Visual Working Memory Differences in Relation to Measures of Delusional Ideation

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Bachelor of Sciences

Submitted in partial fulfilment of the requirements for

College Honors

Departmental Distinction in Psychology

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Abstract

The current study examines the relationship between visual working memory, approximate number system (ANS), and established measures of delusional ideation. Participants completed a novel visual working memory centroid response task, the online Panamth.org task, and several questionnaires. It was expected that accuracy on the working memory task would be related to measures of delusional ideation such that poor performance indicated higher scores. The same was expected for the ANS task such that poor performance would indicate higher scores. Results show that the visual working memory task is not related to either the ANS task performance or scores on the delusional ideation questionnaires. Conditions of the working memory task correlated to each other, indicating that individuals perform consistently on the task.

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There is mounting evidence that individuals with schizophrenia have substantial visual abnormalities (Silverstein et al., 2015; Silverstein & Thompson, 2015), ranging from dysfunction in specific visual processes to anatomical aberrations. Some of this pathophysiology may stem from impaired neural circuitry, in which underlying synaptic connections do not communicate efficiently, leading to abnormal information integration (Phillips & Silverstein, 2003). This same impaired circuity could contribute to poor stimuli and information processing in decision making scenarios, leading to inappropriate weighting of non-salient stimuli that results in hallucinations or delusional ideation (Kapur, 2003; Corlett et al., 2009). Similarly, there is evidence that individuals on the schizophrenia spectrum may have motor control abnormalities, possibly resulting from these same inefficient neural circuitry mechanisms, only connecting here to corticomotor circuits instead of visual ones (Lenzenweger, 2002; Nguyen et al., 2016). Because of these corticomotor differences, it may be the case that physical expressions of visually selected information could be inconsistent (such that the location an individual physically touches is different from the location he or she mentally selected).

Schizophrenia has been found to have a genetic link, but supplies only a predisposition and requires environmental factors to be present to develop into the disorder (Wray & Gottesman, 2012). Some traits have been found to be more common in schizophrenic individuals and their family members, suggesting that the traits are genetically linked, but while some traits are beneficial others are deleterious. Acar and Runco (2012) conducted a meta-analysis of 32 studies and established a strong link between schizophrenia and creativity. Diwadkar and colleagues (2011) found consistent deficits in working memory and attention in children of schizophrenic parents, again suggesting a genetic element. Because of these paired genes, individuals with the traits associated with schizophrenia may not show symptoms of the disorder but may still inherit some of the benefits and deficits associated with schizophrenia. As a result of this phenomenon, delusional ideation can be studied in the general population, and people scoring high on these measures may represent an at-risk group for developing schizophrenia (Van Os et al., 2000; Teufel et al., 2010). I therefore posit that individuals scoring high on measures of delusional ideation should show abnormal performance on tasks involving integration of cognitive and visuo-corticomotor functions relative to individuals scoring low on these measures. Additionally, we hypothesize that individuals scoring high on measures of delusional ideation should show more discrepancies between visual and kinesthetic responses to a similar task compared to individuals scoring low on these measures.

Visual memory describes the relationship between sensing and processing visual information and encoding, storing, and retrieving that information. As the number of objects that must be remembered increases, recall for visual objects becomes less accurate, as expected (Myers, 2013). Additionally, the number of pieces of information about each object (size, position, color, etc.) also plays a role in visual memory such that the integration of more characteristics of an object results in less accurate recollection (Palmer et al., 2015). Engle, Tuholski, Laughlin, and Conway (1999) demonstrated that visual working memory is an important element of fluid intelligence. A follow up study by Engle (2002) also showed that auditory working memory relates to performance on the dichotic listening task in which participants must repeat words heard in one ear while ignoring words hear in the other ear. Significantly fewer participants with high working memory ability heard their name in the ignored words than did participants with low working memory ability, indicating that those with low working memory spans are less capable of blocking distractions.

Bayesian reasoning is a process based on statistics by which the probability of an event can be predicted more accurately as more information is made available. It has been shown that stronger spatial reasoning ability is indicative of more accurate performance on Bayesian reasoning tasks so long as the information was provided as text or as a visual (but not both). This phenomenon indicates that text and visual processing may use similar neural pathways, resulting in interference when used simultaneously (Ottley et al., 2016). Additionally, there is evidence that both visual perceptual and memory tasks utilize similar pathways, shown by creating a color bias for smaller and larger center circles in an Ebbinghaus illusion task which then impacts responses in a neutral task of the same type (Rey, Riou, & Versace, 2014).

Often times when visual memory systems are impaired, other disorders or diseases may present themselves. Visual memory deficits are highly comorbid with diagnoses of schizophrenia (Rabinowitz et al., 1996; Skelley et al., 2008), and may be exacerbated with increased severity of delusional ideation (Lysaker et al., 2003). Because schizotypal behaviors exist on a spectrum and are present in members of the general population, it can be expected that individuals who score high on schizotypal characteristics represent an at-risk population. As a result, testing for visual memory deficits may act as a way to identify individuals who carry a genetic predisposition for schizophrenia. Visual short term memory deficits have also been found in carriers of familial Alzheimer's disease, along with an impaired ability to bind object location and object identity in asymptomatic gene carriers for the disease (Liang et al., 2016). Additionally, it has been shown that visual memory systems are also impaired in individuals with REM sleep behavior disorder (Rolinski et al., 2016) and Parkinson's disease (Berg et al., 2012). Because visual memory deficits are associated with a variety of disorders and diseases, multiple measures allow for more accurate risk assessment.

One particular system that relies heavily on visual memory is the approximate number system (ANS). ANS is the mechanism used to quickly form representations of the absolute value of stimuli, such as dots or sequences of tones. Adults are able to form a mental representation of the approximate number of units observed despite noise (extraneous information such as color, shape, or tone), and this is an entirely nonverbal representation (Cordes, Gelman, Gallistel, & Whalen, 2001). ANS aptitude shows how well someone can estimate which of two groups contains more items (Clayton, Gilmore, & Inglis, 2015). The online Panamath.org task is an established measure of ANS aptitude in which participants are briefly shown a display of dots in varying quantities, sizes, colors, and positions and are asked to report which color showed more dots. The quantity of dots by color is the important element, and the size and position of the dots represent extraneous information (noise). As the ratio nears 1:1, it becomes more difficult to tell which color has the larger quantity and noise has a larger effect on the mental representation of quantity (Panamath.org, 2011; Ross, 2003). While this task has not specifically been examined in schizophrenia populations, we have preliminary data suggesting it may relate to aspects of probabilistic reasoning, a mental faculty that is also impaired in schizophrenia (O'Hara, Turbett, & Feigenson, in preparation). ANS aptitude should also relate to accuracy on visual and kinesthetic response tasks as these tasks all rely on similar mental functions to remember specific aspects of stimuli when given excess information. Reliability between the ANS task and the kinesthetic and visual centroid response tasks should be high.

The present research aims to investigate differences in visual working memory accuracy, the accuracy of a kinesthetic representation of visual memory, and ANS aptitude, all in relation to measures of delusional ideation. Ultimately, this could lead to better diagnostic and treatment paradigms for such individuals. I hypothesize that ANS aptitude should relate to accuracy on the visual and kinesthetic centroid response tasks as these tasks all rely on similar mental functions to identify and remember specific aspects of stimuli when given excess information. As a result, the visual and kinesthetic centroid response tasks may also be able to identify at-risk populations. Approximate number discrimination has been shown to be related to math abilities such as symbolic math ability and formula math in children (Odic, Lisboa, Eisinger, Olivera, Maiche, & Halberda, 2016). Additionally, ANS has been established as a relatively strong predictor of math ability and a relationship has been shown between ANS aptitude and future performance on mathematic tasks (Libertus, Feigenson, & Halberda, 2013). Numeric problem solving involves common neural pathways for different mathematical operations, and these pathways are more developed in adults than in children (Chang, Rosenberg-Lee, Metcalfe, Chen, & Menon, 2015). Combined, this evidence demonstrates that a relationship between ANS and the centroid response tasks could provide a new method of predicting future math ability and related concepts in school children. Reliability between the visual and kinesthetic centroid response tasks should be high. Any significant discrepancies could potentially contribute to understanding how visually based responses differ from touch based responses using a biological prediction mechanism that may be disrupted in individuals afflicted with certain mental disorders, such as schizophrenia.

Methods

Participants & Materials

Participants were 38 adults ranging from 18-25 years of age (81.6% female, 15.8% male, 2.6% other, M_{age} = 19.66 years, SD_{age} = 1.564). Participants were 81.6% Albright College students enrolled in a psychology course who participated for extra credit at the discretion of the professor and 18.4% Albright College students who did not receive any kind of compensation. All participants gave informed consent and were debriefed after the experiment was completed.

Data for the visual centroid response task was recorded using a Tobii T60 eye tracker. The resolution used was 1280 x 960 pixels and participants sat a distance of 60 centimeters away from the screen. A printed copy of the Peters Delusional Inventory (PDI) was used to collect responses for each participant, along with an electronic version of the Cognitive Failure Questionnaire (CFQ), the General Conspiracy Beliefs Inventory (GCBI), and the Magical Ideation Scale (MIS) via Survey Monkey.

Shapes for the visual working memory centroid response task (VWM-CRT) were developed by forming convex polygon shapes placed in a coordinate plane (Appendix A). Shapes differed on both the number of dots used to form the outline (from here on referred to as density; 8, 12, 16) and the type of outline presented (from here on referred to as form; full outline, dots, Gabor patches). The centroid coordinate of each shape was then calculated by using the following formula: centroid = (average X, average Y); in which the average X was the average X coordinate value of each point used to outline the shape and the average Y was the average Y coordinate value of each point used to outline the shape.

Procedure

The current study was conducted in person in a laboratory setting. The order of the VWM-CRT, the Panamath.org task, and the inventories was counterbalanced in order to eliminate any confounding order effects on performance or responses. Participants filled out a demographic form which requested information about age, gender, race, and dominant handedness following the completion of the electronic surveys. During each of these tasks, the researcher stayed in the room but sat away from participants to reduce performance pressure. Following the previously mentioned tasks, participants were debriefed and given information about the true nature of the study as well as experimenter and health center contact information.

Centroid location accuracy was measured using the novel eye tracker VWM-CRT task which opened with instructions about how the task runs, informing participants that each trial would show either an array of dots representing a shape or an outline of a shape, followed by a blank screen which would record their responses (Figure 1). Participants were instructed to stare at the location where the center of the shape previously shown was. Participants were shown a sample image with the centroid displayed until they chose to proceed. Three example trials were also displayed using stimuli with the centroid shown. Next 324 experimental trials were conducted with two breaks during which participants were allowed to rest their eyes for as long as they wished. Mixed in with the experimental trials, 36 control trials with the centroid shown were also included. Due to software limitations, all participants saw stimuli in the same order but no two identical density x form combinations were displayed in a row.

ANS aptitude was measured using the 10-minute version of the online Panamath.org task. In this task, yellow and blue dots of varying quantity, size, and position were flashed on the screen for 600 milliseconds. The participant was then asked determine whether there were more yellow or more blue dots shown by selecting "y" or "b" on a keyboard, respectively. From this task, both a Weber's fraction score (w) and a reaction time were reported.

Beliefs and behaviors associated with delusional ideation were measuring using four inventories: the 21 item PDI with three subcategories (Appendix B), the 25 item CFQ (Appendix C), the 16 item GCBI (Appendix D), and the 32 item MIS (Appendix E). Participants were given all inventories at once and could complete them in any order.

Results

Preliminary Calculations & Analyses

All questionnaires were scored according to their instructions to obtain a total score as well as subsection scores of distress, persistence, and belief for the PDI. A positive response on the PDI required a distress, persistence, and belief rating for any question answered “yes”; these ratings were summed by category. The category totals were then added together to give a total PDI score. The CFQ was scored by finding the sum of all ratings, as was the GCBI. MIS socre was obtained by following a true/false endorsement key such that endorsement added 1 point to the total score. The total number of check questions across all inventories was calculated to eliminate participants who incorrectly answered more than one of the three check questions; no participants met these exclusion criteria.

In order to split participants into high and low delusion ideation group, z-scores were calculated for each questionnaire then each participant’s z-scores were averaged. Frequency statistics revealed that 50% of participants had an average z-score of -0.24 or lower while the other 50% of participants had an average z-score of -0.11 or higher, thus creating a low delusional ideation group from average z-score range -1.38 to -0.24 and a high delusional ideation group from average z-score range -0.11 to 2.08.

Outliers were eliminated from individual trials of the VWM-CRT by removing values greater than 2.5 standard deviations above the mean for each trial. VMW-CRT responses from two participants were eliminated altogether as a result of more than 50% of individual trials meeting outlier status (to the point where most of the eliminated trials showed responses in a quadrant of the screen where the stimulus was not shown). VWM-CRT responses from one additional participant were eliminated due to an eye condition that did not allow the eye tracker to make reliable measurements. In order to create a single accuracy value per condition, mean accuracy was computed for each of the following categories of stimuli on the VWM-CRT: 8-

point outline, 8-point dots, 8-point Gabor patches, 12-point outline, 12-point dots, 12-point Gabor patches, 16-point outline, 16-point dots, and 16-point Gabor patches.

Main Analyses

Analyses focused on accuracy on the VWM-CRT, performance and reaction time on the Panamath task, and delusional ideation score as calculated above. In order to examine the relationship between density and form on the VWM-CRT, a 3 (density: 8, 12, or 16 points) X 3 (form: outline, dot, or Gabor patch) repeated measures ANOVA was conducted using distance from response to true centroid in degrees of visual angle (VWM-CRT accuracy) as the dependent variable. Inconsistent with the hypothesis, there was no significant main effect of density such that there were no differences in accuracy across the three densities, $F(2,34) = 0.375$, *ns,* and no significant main effect of form such that there were no differences in accuracy across the three forms, $F(2,34) = 0.170$, *ns* (See Table 1 for all means and standard deviations; the shapes averaged radii of 8.41 degrees of visual angle such that 4.20 degrees would be 50% off). There was also no significant interaction between density and form, $F(4,68) = 1.502$, *ns*.

In order to examine the relationship between density and form on the VWM-CRT and the delusional ideation questionnaire scores, a 3 (density: 8, 12, or 16 points) X 3 (form: outline, dot, or Gabor patch) X 2 (delusional ideation score: high or low) mixed model ANOVA was conducted using distance from response to true centroid in degrees of visual angle (VWM-CRT accuracy) as the dependent variable. Inconsistent with the hypothesis, there was no significant main effect of density such that there were no differences in accuracy across the three densities, $F(2,30) = 1.007$, *ns,* and no significant main effect of form such that there were no differences in accuracy across the three forms, $F(2,30) = 0.638$, *ns*. There was a marginally significant interaction between density and form, $F(4,60) = 2.128$, $p < .100$. Inconsistent with the hypothesis that individuals who scored higher on the delusional ideation questionnaires would perform more poorly on the VWM-CRT, there was no significant main effect of delusional ideation score, $F(1,15) = 0.543$, *ns*. There was also no significant interaction between delusional ideation score and density, $F(2,30) = 2.104$, *ns*, or delusional ideation score and form, $F(2,30) = 2.120$, *ns*. There was a marginally significant interaction between delusional ideation score, density, and form, $F(4,60) = 2.110$, $p < .100$.

A Pearson's correlation was run between Panamath w score, Panamath reaction time, accuracy on each density x form combination of the VWM-CRT, and average delusional ideation z-score (See Table 2 for all correlation coefficients and significance values). As expected, Panamath w score and reaction time were significantly negatively correlated such that better performance indicates slower reaction time, $r = -.512$, $n = 37$, $p = .001$. Inconsistent with the hypothesis, average delusional ideation score did not correlate with any other measures. All VWM-CRT accuracy scores correlated with each other, $r \geq .482$, $n = 18$, $p \leq .043$, with the exception of 8 dot and 16 outline, and 8 dot and 8 Gabor patch which were not significant. Completely excluding the 8 dot condition, all conditions are strongly correlated, $r \geq .717$, $n = 18$, $p \leq .001$.

Discussion

The purpose of this study was to determine if differences in visual working memory accuracy, ANS aptitude, and measures of delusional ideation are related as a means to improve diagnostic and treatment paradigms for individuals in the at-risk population for schizophrenia. As stated previously, it was expected that reliability between the ANS task and the VWM-CRT should be high. The results do not support this prediction, as there was no significant correlation between Panamath performance or reaction time and any conditions of the VWM-CRT. Instead, it appears that performance on the two tasks are unrelated. It was also expected that higher scores on the established measures of delusional ideation would correspond to poorer performance on the VMW-CRT, however, the results do not support this prediction, instead showing no relationship between the two.

Limitations of the current study include visual acuity differences, VWM-CRT trial order, and sample size. While most people have normal or corrected to normal vision, visual acuity may vary across individuals. In order to correct for individual differences in vision, a simple visual acuity test could be administered using the Snellen chart. Participants whose vision does not meet 20/20 standards could be given adjustable lenses and tested until vision reaches 20/20, or as close as the corrective technology allows for. This may result in more reliable data for both the Panamath task and the VWM-CRT. Because of the current eye tracker software, the VWM-CRT was unable to be counterbalanced properly. Despite finding no ordering effects in the current study, presenting trials in a different and randomized order each time would ensure that there continue to be no ordering effects for future use of the task. The overall study can also be improved by using a larger sample size; splitting participants into high and low delusional ideation results in two groups of 19 participants in the ANOVA analysis, giving the test low power. Additionally, low sample size is especially underpowered for detecting correlations (Moinester & Gottfried, 2014). By increasing the total number of participants these divided groups can remain larger and thus increase the power of the test. This method can also allow participants to be split into three levels of overall delusional ideation, low, medium, and high, to keep the groups from ranging too large in score. Including participants from a clinical population may also allow for more variation in delusional ideation scores, which though different may be somewhat constricted in the general population.

In addition to the methodological corrections listed above, a kinesthetic representation of the ability tested on the VWM-CRT could also be measured in the future with stimuli generated using the same requirements, this time presented through a touch-receptive screen. The instructions for this task would be identical to the VWM-CRT, with one exception: instead of staring at the centroid, participants would be instructed to touch the location they believe represents the centroid. Should the kinesthetic sense be perfectly synchronized with visual system, we would hypothosize that these two locations should be highly correlated. Discrepancies between the VWM-CRT and its kinesthetic touch-based application would suggest discordant functioning of or communication between the two systems. Because the touch-based task would measure an individual's quick and inexact approximation of information, responses on the Panamath task may also be related to the kinesthetic centroid response task such that poor performance on one may indicate poor performance on the other.

Future studies should also take into consideration two changes to the VWM-CRT: including extraneous noise in the stimuli and creating catch trials for shapes that also have experimental trials. Adding noise may give useful information about how much noise affects performance on VWM-CRT, which would be helpful when applied to the kinesthetic version of the task as well. This could include using dots of different colors to outline the shapes and asking about the centroid of only one color dots or making the dots different sizes and instructing participants to treat the center of the dot as its coordinate point. Through introducing extra noise to the task, performance would likely show more varied scores that may correlate with the other measures in the current study. Currently the task uses a different shape for catch trials than the shapes used for experimental trials. By creating shapes that can be used for both catch trials and experimental trials, future analyses will include performance comparisons drawn from the same shapes. By including all forms, including catch trials, of each shape a difference correlation could be made such that the difference between a catch trial and its corresponding dot outline may relate to the difference between its solid outline and dot outline. The average differences would also be able to take into account circumference of the shape, which the current analysis has yet to control for.

This experiment did not find a relationship between the novel VWM-CRT and ANS aptitude and delusional ideation inventories, the established measures associated with schizophrenia. This means that the VWM-CRT will likely not be a reliable tool for identifying at-risk individuals as predicted, at least not in the current form. As far as the VWM-CRT is concerned, the high correlations between conditions do indicate that people perform consistently on the task, suggesting that the kinesthetic version of the task may have a similar consistency of performance and thus still be a valid comparison to the VWM-CRT.

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Table 1

Means and Standard Deviations for Accuracy on VWM-CRT in Degrees of Visual Angle by Density and Form.

Form	Density		
	8	12	16
		Mean(*SD*)	
Outline	4.33 (4.32)	3.63 (3.05)	3.24 (3.26)
Dot	3.25 (3.60)	4.04 (3.67)	3.35 (3.34)
Gabor Patch	3.85 (3.55)	3.46 (2.96)	3.67 (2.96)

Table 2

Pearson's Correlation between Panamath w Score, Panamath Reaction Time, Accuracy on each Density x Form Condition of the VWM-CRT, and Average Delusional Ideation z-score

r (p)	Pana RT	Outline8	Dot8	Gabor8	Outline12	Dot12	Gabor12	Outline16	Dot16	Gabor16	Qs
Pana w	-0.512 (<.001)**	.409 (.103)	.109 (.676)	.386 (.126)	.252 (.329)	.257 (.319)	.125 (.632)	.009 (.941)	-.122 (.668)	-.059 0.822	0.25 (.136)
Pana RT	1	.207 (.424)	-.092 (.726)	-.237 (.289)	-.216 (.405)	-.114 (.662)	-.283 (.270)	-.0003 (.999)	.161 (.537)	.295 (.251)	.054 (.750)
Outline8		1	.495 (.037)*	.348 (.157)	.482 (.043)*	.503 (.033)*	.533 (.023)*	.385 (.114)	.489 (.040)*	.646 (.004)**	.376 (.124)
Dot8			1	.798* (<.001)**	.830 (<.001)**	.815 (<.001)**	.885 (<.001)**	.905 (<.001)**	.924 (<.001)**	.846 (<.001)**	-.022 (.930)
Gabor8				1	.753 (<.001)**	.805 (<.001)**	.774 (<.001)**	.857 (<.001)**	.831 (<.001)**	.717 (<.001)**	.019 (.939)
Outline12					1	.821 (<.001)**	.840 (<.001)**	.784 (<.001)**	.781 (<.001)**	.823 (<.001)**	.089 (.726)
Dot12						1	.909 (<.001)**	.876 (<.001)**	.888 (<.001)**	.864 (<.001)**	.004 (.988)
Gabor12							1	.920 (<.001)**	.937 (<.001)**	.896 (<.001)**	-.085 (.736)
Outline16								1	.980 (<.001)**	.870 (<.001)**	-.125 (.621)
Dot16									1	.920 (<.001)**	-.089 (.725)
Gabor16										1	-.069 (.786)

Note. * Correlation is significant at the .05 level, ** Correlation is significant at the .01 level (2-tailed), Pana = Panamath.org task, w = Weber score, RT = Reaction time, Qs = Average z-score for inventories.

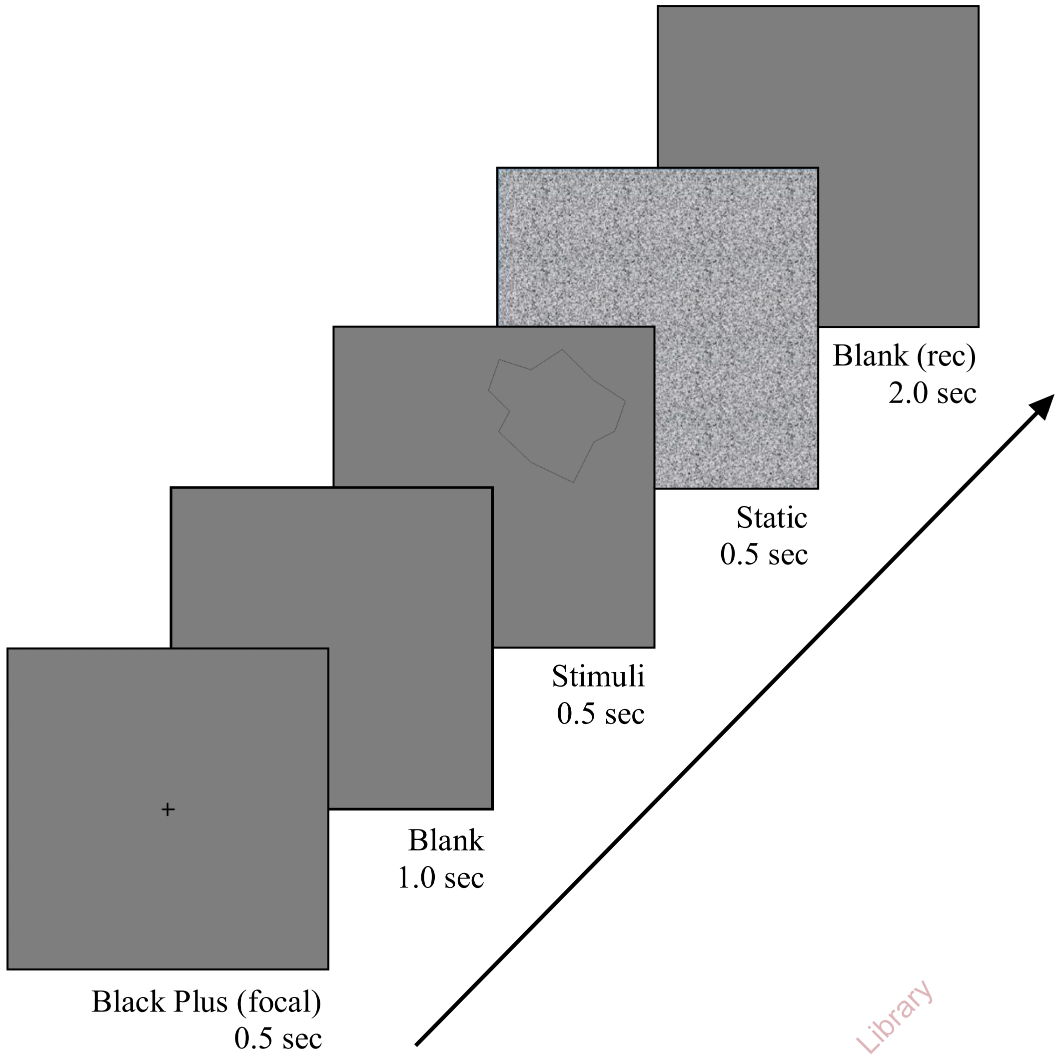
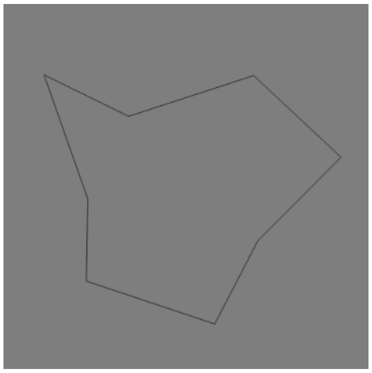
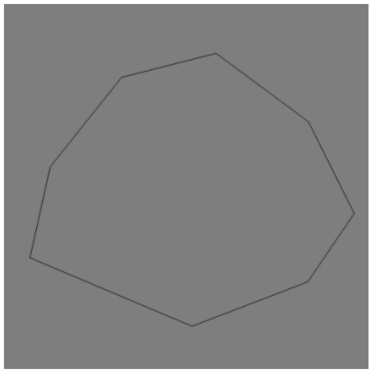


Figure 1. Presentation order and duration for visual working memory centroid response task.

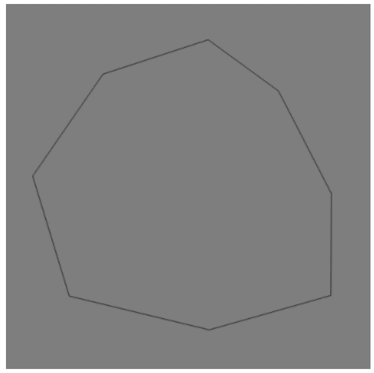
Appendix A – Visual Centroid Response Task Shapes



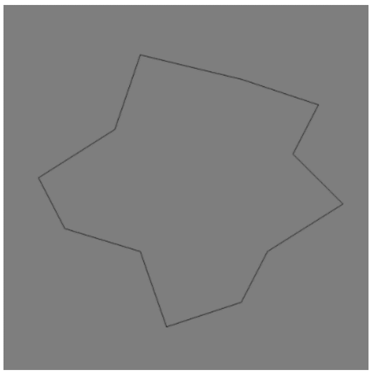
8a outline



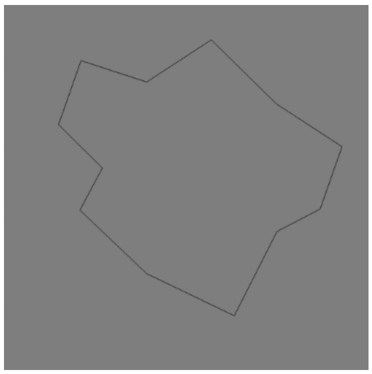
8b outline



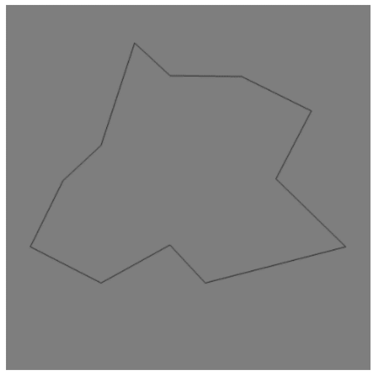
8c outline



12a outline



12b outline



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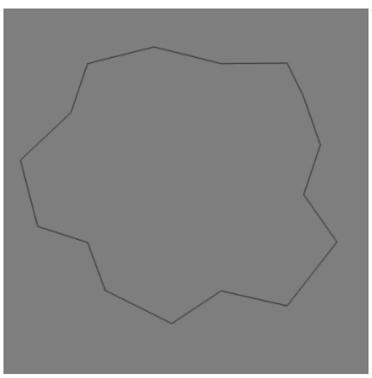
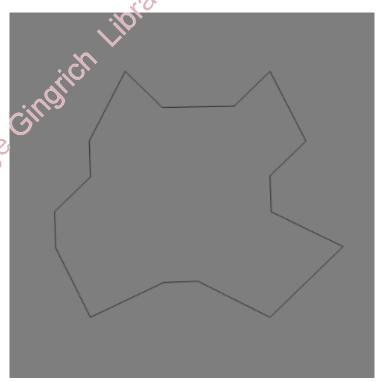
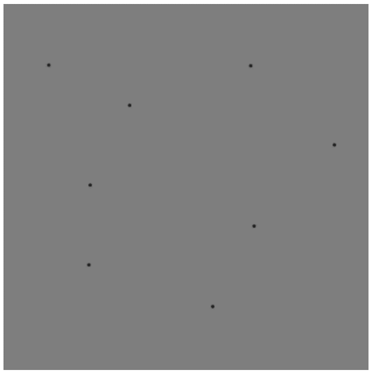


16a outline

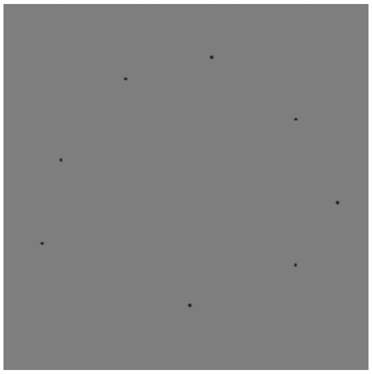
16b outline



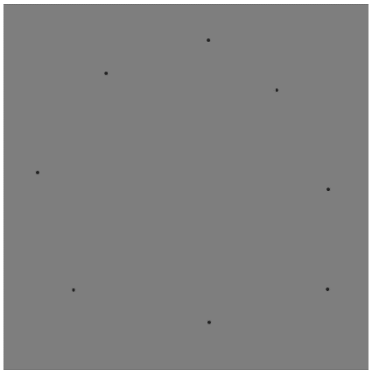
16c outline



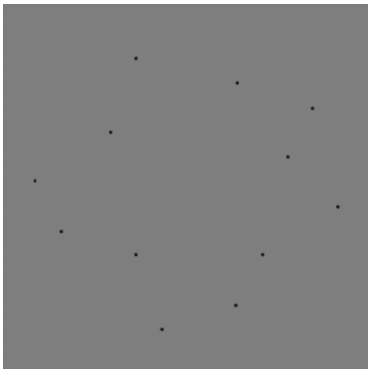
8a dot



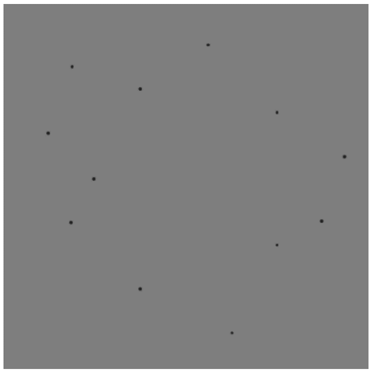
8b dot



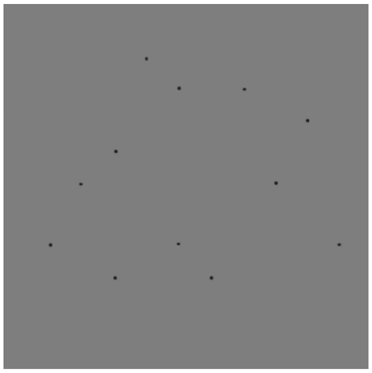
8c dot



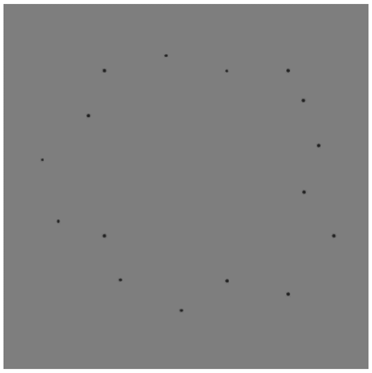
12a dot



12b dot

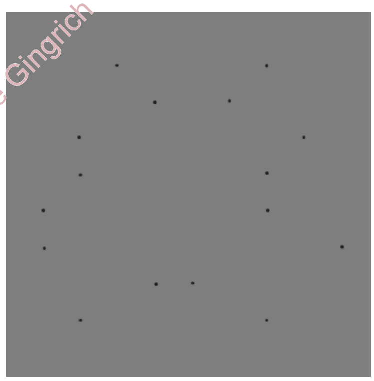


12c dot



16a dot

16b dot



16c dot


8a Gabor

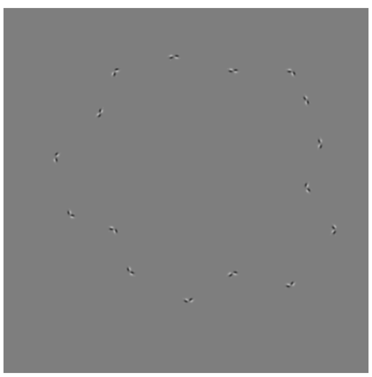

8b Gabor

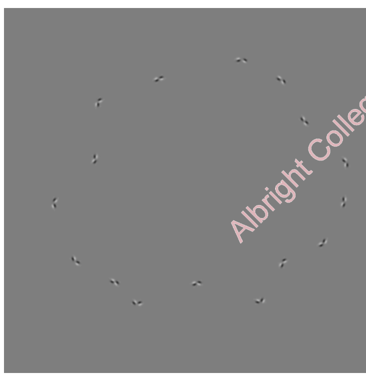

8c Gabor


12a Gabor

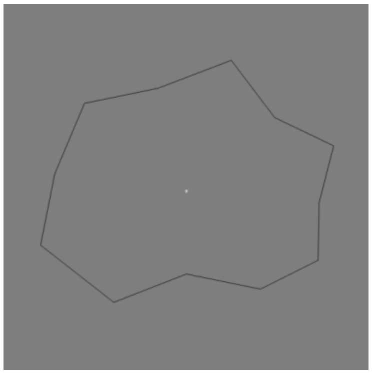

12b Gabor


12c Gabor

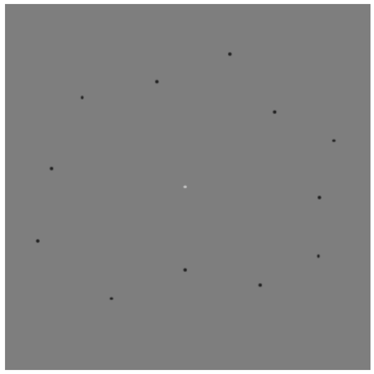

16a Gabor


16b Gabor

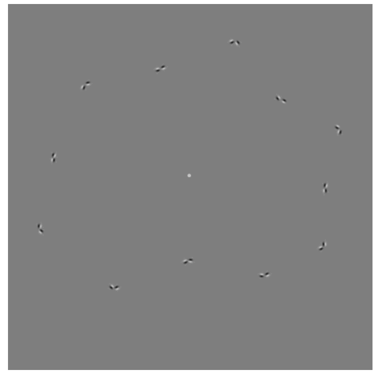

16c Gabor



12d control outline



12d control dot



12d control Gabor

Appendix B – Peter's Delusional Inventory (PDI)

The following questions are each answered on three levels each using a 5-point Likert scale for all "yes" responses; distress (1 = not at all distressing, 5 = very distressing), preoccupation (1 = hardly ever think about it, 5 = think about it all the time), and conviction (1 = don't believe it's true, 5 = believe it is absolutely true) after being given the following directions: "This questionnaire is designed to measure beliefs and vivid mental experiences. We believe that they are much more common than has previously been supposed, and that most people have had some such experiences during their lives. Please answer the following questions as honestly as you can. There are no right or wrong answers, and there are no trick questions."

1. Do you ever feel as if people seem to drop hints about you or say things with a double meaning?
2. Do you ever feel as if things in magazines or on TV were written especially for you?
3. Do you ever feel as if some people are not what they seem to be?
4. Do you ever feel as if you are being persecuted in some way?
5. Do you ever feel as if there is a conspiracy against you?
6. Do you ever feel as if you are, or destined to be someone very important?
7. Do you ever feel that you are a very special or unusual person?
8. Do you ever feel that you are especially close to God?
9. Do you ever think that people can communicate telepathically?
10. Do you ever feel as if electrical devices such as computers can influence the way you think?
11. Do you ever feel as if you have been chosen by God in some way?
12. Do you believe in the power of witchcraft, voodoo, or the occult?
13. Are you often worried that your partner may be unfaithful?
14. Do you ever feel that you have sinned more than the average person?
15. Do you ever feel that people look at you oddly because of your appearance?
16. Do you ever feel as if you had no thoughts in your head at all?
17. Do you ever feel as if the world is about to end?
18. Do your thoughts ever feel alien to you in some way?

19. Have your thoughts ever been so vivid that you were worried other people would hear them?
20. Do you ever feel as if your own thoughts were being echoed back to you?
21. Do you ever feel as if you are a robot or zombie without a will of your own?

Appendix C – Cognitive Failures Questionnaire (CFQ)

The following questions are answered on a 5-point Likert scale from 0 (never) to 4 (very often) after being given the following instructions: "The following questions are about minor mistakes which everyone makes from time to time, but some of which happen more often that others. We want to know how often these things have happened to you in the last six months."

1. Do you read something and find you haven't been thinking about it and must read it again?
2. Do you find you forget why you went from one part of the house to the other?
3. Do you fail to notice signposts on the road?
4. Do you find you confuse right and left when giving directions?
5. Do you bump into people?
6. Do you find you forget whether you've turned off a light or a fire or locked the door?
7. Do you fail to listen to people's names when you are meeting them?
8. Do you say something and realize afterwards that it might be taken as insulting?
9. Do you fail to hear people speaking to you when you are doing something else?
10. Do you lose your temper and regret it?
11. Do you leave important letters unanswered for days?
12. Do you find you forget which way to turn on a road you know well but rarely use?
13. Do you fail to see what you want in a supermarket (although it's there)?
14. Do you find yourself suddenly wondering whether you've used a word correctly?
15. Do you have trouble making up your mind?
16. Do you find you forget appointments?
17. Do you forget where you put something like a newspaper or a book?
18. Do you find you accidentally throw away the thing you want and keep what you meant to throw away -- as in the example of throwing away the matchbox and putting the used match in your pocket?
19. Do you daydream when you ought to be listening to something?
20. Do you find you forget people's names?\
21. Do you start doing one thing at home and get distracted into doing something else (unintentionally)?

22. Do you find you can't quite remember something although it's "on the tip of your tongue"?
23. Do you find you forget what you came to the shops to buy?
24. Do you drop things?
25. Do you find you can't think of anything to say?

Appendix D – General Conspiracy Beliefs Inventory (GCBI)

The following statements are rated on a 5-point Likert scale from 1 (definitely not true) to 5 (definitely true) after being given the following instructions: “There is often debate about whether or not the public is told the whole truth about various important issues. This brief survey is designed to assess your beliefs about some of these subjects.”

1. The government is involved in the murder of innocent citizens and/or well-known public figures, and keeps this a secret.
2. The power held by heads of state is second to that of small unknown groups who really control world politics.
3. For this question, please select '2'.
4. Secret organizations communicate with extraterrestrials, but keep this fact from the public.
5. The spread of certain viruses and/or diseases is the result of the deliberate, concealed efforts of some organization.
6. Groups of scientists manipulate, fabricate, or suppress evidence in order to deceive the public.
7. The government permits or perpetrates acts of terrorism on its own soil, disguising its involvement.
8. A small, secret group of people is responsible for making all major world decisions, such as going to war.
9. Evidence of alien contact is being concealed from the public.
10. Technology with mind-control capacities is used on people without their knowledge.
11. New and advanced technology which would harm current industry is being suppressed.
12. The government uses people as patsies to hide its involvement in criminal activity.
13. Certain significant events have been the result of the activity of a small group who secretly manipulate world events.
14. Some UFO sightings and rumors are planned or staged in order to distract the public from real alien contact.
15. Experiments involving new drugs or technologies are routinely carried out on the public without their knowledge or consent.

16. A lot of important information is deliberately concealed from the public out of self-interest.

Appendix E – Magical Ideation Scale (MIS)

The following statements are labeled as true or false after being given the following instructions: "Please answer the following questions as honestly and accurately as you can."

1. Some people can make me aware of them just by thinking about me.
2. I have had the momentary feeling that I might not be human.
3. I have sometimes been fearful of stepping on sidewalk cracks.
4. I think I could learn to read other's minds if I wanted to.
5. Horoscopes are right to often for it to be coincidence.
6. Things sometimes seem to be in different places when I get home, even though no one has been there.
7. Numbers like 13 and 7 have no special powers.
8. I have occasionally had the silly feeling that a TV or radio broadcaster knew I was listening to him.
9. I have worried that people on other planets may be influencing what happens on earth.
10. The government refuses to tell us the truth about flying saucers.
11. I have felt that there were messages for me in the way things were arranged, like in a store window.
12. I have never doubted that my dreams are the products of my own mind.
13. Good luck charms don't work.
14. I have noticed sounds on my records that are not there at other times.
15. The hand motions that strangers make seem to influence me at times.
16. I almost never dream about things before they happen.
17. I have had the momentary feeling that someone's place has been taken by a look-alike.
18. It is not possible to harm others merely by thinking bad thoughts about them.
19. I have sometimes sensed and evil presence around me, although I could not see it.
20. I sometimes have a feeling of gaining or losing energy when certain people look at me or touch me.
21. I have sometimes had the passing thought that strangers are in love with me.
22. I have never had the feeling that certain thoughts of mine really belonged to someone else.
23. When introduced to strangers, I rarely wonder whether I have known them before.

24. If reincarnation were true, it would explain some unusual experiences I have had.
25. People often behave so strangely that one wonders if they are part of an experiment.
26. At certain times I perform certain little rituals to ward off negative influences.
27. I have felt that I might cause something to happen just by thinking too much about it.
28. I have wondered whether the spirits of the dead can influence the living.
29. At times I have felt that a professor's lecture was meant especially for me.
30. I have sometimes felt that strangers were reading my mind.