpmsingle=rpm(1,a);
    rpmChar=num2str(rpmsingle);
    numberString = num2str(k);
    RMPic = imread( ['C:\Users\GPlab\Documents\STEM to STEAM\ResizedRPM\rpmChar'.png']);
    RPMscreen = Screen('MakeTexture', window, RMPic);
    Screen('DrawTexture', window, RPMscreen);
    Screen ('DrawText',window, numberString, 100, 1000, grey);
    a=a+1;
    Screen('Flip', window);

    %RTBox marker art
    for i=1:20
        RTBox('TTL', TriggerMe15(10));
        pause(sec/10)
    end
end

Screen('FillRect', window, grey);

Screen ('TextSize', window, 72);
Screen('TextFont', window, 'Arial');
Screen ('TextStyle', window, 0);
Screen ('DrawText', window, 'Press any key to continue', 400, texty, white);

Screen('Flip', window);
KbStrokeWait;

%% Art Appreciation 1 (Richard Shulman)
addpath(genpath('C:\Users\GPlab\Documents\STEM to STEAM\ArtPic'));

Screen ('TextSize', window, 30);
Screen('TextFont', window, 'Arial');
Screen ('TextStyle', window, 0);
Screen ('DrawText', window, 'You will now see a series of images, think about', 400, texty, white);
Screen ('DrawText', window, 'what you particularly like or dislike about each one.', 400, texty+100, white);
Screen ('DrawText', window, 'If you have any questions or would like to take a break,', 400, texty+200, white);
Screen ('DrawText', window, 'please ask the administrator.', 400, texty+300, white);
Screen ('DrawText', window, 'Press any key to continue', 400, texty+500, white);

Screen('Flip', window);

KbStrokeWait;

Screen('FillRect', window, white);
Screen('Flip', window);

g=1;

for k=1:15
    Artsingle=ArtOrder(1,g);
    ArtStr=num2str(Artsingle);

    ArtPic = imread(['C:\Users\GP\Documents\STEM to STEAM\ArtPic' ArtStr '.png']);
    ArtScreen = Screen('MakeTexture', window, ArtPic);
    Screen('DrawTexture', window, ArtScreen);

    Screen ('TextSize', window, 12);
    Screen('TextFont', window, 'Arial');
    Screen ('TextStyle', window, 0);
    Screen ('DrawText', window, 'Richard Shulman', 100, 500, grey);

    Screen('Flip', window);

    g=g+1;
end

%RTBox marker art
for i=1:10
    RTBox('TTL', TriggerMe15(1));
    pause(sec/10)
end

end

%% Art Appreciation 2 (Math)
addpath(genpath('C:\Users\GP\lab\Documents\STEM to STEAM\ResizedMathPic'));

Screen('FillRect', window, grey);
Screen('Flip', window);

Screen ('TextSize', window, 30);
Screen('TextFont', window, 'Arial');
Screen ('TextStyle', window, 0);
Screen ('DrawText', window, 'You will now see a series of images, think about', 400, texty, white);
Screen ('DrawText', window, 'what you particularly like or dislike about each one.', 400, texty+100, white);
Screen ('DrawText', window, 'If you have any questions or would like to take a break;', 400, texty+200, white);
Screen ('DrawText', window, 'please ask the administrator.', 400, texty+300, white);
Screen ('DrawText', window, 'Press any key to continue', 400, texty+500, white);

Screen('Flip', window);

KbStrokeWait;

Screen('FillRect', window, white);
Screen('Flip', window);

j=1;
for k=1:15
    Mathsingles=MathOrder(1,j);
    MathStr=num2str(Mathsingles);
    MathPic = imread(['C:\Users\GP\lab\Documents\STEM to STEAM\ResizedMathPic\' MathStr '.png']);
    MathScreen = Screen('MakeTexture', window, MathPic);
    Screen('DrawTexture', window, MathScreen);
    Screen ('TextSize', window, 12);
    Screen('TextFont', window, 'Arial');
    Screen ('TextStyle', window, 0);
    Screen ('DrawText', window, 'Alex Bellos and Edmund Harriss', 100, 500, grey);
    Screen('Flip', window);
    j=j+1;
end

71
%RTBox marker art
for i=1:10
    RTBox('TTL', TriggerMe15(2));
    pause(sec/10)
end
end

%% Drawing

Screen('FillRect', window, grey);
Screen('Flip', window);

Screen ('TextSize', window, 30);
Screen('TextFont', window, 'Arial');
Screen ('TextStyle', window, 0);
Screen ('DrawText', window, 'You will now draw in a special packet for 20 minutes.',
400, texty, white);
Screen ('DrawText', window, 'Please follow the instructions in the packet.', 400,
texty+100, white);
Screen ('DrawText', window, 'If you have any questions please ask the administrator.',
400, texty+300, white);
Screen ('DrawText', window, 'Press any key to continue', 400, texty+500, white);

Screen('Flip', window);
KbStrokeWait;

%% Art Appreciation 3 (Math)

Screen ('DrawText', window, 'You will now see another series of images, think about',
400, texty, white);
Screen ('DrawText', window, 'what you particularly like or dislike about each one.', 400,
texty+100, white);
Screen ('DrawText', window, 'If you have any questions or would like to take a break',,
400, texty+200, white);
Screen ('DrawText', window, 'please ask the administrator.', 400, texty+300, white);
Screen ('DrawText', window, 'Press any key to continue', 400, texty+400, white);

Screen('Flip', window);
KbStrokeWait;

Screen('FillRect', window, white);
Screen('Flip', window);
for k=1:15
    Mathsingle=MathOrder(1,j);
    MathStr=num2str(Mathsingle);
    MathPic = imread(['C:\Users\GPLab\Documents\STEM to STEAM\ResizedMathPic\' MathStr '.png']);
    MathScreen = Screen('MakeTexture', window, MathPic);
    Screen('DrawTexture', window, MathScreen);
    Screen ('TextSize', window, 12);
    Screen('TextFont', window, 'Arial');
    Screen ('TextStyle', window, 0);
    Screen ('DrawText', window, 'Alex Bellos and Edmund Harriss', 100, 500, grey);
    Screen('Flip', window);
    j=j+1;
    
    end
    
end

  %% Second Raven Game

Screen('FillRect', window, grey);
    Screen ('TextSize', window, 30);
    Screen('TextFont', window, 'Arial');
    Screen ('TextStyle', window, 0);
    Screen ('DrawText', window, 'You will now do another Raven game for 5 minutes.', 400, texty, white);
    Screen ('DrawText', window, 'If you have any questions please ask the administrator.', 400, texty+200, white);
    Screen ('DrawText', window, 'Press any key to continue', 400, texty+400, white);
    Screen('Flip', window)
    KbStrokeWait;
    Screen('FillRect', window, white);
    Screen('Flip', window);
for k=1:15
    rpmsingle=rpm(1,a);
    rpmChar=num2str(rpmsingle);

    numberString = num2str(k);

    RPMpic = imread([\'C:\Users\GPlab\Documents\STEM to STEAM\ResizedRPM\rnmChar \'.png']);
    RPMScreen = Screen('MakeTexture', window, RPMpic);
    Screen('DrawTexture', window, RPMScreen);
    Screen ('DrawText',window, numberString, 100, 1000, grey);

    a=a+1;

    Screen('Flip', window);

    %RTBox marker art
    for i=1:20
        RTBox('TTL', TriggerMe15(11));
        pause(sec/10)
    end
end

Screen('FillRect', window, grey);

Screen ('TextSize', window, 72);
Screen('TextFont', window, 'Arial');
Screen ('TextStyle', window, 0);
Screen ('DrawText', window, 'Press any key to continue', 400, texty+300, white);

Screen('Flip', window);

KbStrokeWait;

%% End

Screen('FillRect', window, grey);
Screen('Flip', window);

Screen ('TextSize', window, 30);
Screen('TextFont', window, 'Arial');
Screen ('TextStyle', window, 0);
Screen ('DrawText', window, 'Thanks for participating! Rememeber to fill out the end survey!', 400, texty, white);

% Flip to the screen
Screen('Flip', window);

KbStrokeWait;

% Clear the screen.
sca;
6.3 Prescreening Survey

Prescreening Survey

Start of Block: Default Question Block

Q1
Thank you for your interest in this study! Please take the time to read through all the information presented, and answer honestly.

You are invited to participate in this survey. I am a graduate student at the University of Connecticut, and I am conducting this survey as part of my course work. I am interested in finding out about the effects of visual art exercises on creative problem solving.

Your participation in this study will require completion of the following questionnaire, which will determine if you qualify for the rest of the study. This should take approximately 10 minutes of your time. Your participation will be anonymous and you will be contacted again in the future should you qualify for our study. This survey does not involve any risk to you. However, the benefits of your participation may impact society by helping create a new method of STEM education.

You do not have to be in this study if you do not want to be. You do not have to answer any question that you do not want to answer for any reason. Should you decide to not participate, simply close out of the following questionnaire and your data will not be recorded. We will be happy to answer any questions you have about this study. If you have further questions about this project or if you have a research-related problem, you may contact the student investigator Gina DiGiacomo at gina.digiacomo@uconn.edu, or the PI Krystyna Gielo-Perczak at krystyna.gielo-perczak@uconn.edu. If you have any questions about your rights as a research participant you may contact the University of Connecticut Institutional Review Board (IRB) at 860-486-8802. The IRB is a group of people who review research studies to protect the rights and welfare of research participants.

By answering “I agree” below, you certify that you are:

- 18 years of age or older.
- Fluent in English
If you have read and understood the statement above, please indicate whether you agree or disagree to participate in the following questionnaire.

- I agree (1)
- I do not agree (2)

Q3
Due to the nature of collecting EEG data, there are some factors that may disqualify your participation. Please indicate if you:
- Have ever had a traumatic brain injury
- Do not have normal or corrected-to-normal vision (glasses or contact lenses are ok)
- Have severely impaired hearing
- Are currently taking any psychoactive medications
- Are not fluent in English
- Are left handed
- Have trouble wearing a tight-fitting cap on your head

- Any of the above items pertain to me (1)
- None of the above items pertain to me (2)

Q4
Due to the nature of collecting posturography data, there are some factors that may disqualify your participation in this particular activity. Please indicate if you:
- Have any musculoskeletal or neurological disorders
- Have trouble standing for periods of 10 minutes or longer

- Any of the above items pertain to me (1)
- None of the above items pertain to me (2)
If Thank you for your interest in this study! Please take the time to read through all the information... = I do not agree

And Due to the nature of collecting EEG data, there are some factors that may disqualify your participation... = Any of the above items pertain to me

And Due to the nature of collecting posturography data, there are some factors that may disqualify you... = Any of the above items pertain to me

Q14 Your responses to the screening questions indicate that you do not meet the eligibility criteria. Thank you for taking the time to complete the questions.

Q5 What is your preferred email?

____________________________________________________________________________________

Q6 What is your weight, in lbs?

____________________________________________________________________________________

Q7 What is your height, in feet and inches? (ex. 5' 11")

____________________________________________________________________________________
Q8 What is your gender?

- Male (1)
- Female (2)
- Prefer not to say (3)
- Other (4)

Q9 Are you an undergraduate STEM student at the University of Connecticut?

- Yes (1)
- No (2)

End of Block: Block 2

Start of Block: Block 3

Q10 What is your major?

________________________________________________________________

Q11 In general, how often do you engage in any type of creative art? (Drawing, music creation, dance, etc.)

0 = Never, 100 = 10 or more hours per week ()
Q12 If applicable, what kind of creative art do you do? Multiple answers are allowed.

________________________________________________________________

End of Block: Block 3
In this exercise, you will be drawing a visual description of three mathematical sequences. Your drawing or drawings can be of anything, and we encourage you to be as creative as possible! Below is an example of how a mathematical sequence can be described visually:

The Fibonacci sequence is a very well-known string of numbers where each entry is defined by the sum of the two preceding numbers. The simplest form of this series starts from 1 (where 0 is inferred to be before 1) and looks like this:

**The Fibonacci Sequence**

*Formula:* \( F(n) = F(n-1) + F(n-2) \) with \( F(0) = 0 \) and \( F(1) = 1 \).

*Sequence:* 1, 1, 2, 3, 5, 8, 13, 21, 34, 55...

However, there are other ways to describe this series using drawings and shapes. The most famous of these are the Golden Rectangle and Golden Spiral. The golden rectangle is a specific rectangle whose sides, when their lengths are divided, equal a ratio around 1.6179. This rectangle is then used to create the Golden Spiral.

Interestingly, if you divide two subsequent numbers of the Fibonacci Sequence, their ratio will tend to be around 1.6179 as well. This links the mathematical sequence to the picture above.

The following formulas will all follow a similar structure, with the variable \( a \) being the value of the number in the sequence, and the variable \( n \) being its position in the sequence. For the Fibonacci example above, the 6\(^{th}\) term ‘8’ would have \( a=8 \) and \( n=6 \).

Now, you will have the chance to show your own interpretations of different mathematical sequences. Don’t worry if your ideas seem too abstract or too simple, have fun with the exercise and let your mind wander! If you need help understanding any of the sequences, please feel free to ask the administrator.
The Prime Numbers

Formula: A number n is prime if it is greater than 1 and has no positive divisors except 1 and n (itself).

Sequence: 2, 3, 5, 7, 11, 13, 17, 19, 23, 29...
The Collatz Conjecture

Formula: \( a_n = \frac{n}{2} \) if \( n \) is even, \( 3n + 1 \) if \( n \) is odd

Sequence: \((n=13)\) 13, 40, 20, 10, 5, 16, 8, 4, 2, 1

The 3n+1 or Collatz problem is as follows: start with any number \( n \). If \( n \) is even, divide it by 2, otherwise multiply it by 3 and add 1. Do we always reach 1? This is an unsolved problem. It is conjectured that the answer is yes [Sloane]. Your drawing(s) may start with any number for \( n \).
Recamán's Sequence

Formula: \( a_n = a_{(n-1)} - n \) if positive and not already in the sequence, otherwise \( a_n = a_{(n-1)} + n \).

Sequence: 0, 1, 3, 6, 2, 7, 13, 20, 12, 21...

Recamán's sequence is as follows: start with \( a=0 \) at \( n=1 \) (first entry), then plug it into the formula \( a_n = a_{(n-1)} - n \), where \( a_{(n-1)} = 0 \) (because we are now on the second entry). If the resulting \( a_n \) is positive (it is, because it is 1) then keep it. However, if it is negative or it has been in the sequence before, then use the formula \( a_n = a_{(n-1)} + n \). This is seen at \( n=5 \), where \( a_{(n-1)} = 6 \). If the first formula is used, you would get \( a_n = 1 \), however since this has already been used, we must use the second formula to get \( a_n = 2 \).
End of Study Survey

Start of Block: Default Question Block

Q1 Have you ever been asked to do tasks similar to what you've done today?

Q2 How typical was your day today?

0 10 20 30 40 50 60 70 80 90 100

0 = Not very typical, 100 = Very typical ()

Q3 How anxious did this study make you feel?

0 10 20 30 40 50 60 70 80 90 100

0 = Not very anxious, 100 = Very anxious ()

Q4 How anxious have you felt in the past week, in general?

0 10 20 30 40 50 60 70 80 90 100
0 = Not very anxious, 100 = Very anxious ()

Q5 If you've been particularly stressed or otherwise have any other strong feelings while participating in this experiment, please let us know.

End of Block: Default Question Block

Start of Block: Block 1

Q6 Thank you for your participation today!

End of Block: Block 1

Start of Block: Block 2

Q7 Indicate participant number.

Q8 Indicate the date

End of Block: Block 2
### 6.6 Mann-Whitney Analysis

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<td>Fail</td>
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| RPM 1   | Sum of Ranks | 452.5 | 413.5 | 20  | 26  | 27  |
| RPM 2   | Sum of Ranks | 367.5 | 406.5 | 35  | 29  | 28  |
| RPM 1   | Count, RPM 1 | 20   | 20   | 5   | 5   | 5   |
| RPM 2   | Count, RPM 2 | 20   | 20   | 5   | 5   | 5   |
| RPM 1   | U Statistic, RPM 1 | 242.5 | 203.5 | 5   | 11  | 12  |
| RPM 2   | U Statistic, RPM 2 | 157.5 | 196.5 | 20  | 14  | 13  |
| RPM 1   | Critical Value (alpha=.1) | 138  | 138  | 4   | 4   | 4   |
| RPM 2   | Reject null? | Fail | Fail | Fail | Fail | Fail |