The Effects of Working Memory and Executive Functioning on Performance in Complex Tasks

by

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ABSTRACT

This study is concerned with the degree to which the psychological constructs of executive functioning and working memory influence success in majors requiring high levels of complex tasks. Executive functioning refers to the process of control and planning of complex tasks. Working memory is a facet of executive functioning that we hypothesize to be an especially import part of multitasking performance. We wished to see if these constructs were related to student enrollment in STEM vs. Non-STEM programs. Our findings showed that overall executive functioning scores and working memory scores were not related to whether students were STEM or Non-STEM. However, one factor of our executive functioning battery which measured cognitive control was shown to be near significance ($p = .051$). We also showed that scores on the measures used were not influenced by race or gender in this sample. We recommend further research take place using greater numbers and better populations to confirm our findings.

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CHAPTER I: INTRODUCTION AND LITERATURE REVIEW

Introduction to Working Memory

Since the concept was first proposed, working memory capacity has been shown to have a large effect on a number of performance domains. Working memory is a short-term memory system that allows a person to manipulate the information held in it. In addition to being an important theoretical structure in its own right, working memory has also been shown to be a distinct part of executive functioning (Miyake et. al., 2000). This is sometimes referred to as the updating and monitoring component of executive function (Diestel, Cosmar, & Schmidt, 2013). Working memory differs from the construct of short-term memory in that working memory is more multidimensional. This can be seen in the multiple resources model of working memory (Wickens, 2008). This model postulates the existence of different pools of resources for different types of processing. According to this theory there are separate resources used for verbal, spatial, auditory, and visual forms of processing (Wickens, 2008). This concept of different pools of resources being used for different tasks may help explain why working memory plays such a large role in multitasking effectiveness.

Working Memory and Multitasking

There have been many studies that demonstrate a strong relationship between working memory capacity and complex tasks involving multitasking. There have been multiple studies that have used working memory capacity as a predictor of performance in multitasking scenarios. These studies consistently found that working memory capacity is highly predictive of performance in these tasks (e.g. Buhner, Konig, Pick, &

Krumm, 2006; Colom, Martinez-Molina, Shih, & Santacreu, 2010; Hambrick, Oswald, Darowski, Rench, & Brou, 2010). These studies have found that individuals with higher working memory capacity were less likely to become distracted during a task, were likely to use better strategies to complete tasks, and were more adept at learning complex skills (Hambrick et. al., 2010; Perlow, Jattuso, & Moore, 1997). Another study in which participants completed a sustained attention to response task, found that working memory capacity was related to rates of mind-wandering among participants, and that this mediated the relationship between working memory capacity and performance on the sustained attention task (McVay & Kane, 2009). However, while individuals with higher working memory capacity have been shown in to be less susceptible to distraction, it has been shown that the way irrelevant information is presented can affect this outcome (Gao, Chen, & Russell, 2007). For instance, one study showed that working memory load did not affect interference when the irrelevant information came from the same stimulus as the relevant information (Gao, Chen, and Russell, 2007).

Sohn and Doane (2004) have also presented evidence that working memory capacity plays a role in situational awareness. It was shown that working memory capacity has an especially profound effect on early learning in novices (Sohn & Doane, 2004). In the same study, experts on the other hand, were shown to rely more on long-term memory. These findings indicate that working memory capacity plays an important role in the cognitive and associative phases of skill acquisition that novices rely upon, and that it plays less of a role once someone is an expert and is relying on long-term memory to make the task autonomous (Sohn & Doane, 2004).

Working Memory as a Selection Tool

Given the very strong and long established ties between working memory capacity and performance in complex tasks involving multitasking, it is an obvious contender as a tool for personnel selection in fields requiring multitasking behaviors. For instance, a recent validation study of the selection procedures for air traffic controllers used by the German Aerospace Center showed that only 55% of candidates who were put through a multitasking assessment progressed beyond that point in the selection process (Pecena et. al., 2013). Multitasking in this case was assessed by work sample tests. Work sample tests, while a good way to assess performance, are expensive and time consuming to administer. Therefore, if a viable alternative to predicting multitasking performance could be found, such as that suggested by the current study, the cost and time commitment of such selection procedures could be greatly reduced.

There have been many studies demonstrating that working memory capacity is highly correlated to general mental ability, the single best predictor of overall performance. A comprehensive review of literature by Schmidt and Hunter (2004) showed that general mental ability, also known as g, is highly correlated to job performance, training, and level of success achieved in an occupation. This construct is even more highly correlated with performance than job specific measures were (Schmidt & Hunter, 2004). General mental ability has long been considered the best predictor of job performance, and a number of studies have recently suggested that the working memory portion of mental ability is a major contributing factor to this.

A recent study found that while working memory, fluid intelligence, and attention were all predictive of multitasking performance, working memory was the most predictive overall, accounting for more variance than fluid intelligence or attention (Konig, Buhner, & Murling, 2005). In fact, one study found that 92% of the variance in working memory can be explained by g (Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004). This high correlation has led some researchers to speculate that g and working memory are in fact the same construct. However, studies have shown that while highly correlated, g and working memory are in fact separate constructs (Oberauer, Schulze, Wilhelm, & Sub, 2005). Studies have also shown that working memory capacity is a very strong predictor of fluid intelligence, attentional control and individual differences in strategy use, being a possible common link between the three (Conway, Cowan, Bunting, Therriault, & Minkoff, 2002). This body of research suggests that working memory capacity could account for a large part of what makes g so predictive of success.

Improving Working Memory Capacity

We have already mentioned the possibility of using working memory capacity in personnel selection, given the abundance of research linking working memory capacity with performance of complex tasks. However, another possibility that could take advantage of these findings would be to try and increase an individual's working memory capacity using training. There has been quite a bit research on the effectiveness of such training. Much of this research however, has provided conflicting results. A number of studies have found positive effects from working memory training, as well as training focused on related constructs (Bomyea & Amir, 2011; Rode, Robson, & Purviance, 2014). However, many of these studies have suffered methodological problems such as failure to provide adequate control groups, failure to look at transfer efficacy, and failure to look at long-term effects (Melby-Lervag & Hulme, 2013). Indeed, in one study that did look at transfer, the researchers found that the improvement seen in training was only present in the tasks used for training, or very similar tasks, and was not present in tasks that should make use of working memory (Rode, Robson, & Purviance, 2014). There have also been several studies showing that working memory training produces changes in EEG brain scans (Jausovec & Jausovec, 2012; Xiong et. al., 2014). However, these studies again failed to provide data on long-term effectiveness and changing brain activity. Finally, a meta-analysis conducted by Melby-Lervag and Hulme (2013) concluded that there was no evidence of long-term benefits from working memory training in terms of transfer to other working memory tasks, only short-term gains in tasks similar to the training. Until better research on working memory training becomes available, this approach to improving working memory is not likely to be recommended.

In theory, the best way to reduce working memory load is to provide external support to individuals performing complex tasks. One study that explored this method found that it was easier for individuals to perform complex tasks when more of the information needed was external (Zhang & Wang, 2009). The researchers also found that when information is split between internal information and external, participants performed best when the internal information closely matched the extra information (Zhang & Wang, 2009). Given these findings, it may be possible to mitigate the effects of low working memory capacity by designing the task with as much externally available information as possible.

Hypothesis 1: Students with higher Working Memory Capacities that are in academic programs requiring a high degree of multitasking and performance of complex tasks will be more likely to perform better on the experiment tasks.

Introduction to Executive Functioning

The term “executive functioning” refers to the process through which individuals exercise control and planning over complex cognitive functions (Carlson, 2005). According to McCabe, Roediger, McDaniel, Balota, and Hambrick (2010) executive functioning includes “inhibition of prepotent responses, shifting mental sets, monitoring and regulating performance, updating task demands, goal maintenance, planning, working memory, and cognitive flexibility, among others”. These functions are often associated with frontal lobe functioning in the brain (Carlson, 2005). The exact nature of executive functioning has been disputed in the research literature. Some researchers maintain that executive functioning is a single construct, while other researchers believe that executive functioning consists of a group of distinct constructs that are interrelated (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010).

Executive Functioning and Complex Tasks

Various aspects of executive functioning have been shown to be particularly important in learning and remembering extensive and complex information (Beebe, Ris, Brown, & Dietrich, 2004). One study investigating adolescent’s performance in a complex visual task found that organizational processes and encoding/retrieval of visual memory, both aspects of executive functioning, were related to success in the task (Beebe, Ris, Brown, & Dietrich, 2004). It has been suggested that the set shifting component of executive function could aid in multitasking situations (Culbertson, Huffcutt, & Goeble, 2013). There is also research with special populations (e.g. schizophrenics) that has shown strong correlations between measures of executive functioning and ability to multitask (Laloyaux et. al., 2014).

Executive Functioning and Job Performance

Historically, there has been very little research on the role of executive functioning in job performance. However, recent research has begun to investigate the relationship between executive functioning and job performance, opening up the possibility of using it as a selection tool. While the updating component of executive functioning is highly correlated with general mental ability, the set shifting and inhibition components may be valuable new constructs to consider for selection purposes (Culbertson, Huffcutt, & Goeble, 2013). However, there are issues with using executive functioning as a tool for employee selection.

First, many of the measures used to assess executive functioning were designed for use in children or in the field of neuropsychology. Therefore, it is difficult to find a suitable measure for normal populations. Second, there has been very little research done that explores the relationship between executive functioning and job performance, and the research that has been done has shown some conflicting results (Culbertson, Huffcutt, & Goeble, 2013). Therefore, due to the theoretical benefits such a measure could provide, it is important for the field of Industrial/Organizational Psychology that more research is done to explore the potential benefits in predicting job performance.

Executive Functioning and its Relationship to Working Memory

Executive functioning and working memory have been shown to be highly related to one another. Indeed, many models of executive functioning include working memory as one of the constructs that make up executive functioning (Beebe, Ris, Brown, & Dietrich, 2004). Indeed, there has been research demonstrating that the two constructs are highly correlated (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010). Recently, it has been postulated that the two constructs share an underlying resource referred to as executive attention. This high correlation between the two constructs and the possibility of a shared resource underlying both, makes it especially important to use multiple measures of each construct in order to determine whether the construct itself is being measured, or whether we are measuring a task specific skill (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010).

Hypothesis 2: Students with higher Executive Functioning Capabilities that are in academic programs requiring a high degree of multitasking and performance of complex tasks will be more likely to perform better on the experiment tasks.

Success in STEM vs. Non-STEM Majors

Much research has looked at the factors that influence enrollment, retention, and success in STEM studies (e.g. Astin & Astin, 1993; DesJardins, Ahlburg, & McCall, 2002; Robinson, 2003; Takruri-Rizk et. al., 2008). Retention is a particularly important issue, with one study showing that students in STEM programs decline by 40% from Freshman to Senior years (Astin & Astin, 1993). However, while research has focused on the effects of things such as the academic quality of institutions, active learning by students, academic integration, gender, GPA, and availability of financial aid, there has been little research on individual differences between student traits, and no research on the cognitive abilities of executive functioning or working memory on student's ability to succeed in these disciplines (Ackerman, Kanfer, & Beier, 2013). As STEM disciplines (e.g. chemistry, engineering science, mathematics, etc.) tend to incorporate complex tasks, we decided to use STEM and non-STEM groups to test our previously stated hypotheses.

History of Working Memory and Executive Functioning Measurement

Working Memory

Working memory capacity has been measured using memory span tasks for the past thirty-five years (Daneman & Carpenter, 1980). The principle that these tasks work on is that the individual is given a task followed by an item to recall, so every new task interferes with the ability to recall the items. Those with greater working memory capacities will be better able to hold this information for later recall while they are performing the task.

There are two views of working memory measures. The first is that the measure is domain-specific, meaning that the type of task that is used in the measure (reading, symmetry, etc.) better predicts performance in that task than it does in other tasks using working memory. The second view is called the domain-general view, which holds that the type of task performed does not limit the ability of the measure to predict performance on other tasks involving working memory, but that the capacity generalizes to other domains (Oswald, McAbee, Redick, & Hambrick 2014). Research has shown that the domain-general view is much better supported than the domain-specific view (Kane et. al. 2004). However, it is still considered good practice to take the domain-specific view into account and use a representative measure of different types of tasks when measuring working memory (Oswald, McAbee, Redick, & Hambrick 2014). Therefore, we will use the Operation Span, Reading Span, and Symmetry Span Tasks in this study, to ensure an accurate measure of general working memory.

Although these measures provide a good evaluation of an individual's working memory capacity, they are often time consuming to administer (Oswald, McAbee, Redick, & Hambrick 2014). Since the initial creation of these span tasks, several have been computerized for easier administration and scoring.

Executive Functioning

As discussed earlier, executive functioning is a construct that consists of many different facets. Given this fact, it has been difficult for researchers to come to a consensus on exactly what constitutes executive functioning and how to measure it. One of the most popular frameworks that attempts to explain exactly what functions constitute executive functioning is Miyake and colleagues (2000) model, which showed that mental set shifting, inhibition of pre-potent responses, and information updating and monitoring components make up executive functioning, and are all correlated but separable constructs. This is the model of Executive Functioning that we have chosen to measure in this study.

In an attempt to provide a comprehensive and psychometrically sound test battery for measuring executive functioning, the National Institutes of Health called for the development of a test battery that would fill this need. As a result, the NIH-EXAMINER test battery was developed at University of California at San Francisco. This test battery is based on Miyake's model, and includes tests covering the domains of working memory, inhibition, set shifting, fluency, planning, insight, and social cognition and behavior (NIH-EXAMINER user manual 2014). The test battery can be given to most subjects (except those with some specific conditions). The battery was designed to be a time efficient measurement, so that other constructs could be measured in the same study.

CHAPTER II: METHODS

Measures of Working Memory

Unsworth et. al. (2009a, b) created computerized versions of the Operation Span Task, Reading Span Task, and Symmetry Span Task. Given that even these computerized tests are still time consuming, usually taking around 20 minutes per task, shortened versions have been created in an attempt to make administering them easier (Oswald, McAbee, Redick, & Hambrick 2014). After the measures were shortened, they still retained alphas of above .70 (Oswald, McAbee, Redick, & Hambrick 2014). Confirmatory factor analysis also showed good model fit for the shortened measures, indicating that the new shortened versions of these measures are psychometrically sound (Oswald, McAbee, Redick, & Hambrick 2014). Therefore, the shortened versions were used to measure working memory capacity in the current study.

Measures of Executive Functioning

The NIH-EXAMINER test battery described earlier was used in the current study. Coefficient alphas were at acceptable levels for all the tests included in the battery (NIH-EXAMINER user manual 2014). There were some tests in the battery for which coefficient alphas were less appropriate measures, and inter-rater reliability was reported instead. All inter-rater reliabilities for these tests were at acceptable levels (NIH-EXAMINER user manual 2014). Likewise, some of the tests were evaluated using test-retest reliability, and again, these were at acceptable levels (NIH-EXAMINER user manual 2014).

The validity of the EXAMINER test battery was evaluated by comparing scores to measures of day-to-day executive functioning. These comparisons showed good correlations between scores on EXAMINER and other measures, based on samples covering a wide age range (NIH-EXAMINER user manual 2014). Validity was also evaluated using comparisons of normal controls and patients, correlations with age, and longitudinal change (due to the fact that executive function should increase with age). These validity tests were carried out for both the composite score as well as all the factor scores. All comparisons provided further evidence for the validity of the measure (NIH-EXAMINER user manual 2014). Convergent and divergent validity were also tested, and evidence was found for both types of validity (NIH-EXAMINER user manual 2014).

Selection of STEM Disciplines

To compare groups between STEM and non-STEM students, it was necessary to classify each participant’s reported major into one category or another. Participants were asked to fill in a blank space on the paper demographics form with their major. This information was then compared to a list of STEM majors to determine which participants were classified as “STEM” and which were “Non-STEM”. While there is no single standard list of STEM subjects, we decided to utilize the National Science Foundation’s list of STEM instructional programs (see Appendix A).

Participants

The participants included 67 undergraduate students from Middle Tennessee State University. These students were recruited from the MTSU SONA System research pool, and were given course credit for their participation. This resulted in a wide mix of academic programs being represented in the study. The demographic makeup of the sample was 32.8% (n = 22) male and 67.2% (n = 45) female. In terms of race, 56.7% (n = 38) were Caucasian, 28.4% (n = 19) were Black/African American, 6% (n = 4) were Hispanic/Latino, 4.5% (n = 3) were Asian, and 4.5% (n = 3) preferred not to answer.

In terms of classification, 71.2% (n = 47) were Freshmen, 12.1% (n = 8) were Sophomores, 10.6% (n = 7) were Seniors, and 6.1% (n = 4) were Juniors (one participant failed to report classification in the demographics sheet). In terms of academic program, 34.8% (n = 23) of participants were in a STEM major and 65.2% (n = 43) were in a non-STEM major (one participant failed to report major in the demographics sheet).

Procedure

The participants were informed that participation in the research was voluntary and could quit at any time. The Operation Span, Reading Span, and Symmetry Span Tasks were administered to the participants. For each of these tasks, the researcher read out the onscreen instructions to the participant. After the instructions and test trials were complete, the participant completed the tasks. The program then displayed an end message when the task was complete. In the Operation Span task, the participant completes a series of simple math problems by solving the problem in their head, being shown a number on the following screen, and clicking “True” if that was the answer or “False” if that was not the answer. A letter was displayed between each problem, and after a varying number of problems and letters were displayed, the participant was asked to recall the letters in the correct order.

The Reading Span task was similar in format to the Operation Span, but rather than answering true or false to a math problem, the participant was shown a sentence that either made sense or did not, with the participant answering “True” or “False” when asked whether the sentence makes sense. The letters were still presented in between, and they were still asked to recall them in the correct order at the end of each set of sentences and letter. In the Symmetry Span task, participants were shown an image and asked (again by “True” and “False”) whether that image was symmetrical. After each image was presented, a 4x4 grid of white boxes was displayed, with one box colored red. After a series of these images, the participant was given a blank grid and asked to click on the boxes that had been colored red in the order that they appeared.

During each task, the participant was instructed that they must achieve an accuracy score of 85% or higher on the task for that experiment (math, whether a sentence makes sense, or symmetry) or that their data would not be used. After each recall section, the program provided feedback of recall and task performance, and displayed the percentage correct for the experiment task in the upper right corner. Each of these experiments, in their shortened forms, took approximately ten minutes to complete.

After this, participants completed the EXAMINER test battery (see Appendix C). The first task that was completed in the battery was the “Verbal Fluency: Phonemic” task, in which the participant was given a letter and told to provide as many words beginning with that letter as they could in a one minute span, with no repeats. They were instructed not to use numbers, names of people, or places. The researcher then wrote down their responses as they were given. This task was then repeated with a different letter. The next task participants completed was the “Category Fluency” task, in which the participant was asked to provide as many examples of words falling into the given category as they could within one minute. They were then asked to repeat this task with a different category. The letters and categories changed based on which version of the recording form was used (A, B, or C). Participants were then shown a graph of a bell curve and asked to indicate what percentile rank they believe their performance on the previous tasks would be, compared to others of similar age and education.

The next task that was administered was the “Unstructured Task”, in which participants were given three booklets of simple puzzles worth varying amounts of points, with the instruction to gain as many points as possible. They were given six minutes and were allowed to complete any puzzles they wished in any order. Before starting, they were given some practice puzzles to get them familiar with each puzzle type.

The participant was then seated in front of the computer and the researcher started the “Flanker” task, reading the instructions out to the participant. In this task, the participant is presented a series of arrows, and they must indicate using the left and right arrow keys on the keyboard, which way the central arrow in the image is pointing. Next, the “Set-Shifting” task was administered, in which the participant is presented with a red or blue triangle or rectangle and must alternate between matching color or shape using the arrow keys. The participants were given some practice trials before starting.

The participants then completed the “Dot Counting” task, in which they count the number of blue dots in a screen of other shapes, and must recall the count for each screen after several screens have been counted. The next task was the “Continuous Performance Test”, in which the participant is given a particular image to watch for, and is then presented a series of images, and must press the left arrow key whenever they see the image they are watching for. The next task was the “1-Back” task, in which the participant sees a white block on the screen followed by a number that they must say out loud, and then another white block. The participant must indicate with the keyboard whether the white block is in the same place on the screen as the previous white block. This task is followed by the similar “2-Back” task, which displays a series of white blocks with no numbers in between, while the participant indicates with the keyboard whether the white block was in the same place as the block two before it. Since this task is so difficult, the participants were asked to explain the instructions for the task after they completed it, to make sure they understood.

The next task was the “Anti-Saccades” task, in which the participant is shown a dot in the center of the screen which will then move to either the left or right side of the screen. There are three sets of trials in this task. The first set of trials asks the participant to follow the dot with their eyes, without moving their head, directing their eyes to the side of the screen that the dot moves to. The last two sets of trials ask the participant to move their eyes to the side of the screen opposite of where the dot moves. The participant’s eye movements were monitored with a webcam, which was recording that part of the session. After the experiment, the participant’s eye movements were evaluated by the researchers to determine their performance in the task.

After this task, the participant was asked to complete the “Social Norms Questionnaire” using paper and pencil. The researcher read the instructions out loud to the participant. Finally, participants completed a short demographics questionnaire asking them about their age, gender, whether English was their first language, program of study, and years of attendance in their program. Completion of the entire EXAMINER battery takes approximately one hour. After this, participants were debriefed on the details of the study and given contact information for any questions they may have. Given the hour taken to complete EXAMINER, the thirty minutes taken to complete the Span Tasks, the additional time taken for participants to sign informed consents, fill in the demographics survey, and be debriefed, as well as the time taken to transition between experiment tasks, a two hour time window was set aside for the participant to complete the experiment.

Analyses

The main analyses used in the current study were T-tests, to determine whether any significant relationships existed between the measures of executive functioning and working memory used and student enrollment in STEM majors. We compared the STEM and Non-STEM groups using the overall executive functioning composite score, the individual factor scores from the EXAMINER battery, the scores from our three span tasks, and scores from the social norms questionnaire included in the EXAMINER battery. We also used correlations to test for any effects of race and gender on the scores from the measures used.

CHAPTER III: RESULTS

In order to determine whether students classified as STEM would perform better on the working memory tasks, an independent samples *t* test with $\alpha = .05$ was conducted to determine if there were significant differences between working memory factor scores for STEM and Non-STEM students. The results showed that working memory scores by STEM students ($M = 0.429$, $SD = 0.781$) was not significantly different to scores by Non-STEM students ($M = 0.319$, $SD = 0.778$), $t\ (64) = .549$, $p = .585$, two-tailed.

An independent samples *t* test with $\alpha = .05$ was conducted to determine if there were significant differences between operation span scores for STEM and Non-STEM students. The results showed that operation span scores by STEM students ($M = 18.48$, $SD = 6.940$) was not significantly different to scores by Non-STEM students ($M = 17.05$, $SD = 6.655$), $t\ (64) = .821$, $p = .415$, two-tailed.

An independent samples *t* test with $\alpha = .05$ was conducted to determine if there were significant differences between reading span scores for STEM and Non-STEM students. The results showed that composite scores by STEM students ($M = 19.00$, $SD = 7.16$) was not significantly different to scores by Non-STEM students ($M = 18.7$, $SD = 6.26$), $t\ (64) = .178$, $p = .859$, two-tailed.

An independent samples *t* test with $\alpha = .05$ was conducted to determine if there were significant differences between symmetry span scores for STEM and Non-STEM students. The results showed that symmetry span scores by STEM students ($M = 13.61$, *SD* = 4.53) was not significantly different to scores by Non-STEM students (*M* = 13.74, *SD* = 4.96), *t* (64) = -.109, *p* = .914, two-tailed.

In order to determine whether students classified as STEM would perform better on the executive functioning tasks, an independent samples *t* test with α = .05 was conducted to determine if there were significant differences between executive functioning composite scores for STEM and Non-STEM students. The results showed that composite scores by STEM students (*M* = 0.744, *SD* = 0.527) was not significantly different to scores by Non-STEM students (*M* = 0.701, *SD* = 0.559), *t* (64) = .305, *p* = .761, two-tailed.

An independent samples *t* test with α = .05 was conducted to determine if there were significant differences between the fluency factor scores for STEM and Non-STEM students. The results showed that fluency factor scores by STEM students (*M* = 0.379, *SD* = 0.575) was not significantly different to scores by Non-STEM students (*M* = 0.568, *SD* = 0.768), *t* (64) = -1.034, *p* = .305, two-tailed.

An independent samples *t* test with α = .05 was conducted to determine if there were significant differences between cognitive control factor scores for STEM and Non-STEM students. The results showed that cognitive control scores by STEM students (*M* = 1.12, *SD* = 0.536) was on the threshold of being significantly different to scores by Non-STEM students (*M* = 0.851, *SD* = 0.514), *t* (64) = 1.992, *p* = .051, two-tailed.

An independent samples *t* test with α = .05 was conducted to determine if there were significant differences between social norms questionnaire scores for STEM and

Non-STEM students. The results showed that social norms scores by STEM students (*M* = 10.04, *SD* = 2.383) was not significantly different to scores by Non-STEM students (*M* = 20.07, *SD* = 2.063), t (64) = -.047, p = .963, two-tailed.

Pearson correlations were conducted for gender and race with overall executive composite scores, all factor scores from EXAMINER, and all three span tasks used in the study. We found no significant correlations for race or gender with any of our measures. All three of our span tasks were highly correlated with each other (as expected), as well as with the working memory factor from EXAMINER.

CHAPTER IV: DISCUSSION

The idea that Executive Functioning and, in particular, Working Memory can be used to predict performance on complex tasks is not new. It is reasonable to think that the ability to hold and manipulate information in short term memory, exercise control over attentional resources, and plan one's future actions would lead to increased performance on such tasks. Numerous studies have shown that this is indeed the case (e.g. Buhner, Konig, Pick, & Krumm, 2006; Colom, Martinez-Molina, Shih, & Santacreu, 2010; Hambrick, Oswald, Darowski, Rench, & Brou, 2010; Beebe, Ris, Brown, & Dietrich, 2004; Culbertson, Huffcutt, & Goeble, 2013). The goal of the current study is to provide further evidence of this relationship, as well as to provide a possible selection tool for academic programs and professional positions that involve complex multitasking situations.

Our first stated hypothesis was that working memory capacity would be greater in students enrolled in STEM majors. Our results showed no significant differences in STEM vs. Non-STEM majors in either the span task measurements of working memory, or the working memory factor score from the EXAMINER battery.

Our second stated hypothesis was that executive functioning would be greater in students enrolled in STEM majors. Our results found that the overall executive functioning composite score did not show significant differences between STEM and Non-STEM students. However, one of the individual factor scores from EXAMINER, the cognitive control factor, was bordering on significance, with a *p*-value of .051, just over the usual significance threshold of .05.

We also looked at other relationships between our various measurement scores. Some of our findings include the fact that the three span tasks used were highly correlated with each other (as could be expected), and also with the working memory factor of EXAMINER, providing further evidence that they are in fact measuring the same construct. We also looked at the relationship between age and executive functioning which, according to theory, should increase with age. We did not find such a relationship, but this is most likely due to our age range being very restricted. We also looked at the relationship between the social norms questionnaire and the executive composite score given by the EXAMINER program (which does not include the survey score in its calculation), and found that they were highly correlated.

Finally, and crucially, we found no relationship between race or gender and any of the metrics used in this study. This is important for future research potentially looking at ways of using these measures to try and predict performance, whether in academic programs or jobs.

Limitations and Future Research

There are quite a few limitations to this study that we would like to see addressed in future research. First, we did not get as many participants as we would have liked, so it would be beneficial to have greater numbers in similar studies in the future. Also, the population used in the study is likely to be somewhat limited in terms of age and level of education. It would be beneficial in the future to conduct similar studies with different populations, perhaps in a workplace setting where there is more variance in age and access to job performance metrics. A study utilizing better comparison groups would also be beneficial. While it was initially our intention to compare groups that were more specific than the STEM and Non-STEM groups used, this proved impossible due to data collection issues. Therefore, further research utilizing more distinct groups may provide better and more accurate results.

There may also have been a problem of motivation when participants are completing the tasks. The tasks, while efforts were made to use shorter versions of the scales, are long and arduous to complete. While students did receive course credit for completing the study, they had little motivation to put their best efforts into the completion of the tasks themselves.

In terms of practical implications, these constructs could have a greater impact on jobs in which the job analysis more clearly indicates that traits such as multitasking are required. Therefore, these types of tests may be useful in a more applied business setting. It is also important to consider that the current study found no evidence of adverse impact based on gender or race, making these tests potentially less problematic for job selection purposes than cognitive ability tests.

Future research, as previously stated, should try and compare more distinct populations, and should focus on improving the population used. This includes getting greater overall numbers of participants, as well as a more varied sample pool with better comparison groups, possibly within a workplace environment. Also, as we did find potentially significant results with the cognitive control factor score, further research in this area may be warranted. Also, future studies should investigate ways of motivating participants to put as much effort as possible into the tasks, perhaps using incentives that do not simply reward completion of the study.

Conclusion

The purpose of this study was to test the degree to which executive functioning and working memory influence success in majors requiring high levels of complex tasks. We used enrollment in STEM programs to indicate which participants were handling complex tasks on a day to day basis. While our findings showed that overall executive functioning scores and working memory scores were not related to whether students were STEM or Non-STEM, given limitations with the current study and some results that could prove to be promising for future research, namely the fact that the cognitive control construct was close to significant and we saw no gender or race effects with these measures, we still believe that more work in this area is needed. Given better comparison groups and populations, we believe that more could be discovered that could potentially benefit those looking for screening tools for jobs or academic programs.

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APPENDICES

APPENDIX A: NSF STEM CLASSIFICATION OF INSTRUCTIONAL PROGRAMS

Listed below are the NSF CIP Code and major for STEM disciplines.

Agricultural Sciences

01.09	Animal Sciences
01.10	Food Science and Technology
01.12	Soil Sciences
01.99	Agriculture, Agriculture Operations and Related Sciences, Other
03.0101	Natural Resources/Conservation, General
03.02	Natural Resources Management and Policy
03.03	Fishing and Fisheries Sciences and Management
03.05	Forestry
03.06	Wildlife and Wildlands Science and Management
03.99	Natural Resources and Conservation, Other

Chemistry

40.05	Chemistry
40.0507	Polymer Chemistry

Computer Science

11.01	Computer and Information Sciences, General
11.04	Information Science/Studies
11.07	Computer Science
52.1201	Management Information Systems, General
52.1301	Management Science, General

Engineering

14.02	Aerospace, Aeronautical and Astronautical Engineering
14.03	Agricultural/Biological Engineering and Bioengineering
14.05	Biomedical/Medical Engineering
03.0509	Wood Science and Wood Products/Pulp and Paper Technology
14.07	Chemical Engineering
14.32	Polymer/Plastics Engineering
04.02	Architecture
14.04	Architectural Engineering
14.08	Civil Engineering
14.0803	Structural Engineering

14.0805 Water Resources Engineering

14.14 Environmental/Environmental Health Engineering

14.09 Computer Engineering, General
14.10 Electrical, Electronics and Communications Engineering

14.12 Engineering Physics
14.13 Engineering Science

14.27 Systems Engineering
30.06 Systems Science and Theory

14.11 Engineering Mechanics
14.19 Mechanical Engineering

14.06 Ceramic Sciences and Engineering
14.18 Materials Engineering
14.20 Metallurgical Engineering
14.28 Textile Sciences and Engineering
14.31 Materials Science
40.9999 Physical Sciences, Other

14.21 Mining and Mineral Engineering

14.23 Nuclear Engineering

14.25 Petroleum Engineering

14.01 Engineering, General
14.22 Naval Architecture and Marine Engineering
14.24 Ocean Engineering
14.99 Engineering, Other

Environmental Science
03.0103 Environmental Studies
03.0104 Environmental Science

Geosciences
40.06 Geological and Earth Sciences/Geosciences
40.0601 Geology/Earth Science, General

Life/Biological Sciences

26.0403	Anatomy
26.0202	Biochemistry
26.01	Biology, General
26.1101	Biometry/ Biometrics
26.1102	Biostatistics
26.1309	Epidemiology
26.0203	Biophysics
26.03	Botany/Plant Biology
26.0305	Plant Pathology/Phytopathology
26.0307	Plant Physiology
26.04	Cell/Cellular Biology and Anatomical Sciences
26.0401	Cell/Cellular Biology and Histology
26.0204	Molecular Biology
26.1301	Ecology
26.0505	Parasitology
26.0702	Entomology
26.0804	Animal Genetics
26.0805	Plant Genetics
26.1303	Evolutionary Biology
26.0806	Human/Medical Genetics
26.05	Microbiological Sciences and Immunology
26.0507	Immunology
26.0504	Virology
26.0503	Medical Microbiology and Bacteriology
19.05	Foods, Nutrition, and Related Services
30.1901	Nutritional Sciences
26.0910	Pathology/Experimental Pathology
26.1004	Toxicology
26.1001	Pharmacology
26.1004	Toxicology
26.0707	Animal Physiology
26.0901	Physiology, General
26.09	Series Physiology, Pathology and Related Sciences
26.07	Zoology/Animal Biology

APPENDIX B: IRB APPROVAL

MIDDLE TENNESSEE STATE UNIVERSITY

9/14/2015
Investigator(s): Joshua Gelineau; Dr. Michael Hein
Department: Industrial/Organizational Psychology
Investigator(s) Email: jrg6m@mtmail.mtsu.edu Michael.Hein@mtsu.edu

Protocol Title: The Effects of Working Memory and Executive Functioning on Performance in Complex Tasks
Protocol Number: 16-2038

Dear Investigator(s),

The MTSU Institutional Review Board, or a representative of the IRB, has reviewed the research proposal identified above. The MTSU IRB or its representative has determined that the study poses minimal risk to participants and qualifies for an expedited review under 45 CFR 46.110 and 21 CFR 56.110, and you have satisfactorily addressed all of the points brought up during the review.

Approval is granted for one (1) year from the date of this letter for 120 participants.

Please note that any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918. Any change to the protocol must be submitted to the IRB before implementing this change.

You will need to submit an end-of-project form to the Office of Compliance upon completion of your research located on the IRB website. Complete research means that you have finished collecting and analyzing data. **Should you not finish your research within the one (1) year period, you must submit a Progress Report and request a continuation prior to the expiration date.** Please allow time for review and requested revisions. Failure to submit a Progress Report and request for continuation will automatically result in cancellation of your research study. Therefore, you will not be able to use any data and/or collect any data. Your study expires **9/15/2016**.

According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to complete the required training. **If you add researchers to an approved project, please forward an updated list of researchers to the Office of Compliance before they begin to work on the project.**

All research materials must be retained by the PI or faculty advisor (if the PI is a student) for at least three (3) years after study completion and then destroyed in a manner that maintains confidentiality and anonymity.

Sincerely,

Shelley C. Moore,
PhD, MSN, RN, COI
Institutional Review
Board
Middle
Tennessee State
University

APPENDIX C: EXAMINER SCORING FORM

Executive Abilities: Measures and Instruments for Neurobehavioral Evaluation and Research (EXAMINER)

Testing Forms A

NINDS: Domain Specific Tasks of Executive Function
HHS99271200623661

VERBAL FLUENCY: PHONEMIC

MATERIALS: *Timer - 1 minute*

[Examiner]: I'm going to say a letter of the alphabet. When I ask you to start, tell me as many words as you can that begin with that letter. You will have one minute before I tell you to stop. None of the words can be <u>numbers</u> or <u>names of people</u>, or <u>places</u>.

For example, if I gave you the letter *B*, you could say *brown*, *bottle* or *bake*, but you wouldn't say *Barbara, Boston or billion*. Also, don't give me the same word with different endings, so if you said *bake*, you wouldn't also say *baked* or *bakes,* and if you said *big*, you wouldn't also say *bigger* and *biggest.*

Let's begin. Tell me all the words you can, as quickly as you can, that begin with the letter 'F'. Ready? Begin.

ADMINISTRATION:
Start timer after completing instructions. Write actual responses as legibly as possible. Stop the procedure at 1 minute.

PROMPTS:
1. *If the participant pauses for 15 seconds:*
   - **Keep going.**
   - **What other words beginning with 'F' can you think of?**
2. *If participant gives 3 consecutive words that do not start with the designated letter: (Provide this prompt only once during this condition.)*
   - **We are now using the letter 'F'.**

Record responses:

1.	11.	21.	31.
2.	12.	22.	32.
3.	13.	23.	33.
4.	14.	24.	34.
5.	15.	25.	35.
6.	16.	26.	36.
7.	17.	27.	37.
8.	18.	28.	38.
9.	19.	29.	39.
10.	20.	30.	40.

Correct F-words: __________/ 40 F's repetitions: __________ # F's rule violations: __________

VERBAL FLUENCY: PHONEMIC

MATERIALS: *Timer - 1 minute*

[Examiner]: Now I want you to do the same for another letter. The next letter is L. Ready? Begin.

ADMINISTRATION:
Start timer after completing instructions. Write actual responses as legibly as possible. Stop the procedure at 1 minute.

PROMPTS:
1. *If the participant pauses for 15 seconds:*
   - **Keep going.**
   - **What other words beginning with 'L' can you think of?**
2. *If participant gives 3 consecutive words that do not start with the designated letter:*
   - **We are now using the letter 'L'.**

Record responses:

1.	11.	21.	31.
2.	12.	22.	32.
3.	13.	23.	33.
4.	14.	24.	34.
5.	15.	25.	35.
6.	16.	26.	36.
7.	17.	27.	37.
8.	18.	28.	38.
9.	19.	29.	39.
10.	20.	30.	40.

Correct L-words: __________ / 40   L's repetitions: __________   # L's rule violations: __________

CATEGORY FLUENCY: ANIMALS

MATERIALS: *Timer - 1 minute*

[Examiner]: Now I am going to give you a category, and I want you to name, as fast as you can, all of the things that belong to that category. For example, if I say 'Items of furniture, you would say 'chair', 'table', or 'desk'. It doesn't matter what letter the word starts with.

Now I want you to name things that belong to the category: Animals. You will have one minute. I want you to tell me all the animals that you can think of in one minute. Ready? Begin.

ADMINISTRATION:
Start timer after completing instructions. Write actual responses as legibly as possible. Stop the procedure at 1 minute.

Do not cue the participant about including more than mammals. However, if the participant inquires prior to initiating the response or asks during the test, the examiner is permitted to say "yes." It is also permissible to repeat the instruction or category if the participant specifically requests it.

PROMPTS:
1. *If the participant pauses for 15 seconds:*
    - **Keep going.**
    - **What other animals can you think of?**
2. *If participant gives 3 consecutive words that do not fit the category:*
    - **The category we are now using is animals.**

Record responses:

1.	11.	21.	31.
2.	12.	22.	32.
3.	13.	23.	33.
4.	14.	24.	34.
5.	15.	25.	35.
6.	16.	26.	36.
7.	17.	27.	37.
8.	18.	28.	38.
9.	19.	29.	39.
10.	20.	30.	40.

Correct Animals: __________ / 40   Animals Repetitions: __________   # Animal Rule Violations: __________

CATEGORY FLUENCY: VEGETABLES

MATERIALS: *Timer - 1 minute*

[Examiner]: Now I want you to name things that belong to another category: Vegetables.
You will have one minute. I want you to tell me all the vegetables you can think of in one minute.
Ready? Begin.

ADMINISTRATION:
Start timer after completing instructions. Write actual responses as legibly as possible. Stop the procedure at 1 minute.
It is also permissible to repeat the instruction or category if the participant specifically requests it.

PROMPTS:
1. *If the participant pauses for 15 seconds:*
   - **Keep going.**
   - **What other vegetables can you think of?**
2. *If participant gives 3 consecutive words that do not fit the category:*
   - **The category we are now using is vegetables.**

Record responses:

1.	11.	21.	31.
2.	12.	22.	32.
3.	13.	23.	33.
4.	14.	24.	34.
5.	15.	25.	35.
6.	16.	26.	36.
7.	17.	27.	37.
8.	18.	28.	38.
9.	19.	29.	39.
10.	20.	30.	40.

Correct Vegetables: _________ / 40 Vegetable Repetitions: __________ # Vegetable Rule Violations: _________

INSIGHT

MATERIALS: *Normal Distribution Graph (Stimuli Packet)*

After completing Verbal Fluency:

[Examiner]: I would like to know how well you think you did on this task. So compared to other people your age and with a similar level of education, how do you think you did?

I would like you to show me where you would be on this graph. *Display Normal Distribution Graph.*

If we look at a group of 100 people, we see that very few do really poorly [*point to the low end of the graph],* **and very few people do extremely well** [*point to the high end of the graph],* **and most people fall here in the middle around the 50th percentile** [point *to the middle of the graph where the graph peaks].* **How do you think you did?**

ADMINISTRATION:
Record self-appraisal below. Record response as a percentile between 1 and 100.

PROMPTS:
If participant points to graph but does not give a number:

- **What number would that be?**

Self-Appraisal for Verbal Fluency: ___________

UNSTRUCTURED TASK

MATERIALS: *Timer – 6 minutes (to be displayed on computer), Practice Page (attached), 3 Stimulus Booklets (attached), Instruction Sheet (Stimulus Packet), Pen*

[Examiner]: On this practice page there are six puzzles for you to try. Each puzzle has a different instruction, and some puzzles are easier than others. Go ahead and complete this page so you can see the kinds of puzzles you will do.

Position Practice Page in front of participant. Have participant complete the page.

Here are 3 booklets. Each of the booklets has different puzzles you can do. In these booklets, there are four puzzles on each page. Each puzzle has a number of points that you will earn when you complete the puzzle. Some puzzles will have higher points than others. Your goal is to earn as many points as possible.

You do not have to complete all of the pages in a book, and you do not have to complete all the puzzles on each page. You can go in any order you want through the puzzles. Each book is worth the same amount of points. Be sure to read the instructions for each puzzle you do, and complete the puzzles accurately to receive full credit.

You will only have 6 minutes to earn as many points as possible, so choose your puzzles carefully. A timer will be displayed to help you manage your time. Here are the instructions to help you remember.

Display Computer Timer and Instruction Sheet.

ADMINISTRATION:
Position the 3 Stimulus Books in front of participant. Point to instructions if participant appears to have forgotten.

Start computer timer after completing instructions. Stop at 6 minutes.
Do NOT allow participant to complete any item in progress when the time limit is reached.

	BOOK 1, PG1		PG2		PG3		PG4		PG 5		PG 6		
Book 1	**25**	75	**20**	5	15	**10**	5	**10**	5	5	5	5	HVC____LVC____ HVA____ LVA____
	75	10	75	**75**	10	**<u>50</u>**	10	1	5	1	1	1	TOTAL PTS.________
BOOK 2	5	**75**	5	**25**	**50**	1	10	**10**	5	5	1	5	HVC____LVC____ HVA____ LVA____
	75	**20**	75	**75**	**10**	15	5	1	5	1	5	1	TOTAL PTS.________
BOOK 3	**20**	10	5	**20**	**10**	15	1	**10**	5	1	1	5	HVC____LVC____ HVA____ LVA____
	75	75	**75**	75	**50**	1	5	10	5	5	1	5	TOTAL PTS.________

ANSWER KEY:
Use the grid to the left to indicate which puzzles were attempted (A) or completed (C) as you go through the three books. The six bold boxes represent the pages in each of the books. High Value puzzles are in bold and underlined.

# of High Value Items completed: _________	# of Low Value Items completed: _________
# of High Value Items attempted: _________	# of Low Value Items attempted: _________
Total Points earned: _________	

FLANKER

MATERIALS & SET-UP: See Manual for instructions on installing computer tasks and information on set-up.

Use Left and Right arrow keys on the keyboard (no labels).

Read instructions out loud as they appear on each screen.

PRACTICE TRIAL:

[Examiner]: You will be shown a series of arrows on the screen, pointing to the left or to the right. For example: *Point to the central arrows on computer screen.*

Press the RIGHT button if the CENTER arrow points to the right. Press the LEFT button if the CENTER arrow points to the left. *Point to left and right arrow keys as indicated.*

Try to respond as quickly and accurately as you can. Try to keep your attention focused on the cross ("+") at the center of the screen.

Check that participant's fingers are appropriately placed on Left and Right arrow keys. Encourage participant to keep fingers in place until task is complete.

First we'll do a practice trial. Press the SPACEBAR to begin.

Run practice trial. Provide feedback as needed.

After practice is finished, go on to the test. Read instructions out loud as they appear on each screen.

TEST:

[Examiner]: Now we'll move on to the task, the instructions are the same except you will no longer receive feedback after your responses.

Press the LEFT button if the CENTER arrow points to the left. Press the RIGHT button if the CENTER arrow points to the right.

Remember to keep your focus on the center cross ("+") and try to respond as quickly as possible without making mistakes.

Press the SPACEBAR when you are ready to begin.

SET-SHIFTING TASK

Read instructions out loud as they appear on each screen.

PRACTICE TRIAL:

[Examiner]: This is a matching task.

You will see an object in the center of the screen, and a word at the bottom of the screen. The word will be SHAPE or COLOR. The word at the bottom of the screen will tell you how to match the object in the center to one of the objects in the corners.

When you have to match by COLOR, you should push the LEFT button for RED and the RIGHT button for BLUE. When you have to match by SHAPE, you should push the LEFT button for TRIANGLE and the RIGHT button for RECTANGLE.

Check that participant's fingers are appropriately placed on Left and Right arrow keys. Encourage participant to keep fingers in place until task is complete.

Try to respond quickly and accurately, but if you make a mistake just keep going. We'll try some practice trials first. Press the SPACEBAR to begin.

Run practice trial. Provide feedback as needed. After practice is finished, go on to the test. Read instructions out loud as they appear on each screen.

TEST:

[Examiner]: Now let's move on to the task, the instructions are the same but you will no longer receive feedback after your responses. When you have to match by COLOR, you should push the LEFT button for RED and the RIGHT button for BLUE.

When you have to match by shape, you should push the LEFT button for the TRIANGLE and the RIGHT button for the RECTANGLE.

Try to respond quickly and accurately, but if you make a mistake just keep going.

Press the SPACEBAR when you are ready to begin.

DOT COUNTING

MATERIALS & SET-UP: Score Sheet to record responses (attached)

Have Score Sheet ready to record responses. Read instructions out loud as they appear on each screen.

PRACTICE TRIAL:

[Examiner]: You will be shown a series of screens containing blue circles, green circles, and blue squares. You will count and remember the number of BLUE CIRCLES you see on each screen.

Count the BLUE CIRCLES out loud, one at a time, and then repeat the final total out loud IMMEDIATELY. This will indicate to the examiner that you have finished counting. *Press the SPACEBAR to continue.*

Screen with blue and green circles, and blue squares will appear. After participant counts each blue circle out loud, press the SPACEBAR to continue to the next screen.

How many BLUE CIRCLES did you count? *Press the SPACEBAR to continue.*

Now, you will count the BLUE CIRCLES on one screen, and then on another screen. Please begin counting the blue circles out loud as soon as they appear on each screen. Remember to repeat the final total out load once you have finished counting.

After a number of screens you will see question marks. This will be your cue to repeat the final totals you counted on each screen in the correct order.

Let's do some practice first. Press the SPACEBAR to begin.

Run practice trials. Press the SPACEBAR after the participant has finished counting the dots on a screen and repeated the final total. Instruct participant to begin counting immediately after a new screen appears. Record participant's responses on the score sheet.

If the participant does not respond with any correct digit recalls for the practice trials, discontinue the task.

PROMPTS:
If participant does not repeat the total out load after counting, prompt only during the practice trials:
Remember to repeat the total out loud when you are finished counting on the screen.

TEST:

[Examiner]: You have completed the practice trials. Let's continue with the task. The instructions are the same.

Count and remember the number of BLUE CIRCLES you see on each screen. Count the blue circles out loud, one at a time, and then repeat the final total out loud. Repeat the final numbers you counted when you see the question marks appear on the screen.

Press the SPACEBAR when you are ready to begin.

DOT COUNTING SCORE SHEET

ADMINISTRATION:
Record the numbers the participant counts out loud from each display in the Response *column. The actual number of dots on each screen is provided below. At the end of the trial record the numbers the participant recalls in the* Recall *column. Administer all trials.*

SCORING:
Give 1 point for each correct digit recalled in each trial. Give 1 point if the number given as a response is not correct, but the number recalled is the same number. Record total in Correct *column. Add Correct values and record total at bottom of page (See Manual for complete scoring instructions).*

Practice: a. ____ (5) b. ____ (4) ____ (7) c. ____ (6) ____ (2) ____ (4)

Response:	Recall:	# Correct
1. ___ (3) ___ (8)	1. ___ ___	= ________
2. ___ (3) ___ (9) ___ (5)	2. ___ ___ ___	= ________
3. ___ (5) ___ (9) ___ (3) ___ (6)	3. ___ ___ ___ ___	=
4. ___ (3) ___ (7) ___ (6) ___ (5) ___ (8)	4. ___ ___ ___ ___ ___	=
5. ___ (3) ___ (5) ___ (6) ___ (9) ___ (4) ___ (7)	5. ___ ___ ___ ___ ___ ___	= ________
6. ___ (9) ___ (3) ___ (7) ___ (8) ___ (5) ___ (6) ___ (4)	6. ___ ___ ___ ___ ___ ___ ___	=
	TOTAL (Add values in column together for Trials 1 thru 6)	= _______/ 27

CPT/Go-No-Go

MATERIALS & SET-UP: *Use Left arrow key only.*

Read instructions out loud as they appear on each screen.

PRACTICE TRIAL:

[Examiner]: You will be presented with different objects on the screen. If a 5-pointed star is presented on the screen, press the left arrow key. If any other shape is presented, do not press any key. Respond as quickly as you can without making mistakes. If you do make a mistake just keep going.

Check that participant's finger is appropriately placed on Left arrow key. Encourage participant to keep finger in place until task is complete.

We will start with some practice trials. Press the SPACEBAR to begin.

Run practice trial. Provide feedback as needed. The instructions are the same for each trial. After practice is finished, move on to the test.

TEST:

[Examiner]: Now let's move on to the actual test. Press the SPACEBAR when you are ready to begin.

1-BACK

MATERIALS & SET-UP: *Use Left and Right arrow keys.*

Read instructions out loud as they appear on each screen.

[EXAMINER]: You will see a series of white squares appear on the screen. Remember the location of each square when i appears. You will compare it to the location of the next square you see.

If a square matches the location of the previous square, press the LEFT button for YES. If a square does not match the location of the previous square, press the RIGHT button for NO. In between each square, a number will appear in the middle of the screen. Say that number out loud. We'll try some practice trials first. Press the SPACEBAR to begin.

Remember the location of this square, so you can compare it to the location of the next square you see.
Press SPACEBAR to continue. Number appears in the middle of the screen. **Say this number out loud**. *Screen advances. Next square appears on screen*. **Is this location the same as the one just before? If YES press the LEFT key. If NO press the RIGHT key.** *Prompt participant to respond.*

Read instructions for first 3 squares and continue reading if participant shows difficulty understanding task. Provide feedback as needed. If participant performs well, the practice trial will begin.

[Examiner]: Let's try a few more practice squares! For this practice round, You will not receive any directions or feedback. Compare the location of each square to the one just before. Say the number aloud when you see it. Press the SPACEBAR to begin.

Verbalize instructions and provide guidance as needed to help participant understand task. Go on to the practice trial.

PRACTICE TRIAL:

[Examiner]: Let's try a few more practice squares. You will not receive directions or feedback for this round. Each square will appear for a shorter time. Please respond as quickly as possible without making mistakes. Press the SPACEBAR to begin.

Run practice trial. Provide feedback as needed.

After practice is finished, move on to the task.

TEST:

[Examiner]: It is now time to begin the test. Please respond as quickly as possible without making mistakes. Press the SPACEBAR when you are ready to begin.

2-BACK

MATERIALS & SET-UP: Use Left and Right arrow keys.

Read instructions out loud as they appear on each screen.

[Examiner]: Now we will move on to the second part of this task. Once again, you will see a series of white squares appear on the screen and remember the location of each square when it appears. This time, you will compare each square to the location of the square TWO before it. Press the SPACEBAR to continue.

If a square matches the location of the square TWO before it, press the LEFT button for YES. If a square does not match the location of the square TWO before it, press the RIGHT button for NO. Start responding with the third square. We'll try some practice trials first. Press the SPACEBAR to begin.

Remember the location of this square, so you can compare it to the location of the square after the next one. Press SPACEBAR to continue. **Also remember the location of this square so you can compare it to the location of the square after the next one.** Press SPACEBAR to continue. **Does this location match the location TWO before? If YES, press the LEFT key. If NO, press the RIGHT key.** Prompt participant to respond.

Read instructions for first 4 squares and continue reading if participant shows difficulty understanding task. Provide feedback as needed. If participant performs well, the practice trial will begin. Otherwise, a slow example trial will begin:

Verbalize instructions and provide guidance as needed to help participant understand task. Go on to the practice trial.

PRACTICE TRIAL:

[Examiner]: Let's try a few more practice squares. Now, each square will appear for a shorter time. Remember to compare each square to the one TWO before. Start responding with the 3rd square. Please respond as quickly as possible without making mistakes. Press the SPACEBAR to begin.

Run practice trial. Provide feedback as needed. If participant performs well, the test will begin. Otherwise, a new practice trial will begin. The instructions are the same for each trial. If the participant does not perform well on all practice, the task will end.

After practice is finished, move on to the test.

TEST:

[Examiner]: It is now time to begin the task. Please respond as quickly as possible without making mistakes. Press the SPACEBAR when you are ready to begin.

After test is complete:

[Examiner]: The task is complete. This was a challenging test and we want to make sure you understood the instructions. Please explain the instructions to the examiner.

Record response below.

Verbalized correct understanding? Yes □ No □

ANTI-SACCADES

MATERIALS & SET-UP: Score Sheet to record responses (attached). You will need to have the audio setting on the computer adjusted to an audible level.

Set computer centered in front of participant. Computer screen should be approximately 31 inches (80 cm) away from participant and as close to eye level as possible. See Manual for more detailed instructions on set-up.

For both Pro-Trials and Anti-Trials, sit across from the participant so that you are facing him/her. You will not be able to see the computer display. Be sure you can see the participant's eyes.

PRO-TRIAL:

[Examiner]: We are going to do a task to watch your eye movements. You will see a dot in the center of the screen. *Point to the center of the computer screen.*
Move your eyes in the direction the dot moves, which will be either to the left side or to the right side of the screen.

After you have looked in the direction of the dot, return your eyes to the center of the screen.

Do not move your head, just your eyes.

Press the SPACEBAR to continue.

Press the SPACEBAR when you are ready to begin the task. When the task begins, a recorded voice on the computer program will announce the number of each trial. Listen to the number announced to ensure you are recording each eye movement for the correct trial. Record initial direction of eye movement.

There are 10 trials for Pro-Saccades.

After the Pro-Saccades test, the instructions to the Anti-Saccades test will appear on the screen:

~~ANTI-TRIAL:~~

[Examiner]: Now we will move on to the second part of eye movement task. Again, you will see a dot in the center of the screen. *Point to the center of the computer screen.* **This time, I would like you to use your eyes to look in the ~~opposite~~ direction of where the dot moves. Do not move your head, just your eyes. After looking at the opposite side of where the dot is, return your eyes to look at the dot at the center of the screen.** *Press the SPACEBAR to begin the practice trial.*

Now we will begin the task. Use your eyes to look in the OPPOSITE direction of where the dot moves. Do not move your head, just your eyes. After looking at the opposite side of where the dot is, return your eyes to the center of the screen.

Press the SPACEBAR to continue.

Again, you will see a dot in the center of the screen. Use your eyes to look in the OPPOSITE direction of where the dot moves. Do not move your head, just your eyes. After looking at the opposite side of where the dot is, return your eyes to the center of the screen.

Press the SPACEBAR to continue.

ANTI-SACCADES SCORE SHEET

ADMINISTRATION:
*Mark the left or right box for each trial to correspond with the direction of initial eye movement, **from the examiner's perspective**. A recorded voice will help to keep track of the trials.*

SCORING:
Count the number of marked boxes that are not grayed out as the number of correct responses.

PRO-TRIAL	**← EYES**	**EYES →**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Total Correct: _________ / 10

ANTI-TRIAL 1	**← EYES**	**EYES →**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Total Correct: _________ / 20

ANTI-TRIAL 2	**← EYES**	**EYES →**
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Total Correct: ________ / 20

SOCIAL NORMS EVALUATION

Administer to all participants. For participants age 14 and older, administer Adult Social Norms Evaluation. For participants under age 14, administer Child Social Norms Evaluation. Make sure all items are answered.

Instructions for Adult Social Norms Evaluation:

[Examiner]: The following is a list of behaviors that a person might do. Please decide whether or not it would be socially acceptable and appropriate to do these things in the mainstream culture of the United States, and answer yes or no to each. Think about these questions as they would apply to interactions with a stranger or acquaintance, NOT with a close friend or family member.

Instructions for Child Social Norms Evaluation:

[Examiner]: The following is a list of things that a kid might do. Please decide whether other people would mind if you did each thing, or whether it might bother them. Pretend all the kids in your class, and your teacher, see you do these things, and decide if they will think it's OK.

DATA COLLECTION/RESEARCH QUALITY NOTES

Quality Issues:

- ☐ None, Data are Valid (Skip)
- ☐ Yes (Choose up to 3 issues)

- ☐ Motor Difficulties
- ☐ Speech Difficulties
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ ESL
- ☐ Minimal Education
- ☐ Lack of Effort
- ☐ Unreliable Informant
- ☐ Behavioral Disturbances
- ☐ Other *(Describe in Notes)*

Data Quality Notes:

Data Collection Notes:

BEHAVIOR RATING SCALE

INSTRUCTIONS:
***To be completed by the Examiner**. Following the administration of the battery to the study participant, indicate the presence of the following behavioral features observed during the examiners' time with the study participant. None indicates the absence of the feature. When the feature is present, rate it as mild, moderate or severe depending on the extent to which it disrupts the testing or interpersonal exchanges, or the extent to which it deviates from accepted norms.*

Please circle the most accurate response regarding the participant's behavior.

ITEM DESCRIPTORS AND BEHAVIOR CHECKLIST:

1. Agitation	None	Mild	Moderate	Severe
2. Stimulus-boundedness	None	Mild	Moderate	Severe
3. Perseverative	None	Mild	Moderate	Severe
4. Decreased initiation	None	Mild	Moderate	Severe
5. Motor stereotypies	None	Mild	Moderate	Severe
6. Distractibility	None	Mild	Moderate	Severe
7. Lack of social/emotional engagement	None	Mild	Moderate	Severe
8. Impulsivity	None	Mild	Moderate	Severe
9. Socially inappropriate	None	Mild	Moderate	Severe

Descriptions:____
____
____
____
____
____

GENERAL GUIDELINES:

Examiners should restrict their ratings to behaviors that they have observed, and not use this rating scale to reflect behaviors that are described by caregivers, informants, or other health care professionals but not directly observed by the examiner. Examiners should include all observed behaviors, regardless of the context. Thus, although behaviors during the actual assessment will likely provide the bulk of data, examiners should also note behaviors exhibited in all other situations, such as the waiting room and walking to and from the exam room.

There will be some instances when raters will have to decide which of several potential categories to rate a particular behavior. For example, repeatedly pickup up a pencil from the table and scribbling on test forms could be potentially viewed as perseverative, stimulus-bound, or motor stereotypy. It is important for raters to select **only one** category for an observed behavior. Typically, raters will have to use their best clinical judgment as to the most appropriate category. Some suggestions for determining which category to select are mentioned below. Use the space in the bottom half of the rating page to describe the behavior. This is particular important step for subjects being evaluated longitudinally in the event that a different rater will be seeing the subject at the next visit.

DETERMINING SEVERITY:

As a general rule, the severity of the observed behavior should reflect the extent to which it disrupts the testing or interpersonal exchanges, or the extent to which it deviates from generally accepted norms. Mild refers to an infrequent occurrence of the behavior or if the behaviors observed are present but relatively insignificant. Subjects are easily redirected and there is no or minimal impact on the quality of the testing. A rating of moderate would indicate that the occurrence of behaviors begin to infringe on the quality of the data and neuropsychological test performance. Subjects are less easily redirected. For example, if a subject cannot take social cues from the examiner and continues discussing topics that are inappropriate for the clinical setting, “Socially Inappropriate Behavior” would be rated as “moderate.” A rating of “severe” indicates that the behavior occurs very frequently throughout the testing situation. For example, Distractibility would be rated as “severe” when the subject is very difficult to redirect to the task at hand, to the point that test validity is questionable. Additional examples are provided below.

SPECIFIC BEHAVIORS:

1. Agitation: Agitation can involve inappropriate verbal (screaming, cursing) or physical (repetitive body movements, hitting or throwing objects) behaviors and can be aggressive or non-aggressive in nature (pacing versus kicking). Mild agitation might manifest itself as being anxious to complete the evaluation, argumentative, or complaining about testing. Moderate levels might include disruptive but not harmful behaviors that cannot be easily redirected. Severe agitation would include physical behaviors that put others or self in danger (e.g., hitting, pushing, scratching, throwing things, biting or kicking) or extreme verbal aggression (e.g., screaming or cursing loudly).

2. Stimulus-boundedness: Stimulus-boundedness is an inappropriate response to a salient environmental stimulus. Such behaviors could include unsolicited reading of nearby text, environmental dependency (e.g., picking up a pen from the table and writing; eating food from someone else’s plate), excessive attention to irrelevant objects (e.g., picking up objects from floor), echolalia, or, during cognitive testing, writing or drawing on a model or adjacent stimulus. The occurrence of even one instance of stimulus-boundedness warrants a mild rating. Examples of “moderate” include closing in on a stimulus or being distracted by adjacent stimuli and these behaviors result in clearly impaired performance. Environmentally dependent behaviors occur often and subject cannot be easily redirected. Subjects whose environmental dependency makes task completion very difficult would be rated as severe.

3. Perseverative: Perseveration is the inappropriate and unintentional persistence of a behavior, and can be observed behaviorally, on testing, and in conversational speech. As observed on testing, the persisting behavior may be (1) a repetition of a previously generated response within a task, or (2) a repetition of a response appropriate to an earlier task or condition. As observed in conversation speech, a participant appears stuck on an idea or persistently returns to a previously voiced idea or story. (A few repeated responses during testing are not uncommon in normal individuals, so this behavior should only be scored as present when the frequency deviates from normative expectations). Repetitions that slightly exceed normative expectations would be rated as mild. A moderate rating would be given any time the subject makes a perseverate response without any intervening responses (e.g., drawing the exact same design two or more times in a row on Design Fluency) or reverts to previously established response set (e.g., on Category Fluency, gives responses only beginning with the letter L as required by the previous task, or makes numerous perseverations of any type. A pervasive tendency to perseverate that interrupts the testing would be rated as severe.

4. Decreased initiation: Behaviors suggesting decreased initiation include delayed time to start verbal and/or motor response after being given task instructions, need for additional prompting to initiate a response, and low motivation to perform well. This would also include instances when a subject stops in the middle of a task and requires additional prompts to continue. Note: If decreased initiation occurs only in the context of lack of social engagement or distractibility, code as those domains rather than decreased initiation.

5. Motor stereotypies: These are persistent, repetitive behaviors without a clear purpose. Examples include pacing without apparent purpose, rummaging through pockets or drawers, picking at skin or clothes, handling buttons, repeatedly putting on and removing jewelry or clothing, repeated lip smacking or other sounds, or repeating phrases that have no communicative value. Note: If a behavior is coded as a motor stereotypy, that same behavior should not also be coded as a perseveration.

6. Distractibility: Attention is easily diverted away by external stimuli (people, objects, etc.), outside noise, or internal thought. This is observed when the subject loses his/her train of thought, needs multiple reminders about instructions, needs to have their attention redirected to the task at hand, or engages in tangential speech or thought. This can be rated as mild if the distractibility is occasional and does not significantly interfere with collecting valid test data, moderate if the subject needs several reminders and redirection, but still able to complete evaluation and severe if the distractibility significantly disrupts testing to the point that validity is questionable.

7. Lack of Social / Emotional Engagement: This refers to the examiner's impression that the subject displays signs of diminished social interest, interrelatedness, or personal warmth. Examples of behaviors might include lack of eye contact, excessive eye contact (e.g., staring), lack of smiling or reduced range of facial affect (unrelated to Parkinson's disease), lack of awareness of how subject's behavior might affect others, lack of interest in others. Additional behaviors include lack of spontaneity and not initiating conversations. The main distinction between lack of social engagement and social inappropriateness is that lack of social engagement typically reflects an absence of behavior (e.g., empathy, warmth) whereas social inappropriateness typically reflects the distinct presence of an inappropriate behavior (e.g., inappropriate touching or remarks).

8. Impulsivity: This refers to acting with insufficient forethought or patience. Potential behaviors include beginning a task before examiner completes instructions, responding to only part of the instructions (e.g., the first part of multi-step instructions), a careless approach to work, finishing too quickly, and interrupting the examiner. A mild rating would refer to when the examinee works quickly without checking work, appears bored when solving complex problems, or starts one test item before the examiner completes the instructions or without adequate planning time. For a moderate rating, the examinee might respond carelessly at the expense of accuracy, start test items before the examiner completes the instructions or without adequate planning time on more than one occasion, or otherwise tend to do or say things rapidly and without planning. An example of severe impulsivity might be when a participant's tendency to act without forethought disrupts the testing or interpersonal exchanges, or markedly deviates from normal behavior.

9. Socially inappropriate: Refers to conduct which may not be suitable in professional settings. Examples may include talking to strangers on the elevator, questioning the examiner/clinician about personal information or their credentials, disregard for or violation of personal space (e.g., excessive or inappropriate touching of examiner), or lack of response to social cues (e.g., when others attempt to end a conversation). Out-of-place topics, crude or sexually oriented comments, jokes or opinions that may be offensive to others, or poor hygiene/grooming (malodorous, stained, torn, or inappropriate clothing) can also fall under this category. Physical behaviors such as flatulence, touching private body parts, belching, and spitting can also be considered.

CHILD SOCIAL INTERACTIONS

INSTRUCTIONS: The following is a list of things that a kid might do. Please decide whether other people would mind if you did each thing, or whether it might bother them. Pretend all the kids in your class, and your teacher, see you do these things, and decide if they will think it's OK.

Would other people think it's OK to:

1.	Pick your nose in class?	☐ YES	☐ NO
2.	Ask your teacher how to get to the library?	☐ YES	☐ NO
3.	Tell a kid you don't like them?	☐ YES	☐ NO
4.	Ask your teacher for a ride to the store?	☐ YES	☐ NO
5..	Blow your nose on the bus?	☐ YES	☐ NO
6.	Borrow your friend's new shirt without permission?	☐ YES	☐ NO
7.	Brush your teeth once a week?	☐ YES	☐ NO
8.	Take a library book home from school?	☐ YES	☐ NO
9.	Wear the same shoes three days in a row?	☐ YES	☐ NO
10.	Keep money you find on the sidewalk?	☐ YES	☐ NO
11.	Tell another kid they have weird hair?	☐ YES	☐ NO
12.	Laugh at yourself when you trip and fall down?	☐ YES	☐ NO
13.	Kick a ball really hard?	☐ YES	☐ NO
14.	Laugh loudly during a movie at the theater?	☐ YES	☐ NO
15.	Push another kid so you get to the swings first?	☐ YES	☐ NO
16.	Throw your lunch trash on the floor?	☐ YES	☐ NO
17.	Ask a kid if they want to come over to your house?	☐ YES	☐ NO
18.	Eat the last cookie from the cookie jar?	☐ YES	☐ NO
19.	Take the classroom markers home from school?	☐ YES	☐ NO
20.	Rush to sit in the front row the first day of class?	☐ YES	☐ NO
21.	Take a bath or shower every day?	☐ YES	☐ NO
22.	Laugh at a kid when they trip and fall down?	☐ YES	☐ NO
23.	Talk loudly during a movie at the theater?	☐ YES	☐ NO
24.	Talk with your mouth full?	☐ YES	☐ NO
25.	Keep your classmate's game they left on the playground?	☐ YES	☐ NO
26.	Tell another kid they are smart?	☐ YES	☐ NO
27.	Kick the trashcans at school?	☐ YES	☐ NO
28.	Throw your leftover lunch away?	☐ YES	☐ NO
29.	Use a spoon to eat macaroni and cheese?	☐ YES	☐ NO
30.	Wear the same shirt three days in a row?	☐ YES	☐ NO

ADULT SOCIAL INTERACTIONS

The following is a list of behaviors that a person might do. Please decide whether or not it would be socially acceptable and appropriate to do these things in the mainstream culture of the United States, and answer yes or no to each. Think about these questions as they would apply to interactions with a stranger or acquaintance, NOT with a close friend or family member.

Would it be socially acceptable to:

1.	Tell a stranger you don't like their hairstyle?	○YES	○NO
2.	Spit on the floor?	○YES	○NO
3.	Blow your nose in public?	○YES	○NO
4.	Ask a coworker their age?	○YES	○NO
5.	Cry during a movie at the theater?	○YES	○NO
6.	Cut in line if you are in a hurry?	○YES	○NO
7.	Laugh when you yourself trip and fall?	○YES	○NO
8.	Eat pasta with your fingers?	○YES	○NO
9.	Hug an acquaintance without asking first?	○YES	○NO
10.	Tell a coworker your age?	○YES	○NO
11.	Tell someone your opinion of a movie they haven't seen?	○YES	○NO
12.	Laugh when someone else trips and falls?	○YES	○NO
13.	Wear the same shirt every day?	○YES	○NO
14.	Keep money you find on the sidewalk?	○YES	○NO
15.	Pick your nose in public?	○YES	○NO
16.	Tell a coworker you think they are overweight?	○YES	○NO
17.	Drive fast if you are in a hurry?	○YES	○NO
18.	Eat ribs with your fingers?	○YES	○NO
19.	Tell a stranger you like their hairstyle?	○YES	○NO
20.	Wear the same shirt twice in two weeks?	○YES	○NO
21.	Tell someone the ending of a movie they haven't seen?	○YES	○NO
22.	Hug a stranger without asking first?	○YES	○NO
23.	Talk out loud during a movie at the theater?	○YES	○NO
24.	Tell a coworker you think they have lost weight?	○YES	○NO

Appendix A
Additional Testing Materials

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" ! ' " " # $)) "($& " # "#" , # # # " & !
! # ,

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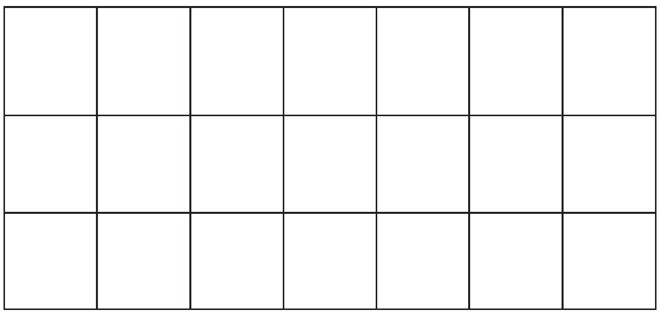

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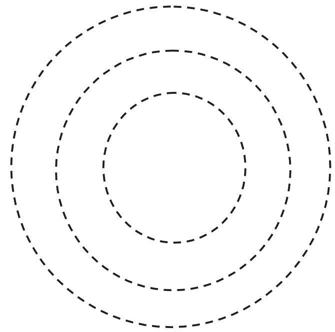

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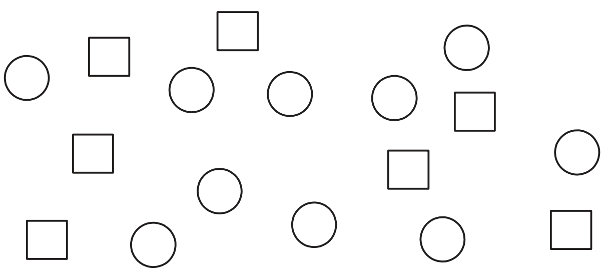

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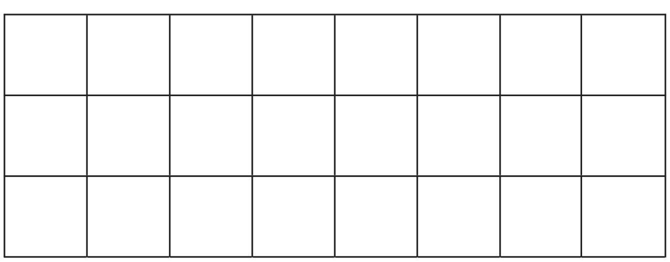

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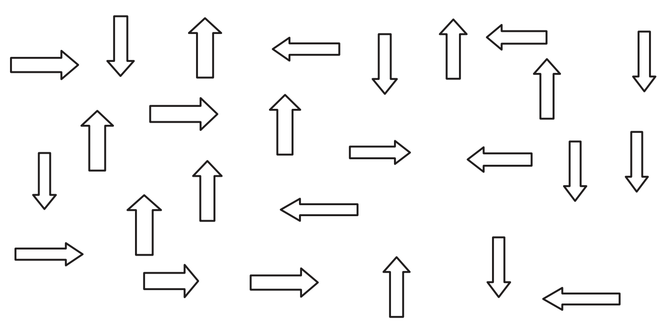

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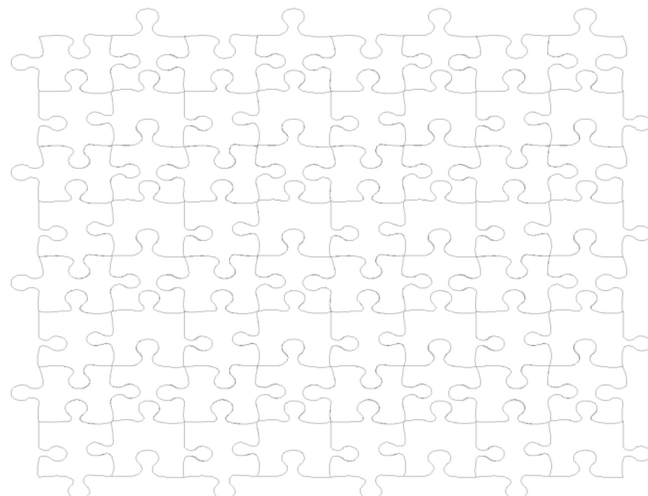

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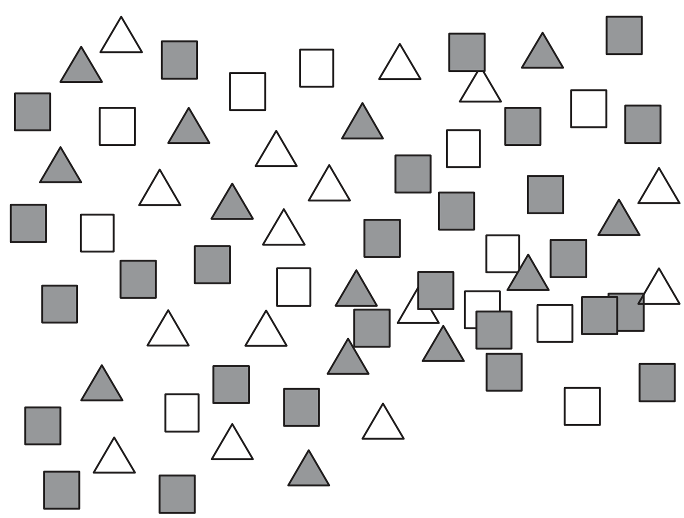

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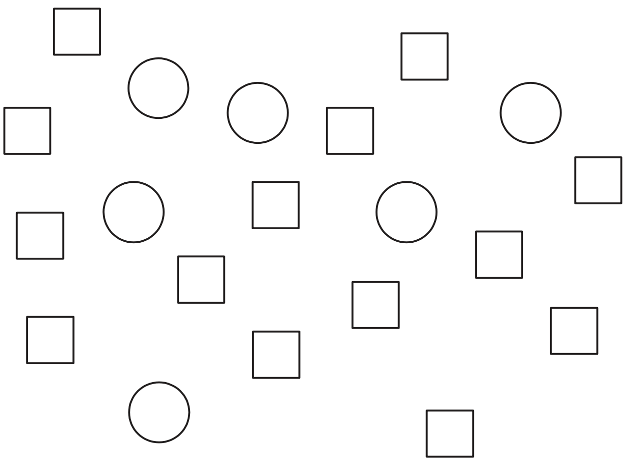

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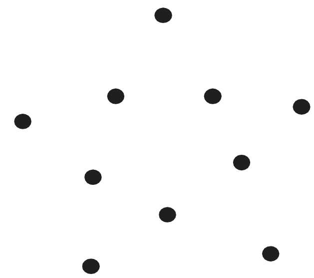

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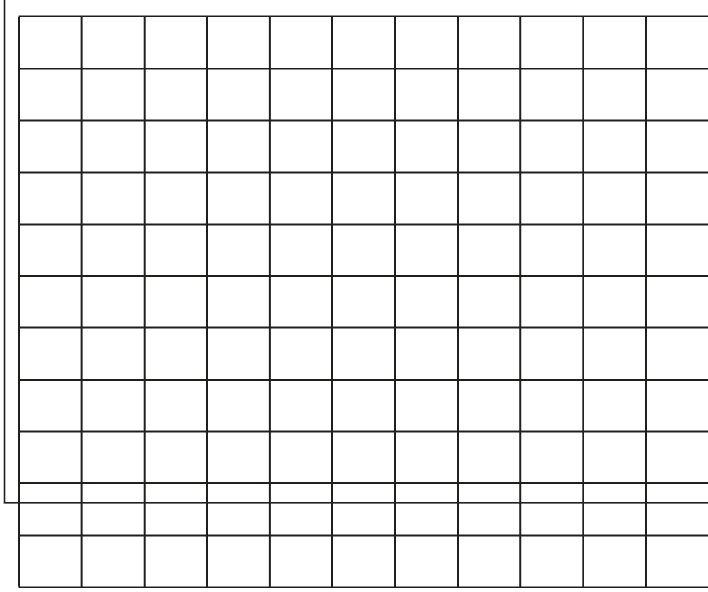

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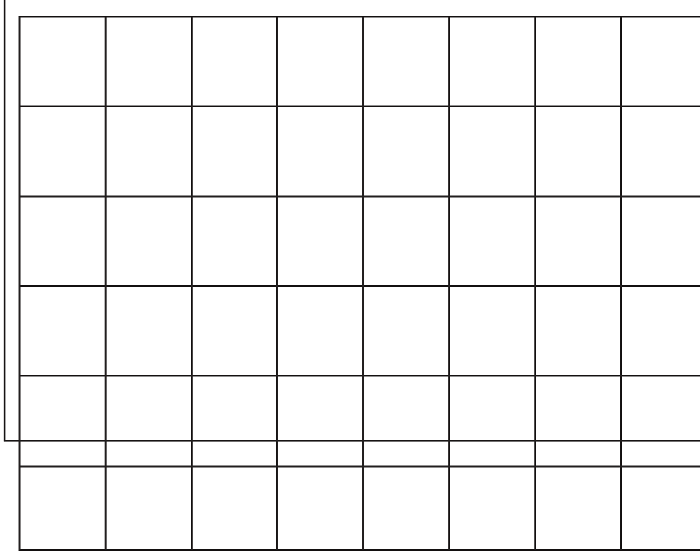

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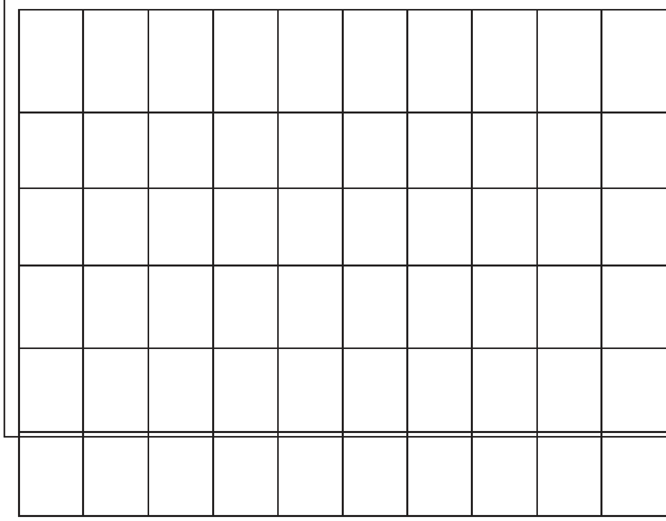

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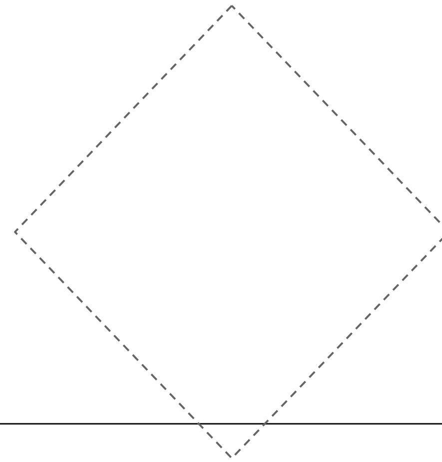

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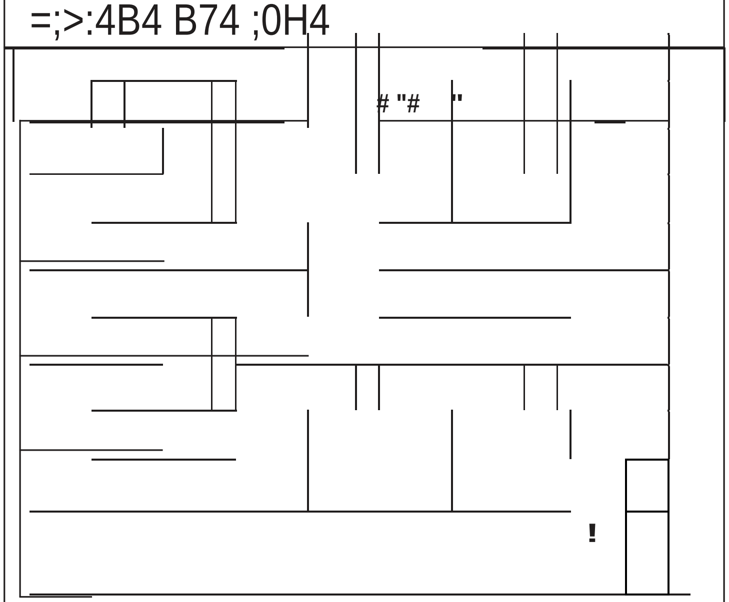

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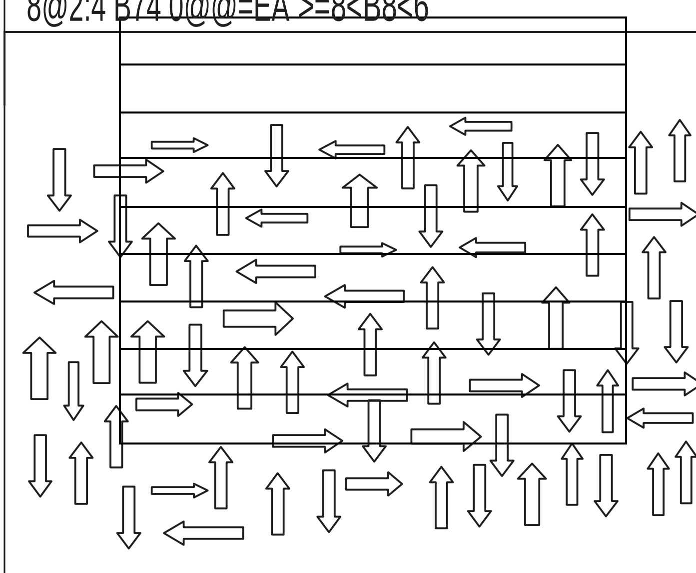

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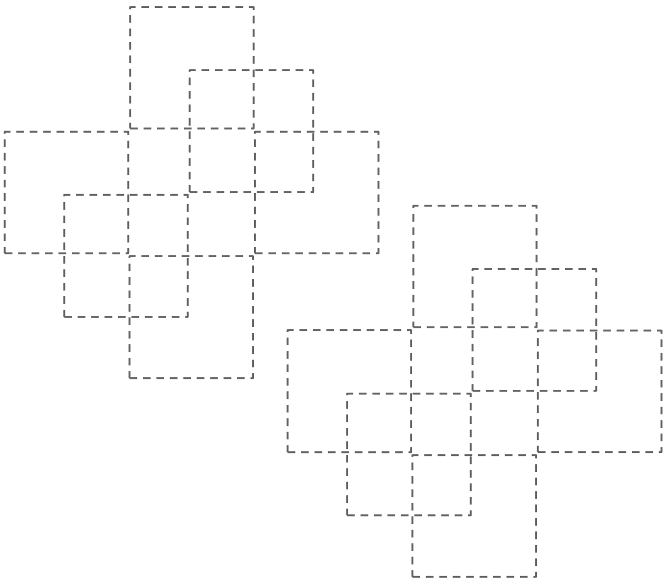

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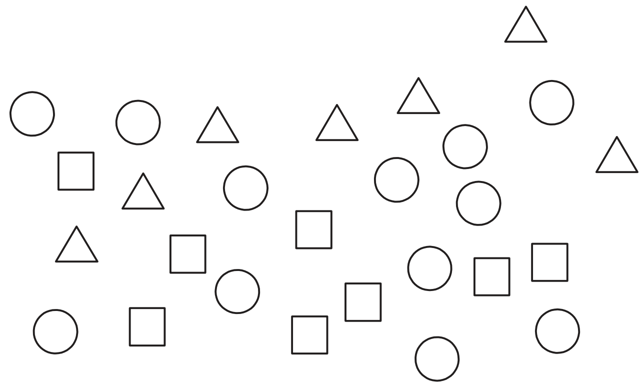

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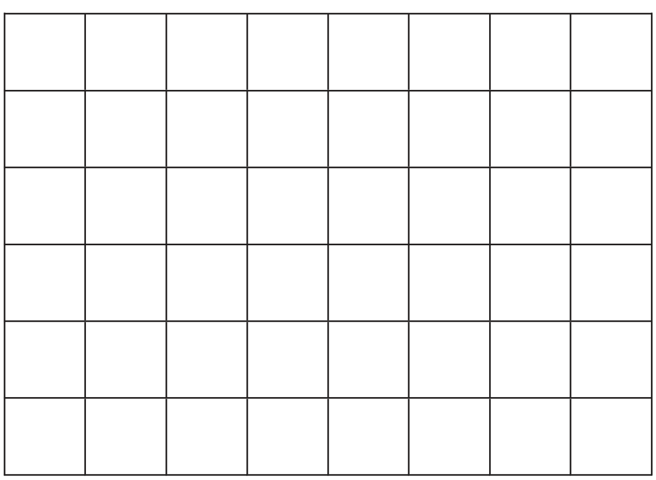

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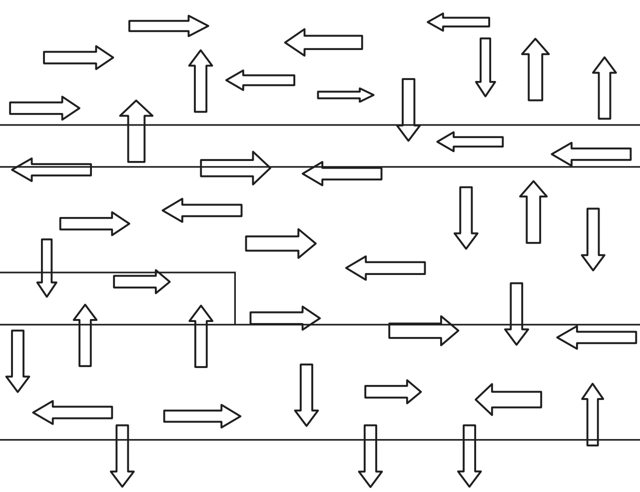

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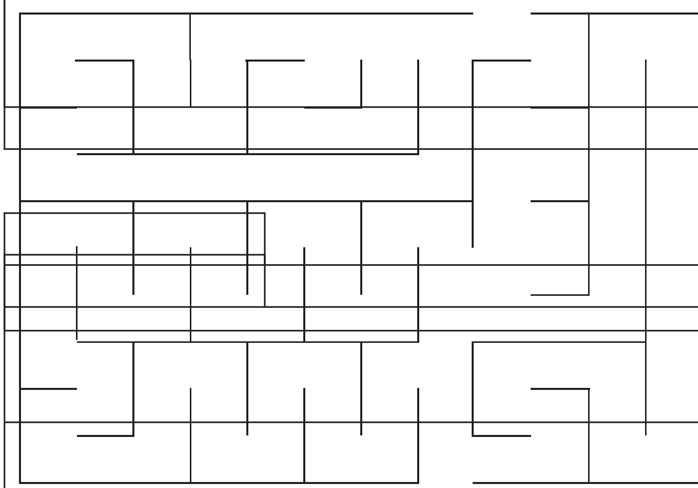

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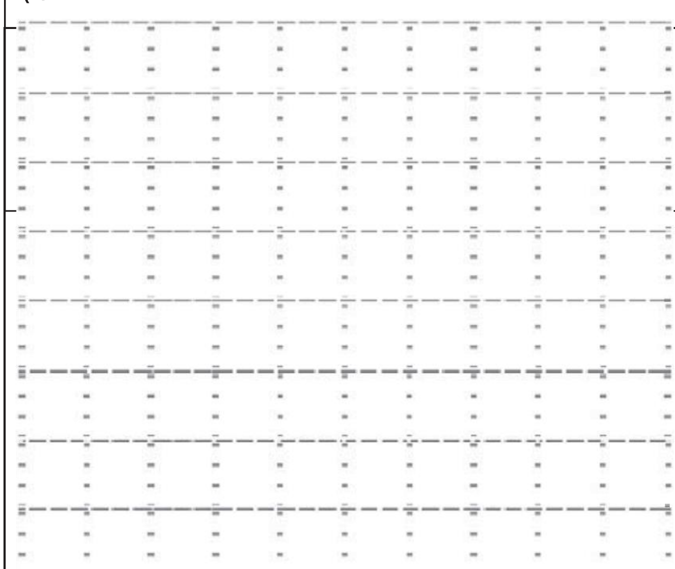

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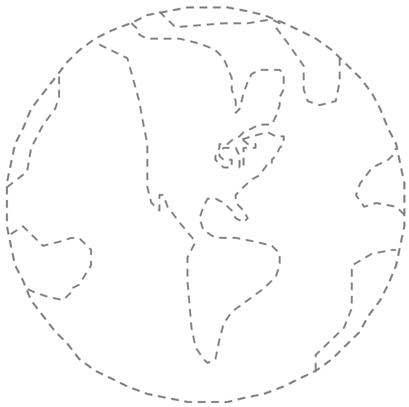

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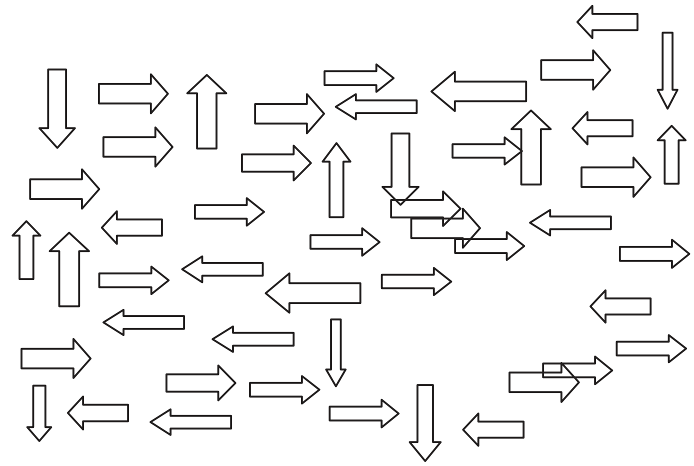

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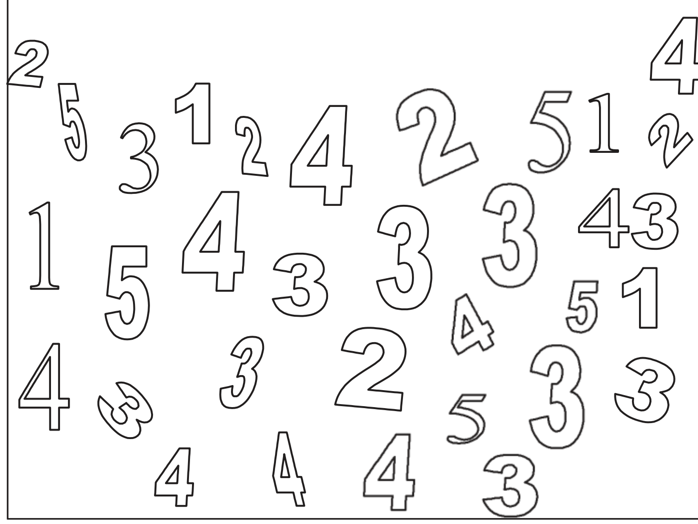

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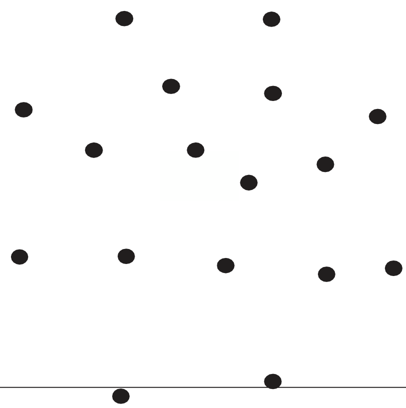

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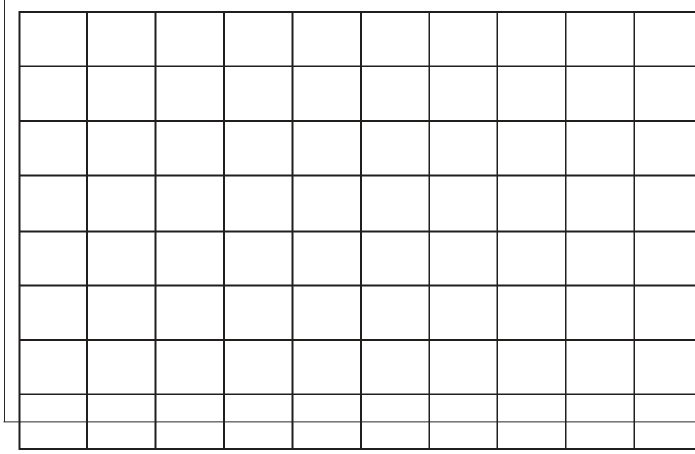

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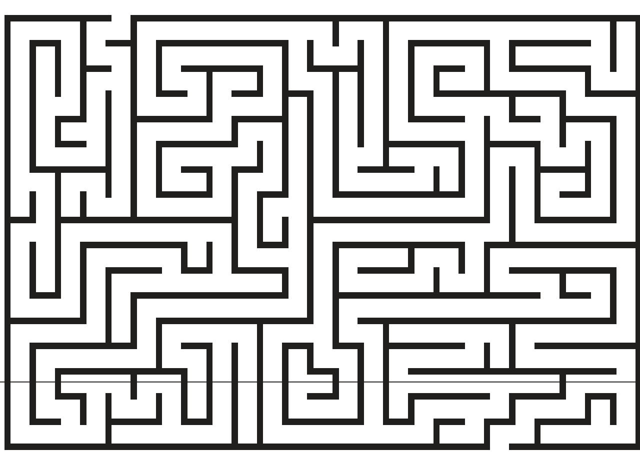

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'=:D4 B74 >@=1:4;A 14:=E

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8@2:4 0:: =5 B74

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8:: 8< B74 ;8AA8<6 <C;14@A

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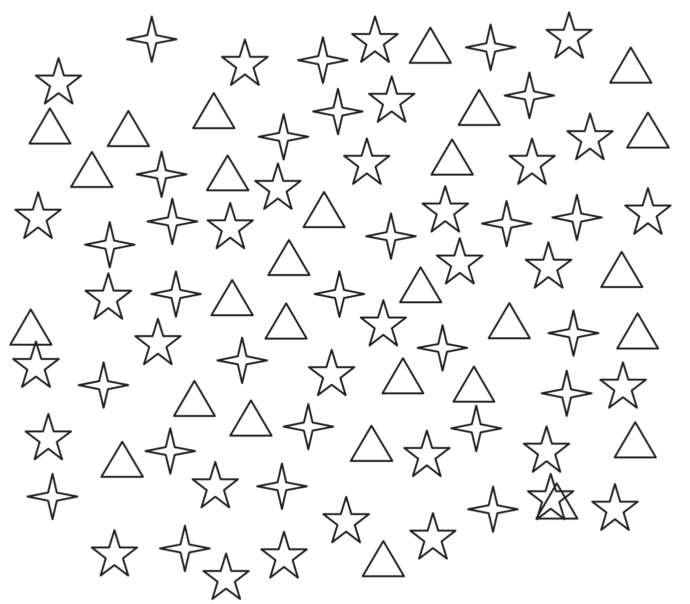
@=AA =CB 0:: =5 B74 AB0@A ☆



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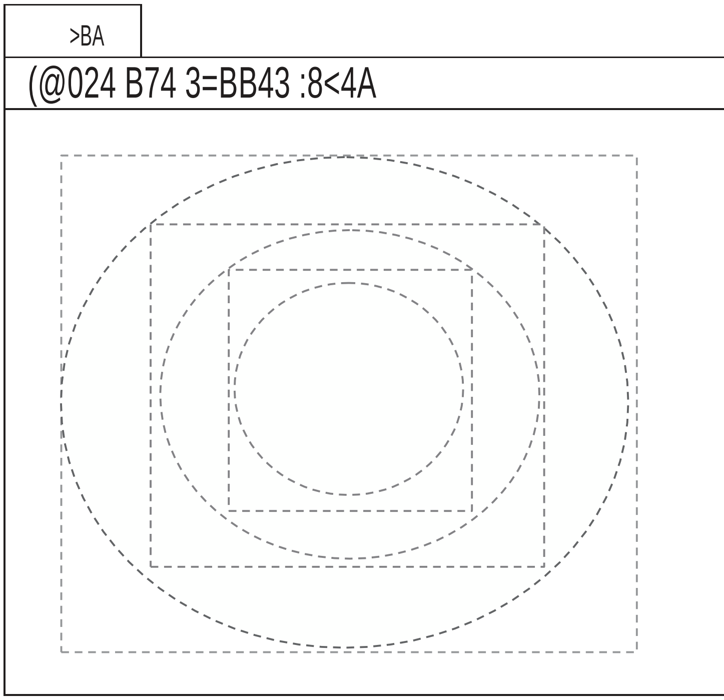

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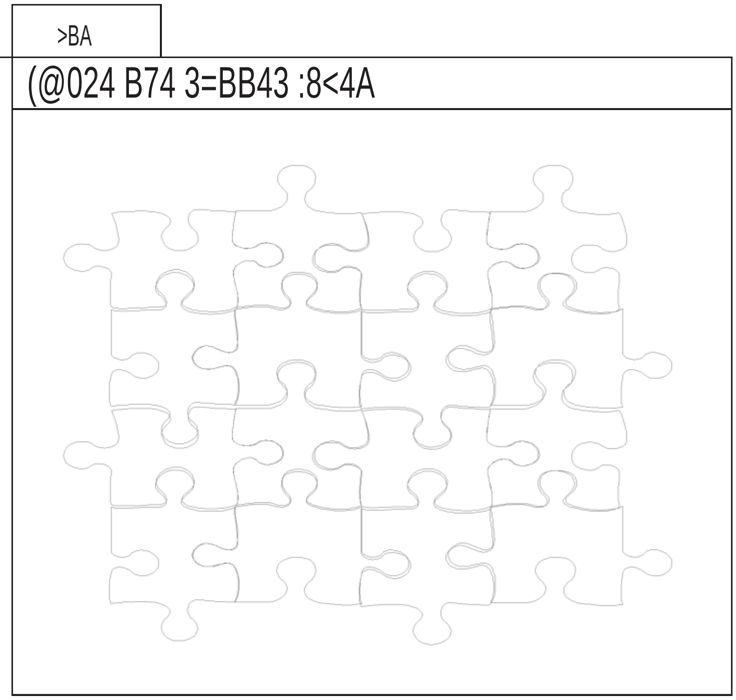

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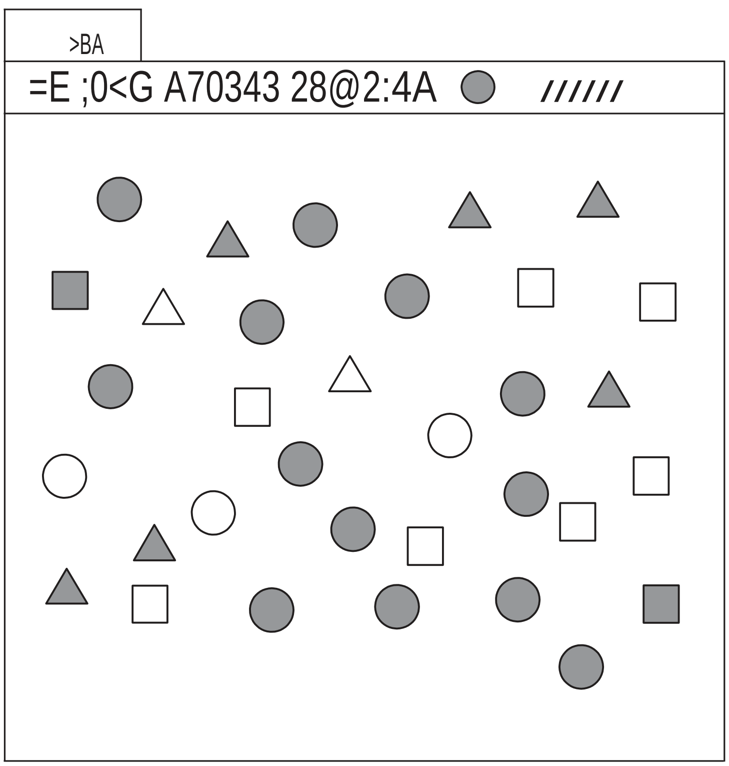

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>BA
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>BA

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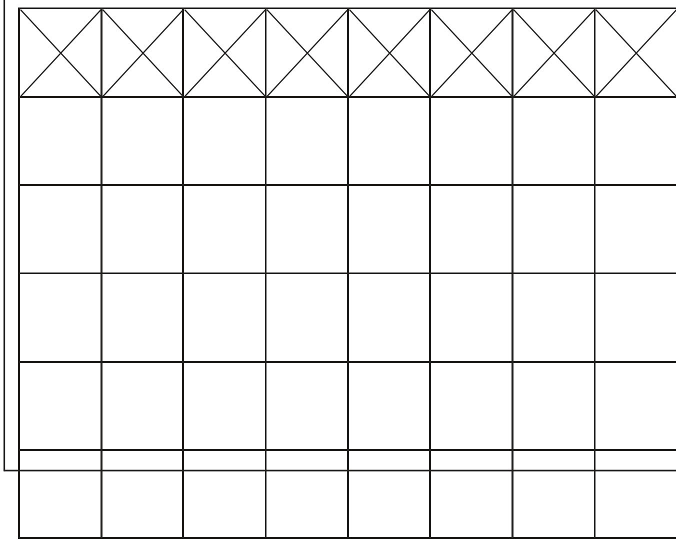

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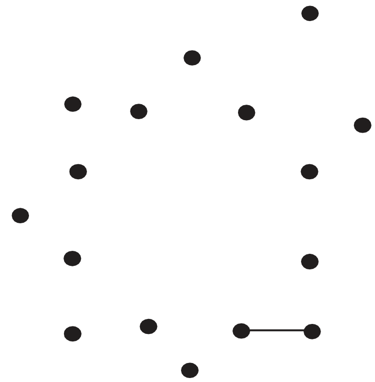

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'=:D4 B74 >@=1:4;A 14:=E

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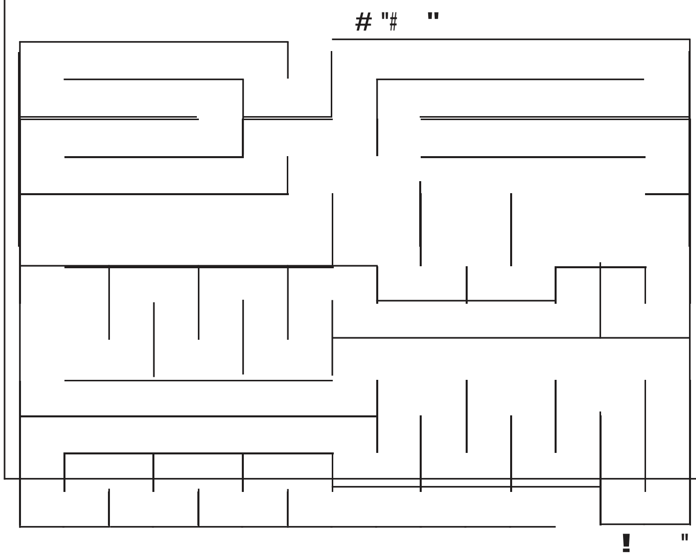
=;>:4B4 B74 !0H4



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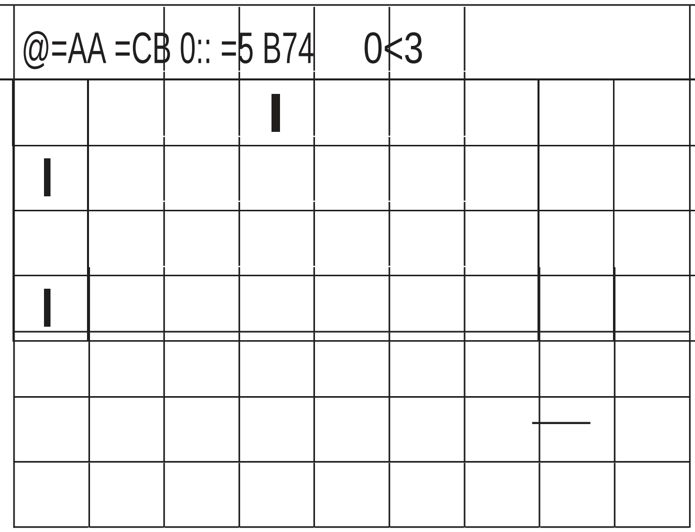

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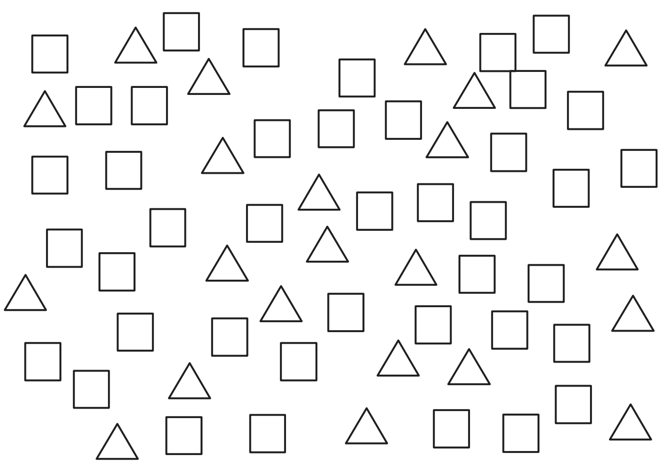

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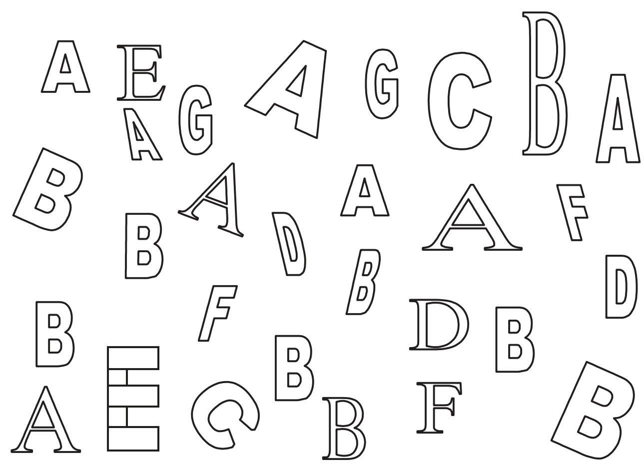

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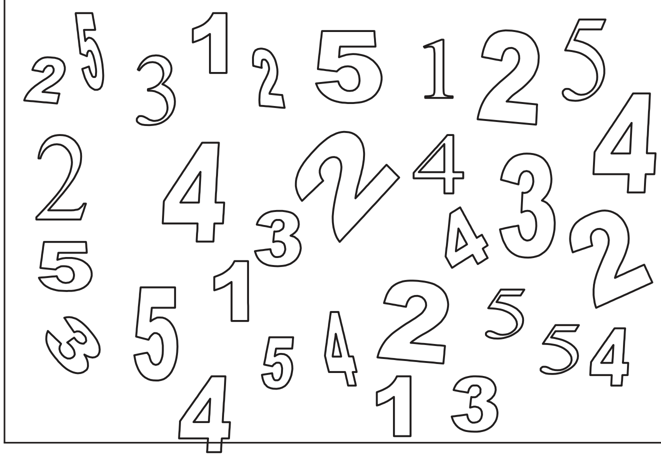

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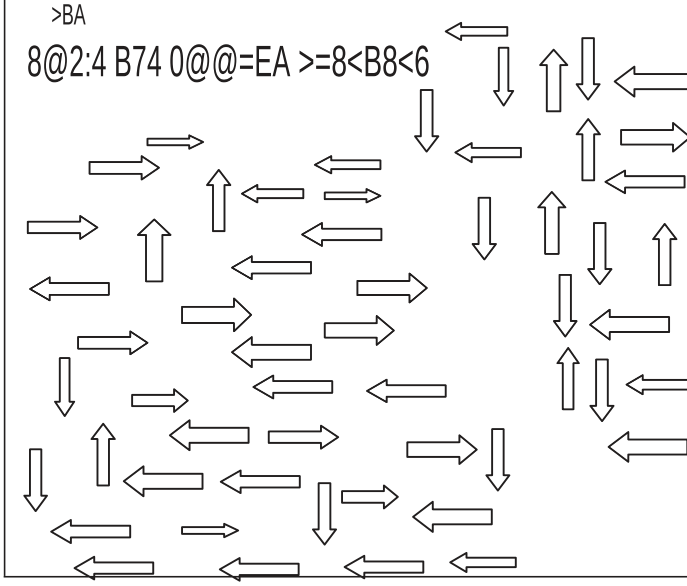

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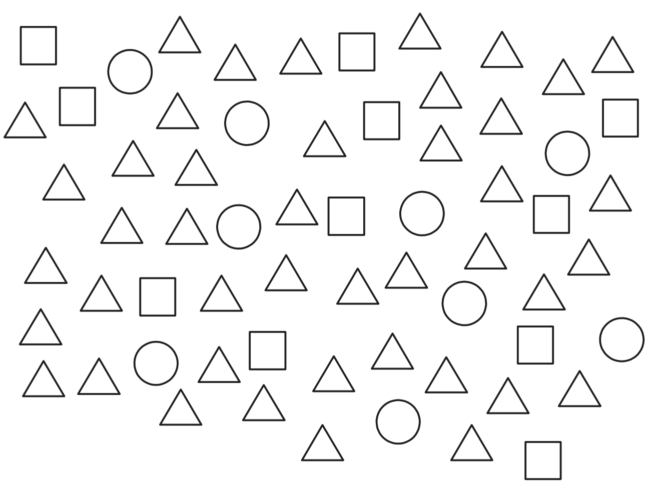

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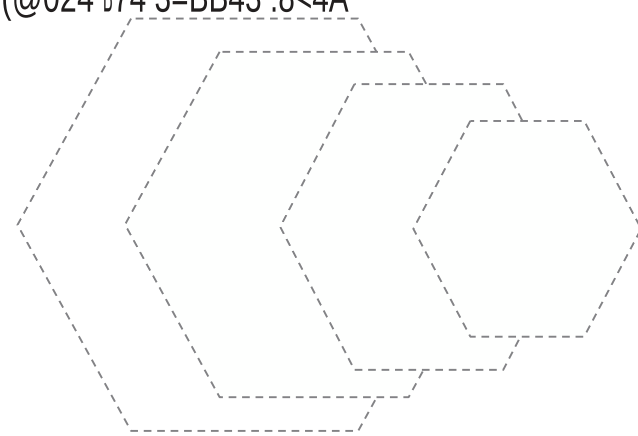

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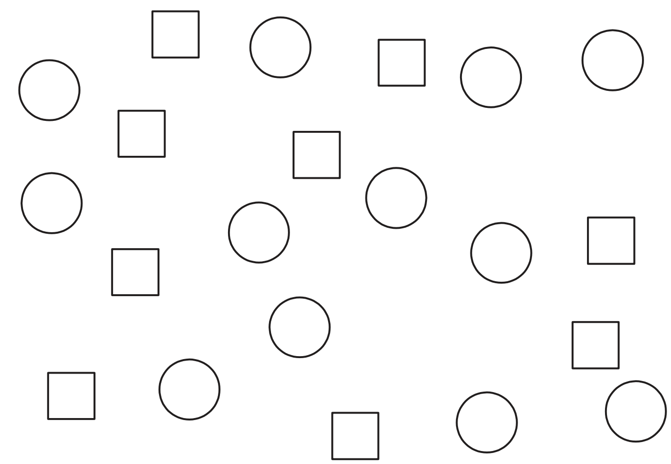
=E ;0<G 28@2:4A ○ /////



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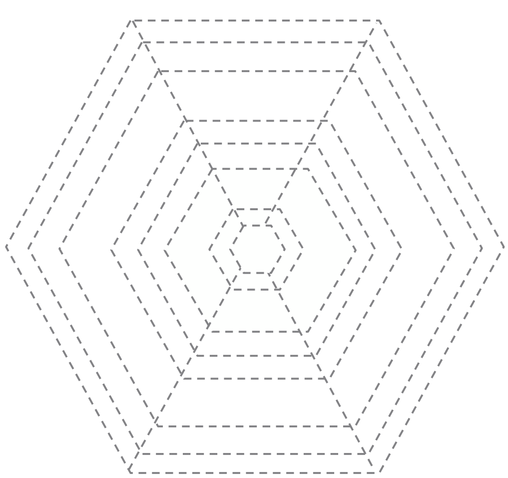

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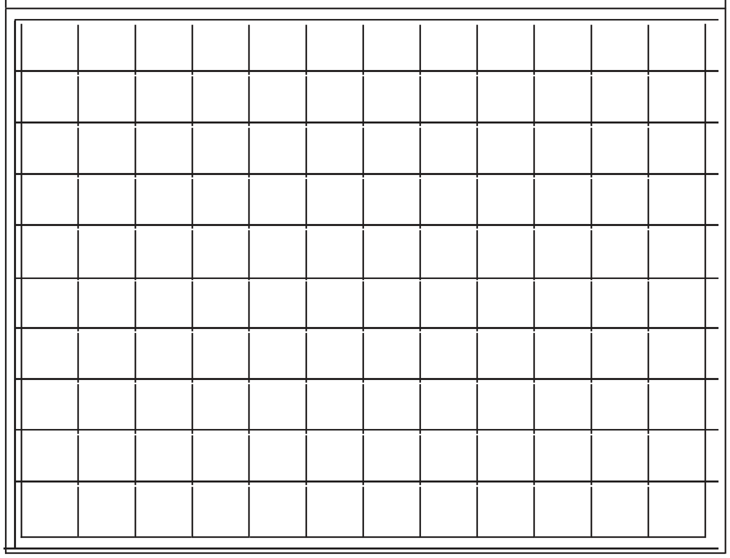

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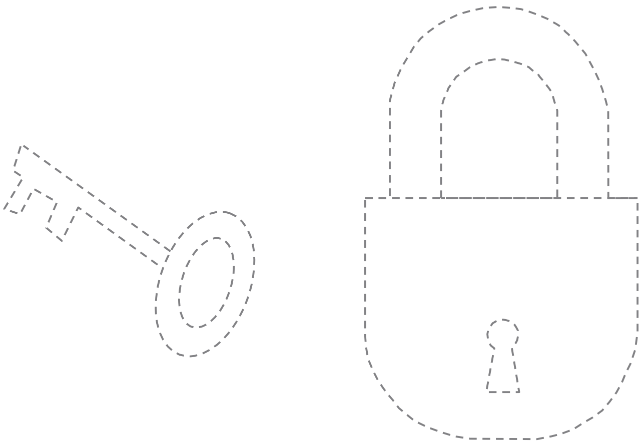

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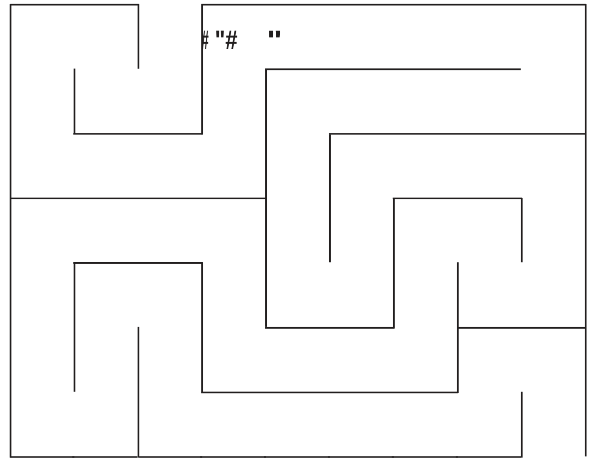

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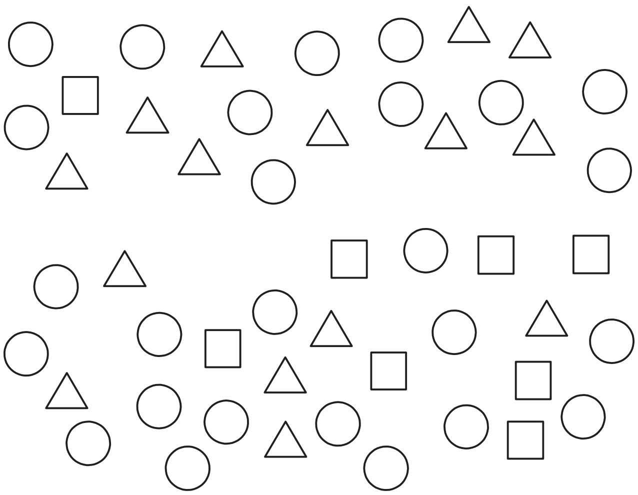

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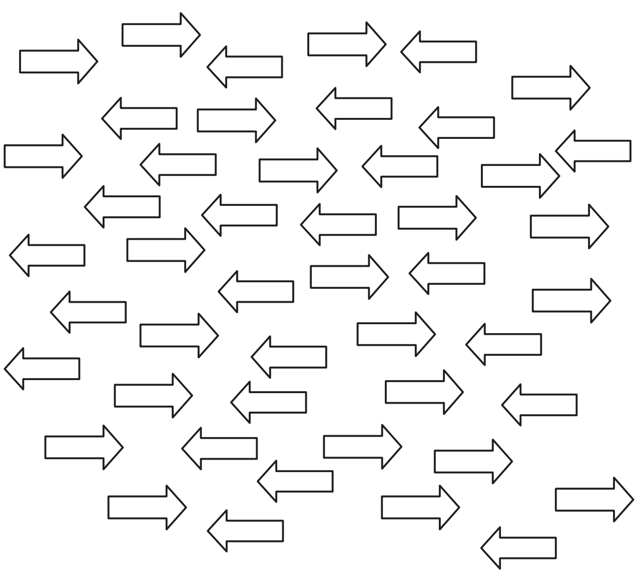

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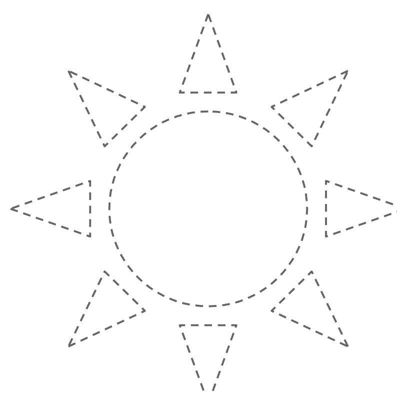

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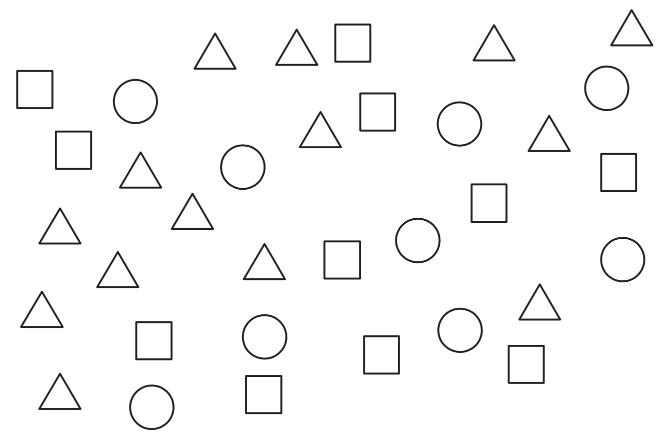

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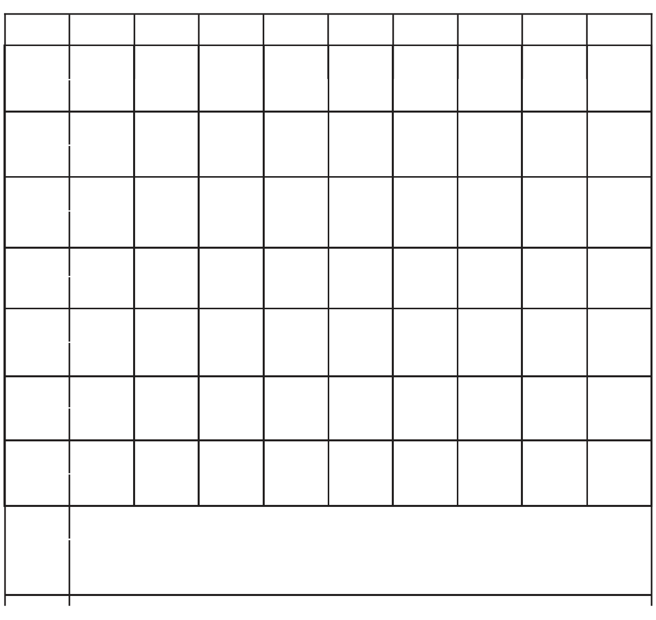

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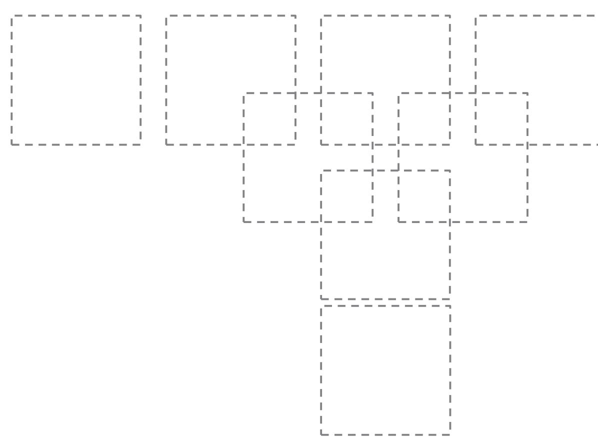

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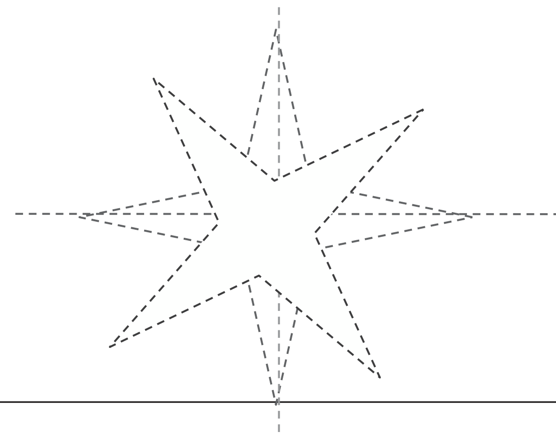

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"#   "

>B

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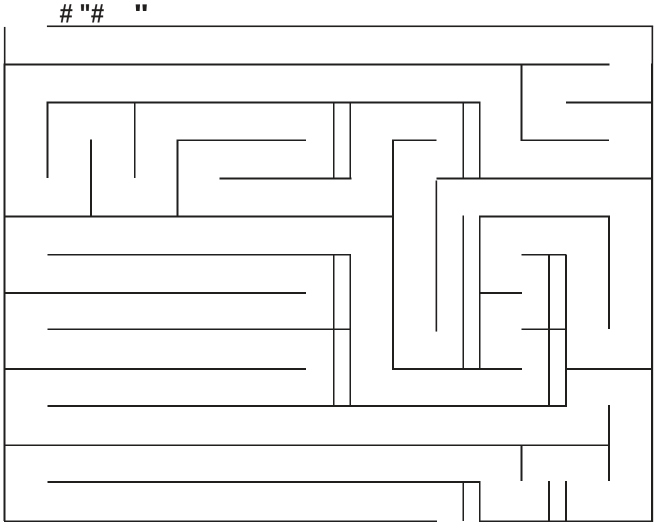

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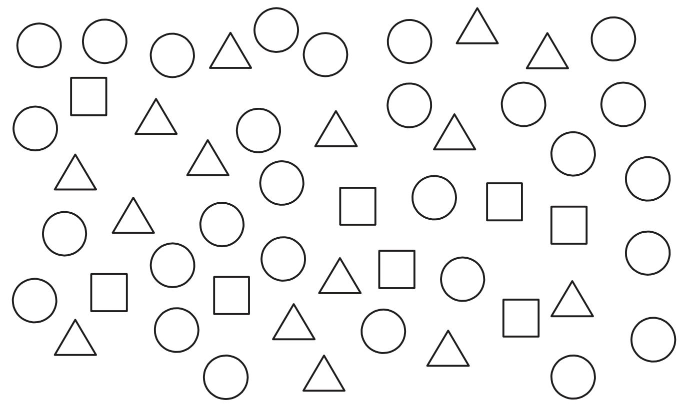

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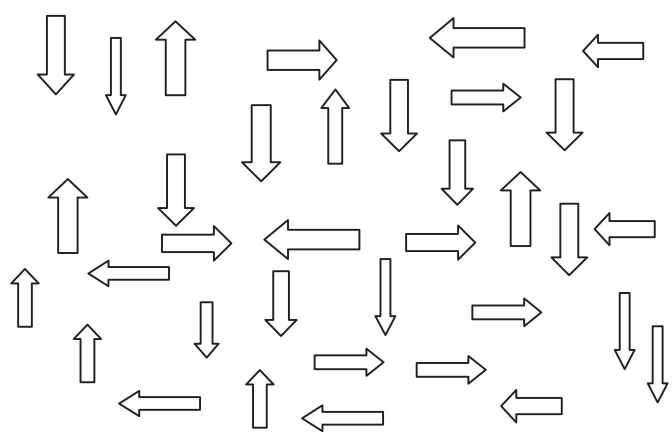

Normal Distribution