Perceptual Organization in Parkinson's Disease:
A Behavioral Investigation of Basal Ganglia Dysfunction

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ABSTRACT

The basal ganglia provide a major neural system through which the cortex affects behavior. Most notable among these effects are those related to the voluntary control of movement as seen in neurodegenerative disorders like Parkinson's disease (PD). Well known tests of visual perception in PD "explicitly" measure object recognition (a high-level visual process) but "implicitly" rely on intact mid-level visual processes like grouping and figure-ground segmentation to structure the image. Hence, exploring the importance of the basal ganglia in perceptual organization (PO) abilities by examining the specific impairments incurred with the damage of such a vital structure is imperative. Therefore, this study attempted to investigate PD performance in tasks in computerized classic gestalt perception experiments with the aim of identifying any mid-level visuo-perceptual deficits. Differences were observed in the grouping by proximity dot counting task but not in other tasks that involved figure-ground segregation, part detection in embedded contexts or shape discrimination.

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GENERAL AUDIENCE ABSTRACT

Damage to the basal ganglia, a group of structures in the subcortical part of the brain (below the cerebral cortex), has long been associated primarily with Parkinson's Disease (PD), a neurological disorder that manifests with symptoms like muscle rigidity and tremors. While several key visual and perceptual problems have also been connected to this area, very few studies have tried to describe the mechanisms by which PD functionally alters their ability to perceive the visual world. Hence, this study attempted to investigate PD performance in computerized classic perception experiments with the aim of exploring mechanisms that organize incoming visual information to structure the image called perceptual organization (PO). Differences were observed in tasks that tested their ability to group "dots" when they are varied by proximity to each other but not in other tasks that involved their ability to segregate figures from the ground, detect parts of shapes in embedded contexts or discriminate between shapes.

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Introduction

The most well-known symptoms of basal ganglia pathologies are degradation of motor control and navigational abilities. Therefore, the contributions of the basal ganglia structures were initially thought to be limited to movement. Converging evidence from behavioral, lesion and neuroimaging studies in humans and animals have challenged this notion and reinforced the idea that they are involved in a range of cognitive functions like procedural memory, habit and skill learning, perception and language.

General working of the striatal network

The striatum, within the cortico-basal circuit, is mostly made up of projection neurons. They are mostly GABAergic and thus tonic during periods of rest. Most projections between the regions of the BG are inhibitory. The main function of the basal ganglia is to modulate these inhibitory signals. (Stocco et al., 2011) Direct and indirect pathways connect the striatum to the output regions like substantia nigra pars reticulata (SNr) and the globus pallidus internal (GPi) by sending projections either directly from the striatum to the output regions (Striatoniagral (SN)) or redirect information through the globus pallidus external (GPe) and subthalamic nucleus (STN) regions before reaching the output regions (Striatopallidal (SP)). All projections from the striatum to either cortex or the thalamus and back are said to be organized topographically so that regions of the cortex project only to corresponding regions in the basal ganglia and so on. Several projections to and from the thalamo-cortical circuit converge on sites within the basal ganglia and hence make their connections and functional significance more dynamic. (Bolam et al, 2000; Stocco et al., 2010)

Basal ganglia dysfunction: Parkinson's Disease

Basal ganglia disorders are common clinical conditions characterized by specific motor dysfunction and associated cognitive and behavioral problems. The underlying impairment primarily relates to alterations in the cortico-striato-thalamo-cortical pathways, which can be related to both neurodegenerative disorders like Parkinson disease (PD) as well as several other neurodevelopmental processes. (Cavanna & Nani, 2013) Significant cognitive and behavioral symptoms associated with depression, dementia, psychosis, impaired executive function, apathy, irritability, aggression and personality changes are observed in other BG disorders like Huntington's disease as well. (Pidgeon & Rickards, 2013)

Visual information processing and the basal ganglia

Electrophysiological recordings of single units in the caudate were studied to examine the sensitivity of the neurons to spatial and temporal properties of stimuli. The caudate neurons from the study demonstrated a preference for very low spatial and high temporal information. (Nagy et al., 2008) Since low spatial frequency information is said to be sufficient for activating a relevant set of stimulus interpretations, findings from the study and the supporting literature suggest a role for these units as finely tuned "spatiotemporal filters". High spatial frequencies (HFs) tend to generate more detail and sharp changes within an image. Hence, they are generally associated with "configural processing" of information with emphasis on the local attributes of the stimulus. Low spatial frequencies (LFs), on the other hand, represent the gestalt features of a shape and are generally associated with "holistic processing" of sensory inputs with emphasis on the global template. (Bar, 2003) However, this region has been associated with other functions as well. The caudate nucleus within the striatum is also one of the main input sites for sensory-motor

information with direct implications to the control of visually guided movement. (Hikosaka et al, 2000) Hence, the exact role of this region in visual information processing warrants further investigation.

Another aspect of basal ganglia involvement in visual processes is through projections to and from the temporal lobe. Temporal lobe involvement in visual perception is well known. The inferior temporal cortex (IFT) forms the site of higher-order visual processes which begin in V1 and continue through V2 and V4. Hence, there is considerable evidence of activity in the IFT relating to performance on visual recognition and object discrimination tasks. It is also known that areas in the temporal lobe projects to the striatum before the information reaches the frontal areas. (Ungerleider & Mishkin, 1982; Webster et al, 1993) However, the temporal region is not only a source of input to the basal ganglia, but also a target of basal ganglia output which implies that this output in some way influences holistic processing of visual information. (Middleton & Strick, 1996)

Cognition

As established earlier, the relevance of the fronto-striatal circuitry in neuropsychological impairments, especially with regard to PD is extensive. Disruption of these circuits leads to prominent executive deficits (Zgalijardic et al. 2003) in response initiation, complex problem solving as well as reinforcement and reward learning behaviors. For instance, a bilateral pallidotomy has shown several neuropsychological side effects as reported in 4 case studies reviewed by Ghika and colleagues (1999). While considerable improvement in motor functions was observed side effects such as abulia, post-operative depression, changes in personality,

behavior, and executive functions was also found indicating that the cognitive and motor pathways are more intricate than previously thought.

Neurological evidence also points to the problems with memory functions as a result of lesions in the lateral and medial PFC, posterior parietal cortex and the lateral occipital cortex. (Kawabata et al, 2002) More specifically, verbal and non-verbal recognition memory, orientation memory, as well as prospective memory deficits have been observed in people diagnosed with PD. A study by Minamoto and colleagues (2001) also established that PD patients showed a greater deficit in delayed recognition memory than immediate recall. In addition, task difficulty and disease severity has been moderate deficits in prospective memory suggesting that these deficits increase progressively with overall disease severity. (Whittington et al. 2006)

Another well-established deficit in basal ganglia patients is in learning. Performance of PD patients and healthy age-matched controls on some contextual cueing tasks indicated that cueing effect of the control group differed significantly from the experimental group. (van Asslen et al., 2009) The latter failed to benefit from a repeated context which suggests an important role for the basal ganglia in implicit contextual learning as well. This finding is further supported by the presence of a neostriatal habit learning system which leads to impairment in the formation of effective habit memories in patients with PD. (Knowlton et al., 1996)

Apart from learning and memory, attentional deficits are also a hallmark of basal ganglia disorders. In a study done by Possin et al (2008), significant attentional impairments were found related to the inhibition of return (IOR) phenomenon. PD patients as compared to healthy age-matched controls found that they were unable to return attention to a cued location once a certain amount of time had elapsed i.e. attention had moved away from that location. The authors found that this deficit was only present with cued spatial locations but not with the cued stimuli

themselves indicating that that this deficit is specialized to space-related phenomenon and not object-related.

Dementia

In PD, the proportion of demented patients is about 40%, the percentage increasing with age. (Aarsland, 2005) Comorbid Lewy-bodies pathology is the most significant correlate of dementia in PD. (Irwin, 2012). With high comorbidity, it is especially challenging to distinguish dementia of PD from other neurodegenerative disorders. One possible difference is that dementia in PD is characterized by progressive memory deficits, in the absence of aphasia, apraxia or agnosia. (Dubois et al. 1997) and associated with other major symptoms like visual hallucinations. The presence of visual hallucinations has been said to increase the risk of developing dementia making investigations into comorbid conditions very relevant to studies involving PD. (Ibarretxe-Bilbao et al. 2011) This is of interest in this area of research due to the research on visual hallucinations

Hallucinations

As proposed by Middleton & Strick (1996), damage to the basal ganglia loop along with the temporal cortex would affect visual perception. The authors went one step further and addressed possible effects on the development of visual hallucinations because of this damage. Lesions in the SNr have led to reports of visual hallucinations (Dunn et al., 1983) As stated previously, the neurons in this area usually project an inhibitory output to the thalamus indicating that lesions in this region may lead to an increase in excitatory thalamic input which could in turn induce hallucinations. fMRI studies have also found that hallucinating PD patients show

significantly greater activation in the inferior frontal gyrus and the caudate nucleus than non-hallucinating patients. (Goetz et al., 2014) Hence, there is cause to believe that certain presentations of visual hallucinations go hand in hand with damage to the basal ganglia networks. These findings further merit investigation of the role of these structures in visual information processing like perceptual organization.

Lateralization

We have already established that the temporal lobe receives output that facilitates higher-order perception. (Middleton & Strick, 1996) Other neuroimaging studies have revealed further functional dissociations of this region by finding greater activation in the right posterior temporal-parietal junction for global processing and greater left posterior temporal-parietal junction during processing of local components of an object (Dolan et al., 1997). This indicates a distinct right visual field advantage for configural processing of local elements and left visual field advantage for holistic processing of global elements (Sergent, 1982).

There is also clear evidence suggesting a functional difference between left-onset PD patients and right-onset PD patients. (Amick, Schenden, & Cronin-Golomb, 2006). Most literature on PD indicates that the symptoms appear unilaterally at first (Cronin-Golomb, 2010) indicating a clear dissociation of the two hemispheres. To fully understand the neuropsychology of PD, it is important to consider hemispheric lateralization effects and the unique circuitry that goes with it. In a previously mentioned study, examining the effects of optic flow manipulation on walking, PD patients demonstrated a clear preference for walking towards the side of the brain that had more damage. (Young et al, 2006) Furthermore, Schenden and colleagues (2009) also found lateralized effects of the parietal-basal ganglia circuit in hierarchical pattern perception (HPP) in PD patients

with right-onset motor symptoms and age-matched controls. Findings from this study indicate that side of onset of motor symptoms is directly linked to other observed deficits where left-onset PD patients demonstrated abnormal processing of global elements and right-onset PD patients' symptoms demonstrated deficits in processing of local features.

Visual Perception

The presence of selective problems in both basic perceptual and semantic visual processing of shapes at an early stage of cognitive deterioration in PD has been discussed in previous sections. fMRI studies have found that occipito-temporal regions are bound by a certain level of specificity to select categories of stimuli. For instance, faces tend to evoke a robust response in the fusiform face area (FFA), scenes in the parahippocampal region (PPA) and bodies in the extrastriate body area (EBA). (Downing et al. 2006) In a study on specific object recognition deficits in PD, findings indicated an inability of PD patients to discriminate between scrambled objects and real coherent objects. These deficits were found to be aggravated with increased cognitive deterioration. (Laatu et al., 2004) Hence, increased cognitive load and not only task manipulation may lead to impaired task performance in PD. (Cohen et al. 2010)

There have been many studies that have explored high-level visual information processing using electrophysiological studies, however clear explanation about the perceptual processes occurring before recognition is lacking. (Kida et al. 2007) Cousins et al. (2000) conducted a study that used face recognition tasks to assess performance of PD patients relative to age-matched controls. Impaired performance was found in holistic processing related to unfamiliar face recognition. No significant impairment was found in tests where configural processing tasks were used. Hence, it can be concluded that holistic processing ability is an important predictor of deficits involving

recognition memory (Whittington et al. 2006) as well as visual working memory (Voytek & Knight, 2010)

Perceptual Organization. Perceptual organization (PO) is the condensation of sensory input into meaningful mid-level categorizations. Silverstein & Keane (2011) defined it as- *"…the process by which visual information is structured into coherent patterns such as groups, contours, perceptual wholes, and object representations."* It involves information processing in a 'figure-ground' manner such that certain salient objects are actively assigned to the foreground or "figure" and other, relatively less salient information is assigned the background or "ground". A system of *dynamic grouping* is initiated where the brain constantly looks for patterns of regularities from incoming, unfamiliar inputs, thus creating new global representations. This top-down mechanism is of special importance when dealing with novel stimuli in the absence of familiar contextual cues that aid in recognition. (Watt & Phillips, 2000) Impairment in perceptual organization has been seen in several neurological disorders like Alzheimer's disease, especially those with white-matter abnormalities in the occipital lobe. (Cavana, 2013) It has also been well documented in association with Schizophrenia (Johnson et al., 2005; Giersch & Rhein, 2008; Tatemichi et al., 1994) Interesting findings have been uncovered where many studies conducted on some aspect of perceptual organization and Schizophrenia have reported a specific impairment in tasks involving unfamiliar stimuli that were presented in fragmented and non-holistic patterns. However, the studies that did not make these conclusions warrant some investigation. Low-level hierarchies of stimulus features like lines, angles, notable edges and so on form the simple geometric shapes we see every day. (For e.g., a square) These hierarchies are formed very early in life and detected early in the visual network (V1 and V2). (Phillips & Singer, 1997) More specifically, PO

impairment is characterized by the lack of or inability to detect regular patterns or cues in complex stimulus information that influence recognition. (Uhlhaas & Silverstein 2005; Silverstien & Keane, 2011) In conclusion, we tend to make sense of the environment in the way that experience tells us is the best possible pattern.

The literature reviewed above enables this study to infer on a role for the basal ganglia in mid-level visual perception that enables people with PD to be selectively impaired in mechanisms relevant to global processing. Hence, the proposed study addressed the following questions- Do PD patients have marked deficits in perceptual organization processes relevant to processing the gestalt features of a shape compared to healthy age-matched controls?

Hypotheses

Having reviewed the relevant literature, this study aimed to investigate possible deficits observed in perceptual organization in PD. Hence, the primary hypotheses revolve around the understanding that PD patients could be selectively impaired at perceptual organization tasks that involve global processing of shapes but will be relatively unimpaired on control tasks that rely on identification of local components of a target image as compared to healthy control participants. They are as follows: -

1. PD patients will show greater impairment in perceptual organization tasks (Dot counting, Fine shape discrimination, Figure-ground segmentation) than the age-matched controls.
2. PD patients will be relatively unimpaired in the Embedded Figures Task compared to age-matched controls.

Methods

Participants

The experimental group comprised of six patients with a PD diagnosis (4 Females, 2 Males). Participant age ranged from 56 to 79 years with mean age of 69.5 years. Patients were recruited from Blacksburg as well as the greater New River Valley and Roanoke areas, mainly through a local PD support group organization. All patients were on dopaminergic medication at the time of testing. Other criteria for inclusion for PD participants was having ambulatory status (outpatient) at the time of consent as well as self-report or report of caregivers for acceptable diagnosis of Parkinson's Disease. The control group comprised of six participants (5 Females, 1 Male). Ages ranged from 61 to 73 years with a mean age of 66 years. Participants were recruited from a volunteer database called the Older Adult Registry (OAR) that was generated by the Center for Gerontology at Virginia Tech. Self-reported history of neurosurgery and/or repeated head trauma were the only criteria for exclusion.

Informed Consent

Participants were provided with the consent form and a verbal overview of their rights by the experimenter. This verbal overview included their right to refuse consent and to withdraw at any time after consent is given. It also included a review of the information for contacting the experimenter or the Virginia Tech Institutional Review Board (VT-IRB) in case of problems and a review of the risks and benefits of participation. Participants were then asked to read the written consent form at their leisure and to sign if they agree. No participants expressed any distress during the experiment. In addition, a provision for the caregivers to give their written consent on behalf

of the participants, if they chose to do so. However, this provision was not utilized by any of the participants.

Procedure

Upon arrival, the experimenter provided participants with information about the various forms and pre-experimental requirements. The consent form and a demographic questionnaire followed by a psychological assessment scale were given. Once they were completed, participants were seated in a comfortable, dimly lit room in front a computer, approximately 35 cm from the screen. Instructions were provided for the first of four experimental tasks. Although two of the four tasks (Embedded Figures and Fine Shape Discrimination) adopted the same match-to-sample task design, new tasks were designed to investigate the others (Figure-ground assignment and Dot Counting) after further inquiry into the literature. Therefore, a new set of instructions were given at the end of every task.

Task design and stimulus generation for each experiment was specific to the perceptual phenomenon of interest. All tasks were developed using MATLAB (Mathworks), Psychophysics Toolbox (Version 3; Brainard, 1997) software. All experiments were run on either a Linux-based on Mac iOS-based system. Stimuli were always displayed on a 24-inch LCD Dell monitor at a size of 300 x 300 pixels (12.94^0).

Pre-Experimental Questionnaires

Participants were provided with the consent form as well as a demographic questionnaire. Subsequently the Geriatric Depression Scale (Yesavage & Sheikh,1986), a 30-question screening

tool for detecting depression in older adults, was also administered. All participants were provided with unique identification numbers for anonymity.

Visual Perception Experiments

This study investigated four facets of visuo-perceptual grouping and organizational process namely- Embedded Figure Detection, Fine Shape Discrimination, Figure-ground Segmentation and Dot Counting. Detailed descriptions of all four experiments are provided below. Task Designs for Embedded Figures and Fine Shape Discrimination were based on the Leuven Perceptual Organization Screening Test (L-POST; Torfs, Vancleef, Lafosse & Wagemans, 2014)

Embedded Figures. The Embedded Figures measures their ability to detect a simplistic "part" when it is embedded in a more complex "whole". The task was constructed using context and target shapes from the stimulus set from the Leuven Embedded Figures Test (L-EFT; de-Wit, Huygelier, Van der Hallen, Chamberlain & Wagemans, 2017) A total of 15 simple line drawings (the targets) which varied in the number of lines (3, 4, 6 and 8 lines), how symmetrical they were around their vertical axes and the closure of target shape, were chosen. (Figures 1A-1D) For each of these target shapes, three complex line shapes (embedding contexts) were presented. The contexts were also varied based on the number of target lines that continued into the target shapes. (Fig. 1E) Instructions were provided for a simple matching-to-target task. A sample set of images was generated from the stimulus set (not included in the main experiment) and was designated a practice trial. Image 1 which was considered the "target image" and was presented above three possible matches (Image 2, 3 and 4), all presented at the bottom of the screen equidistant from one another. Trials were counterbalanced so that all correct matches appeared in all three positions

equal number of times for a total of 135 trials in a randomly generated order. All participants received the same order of trials.

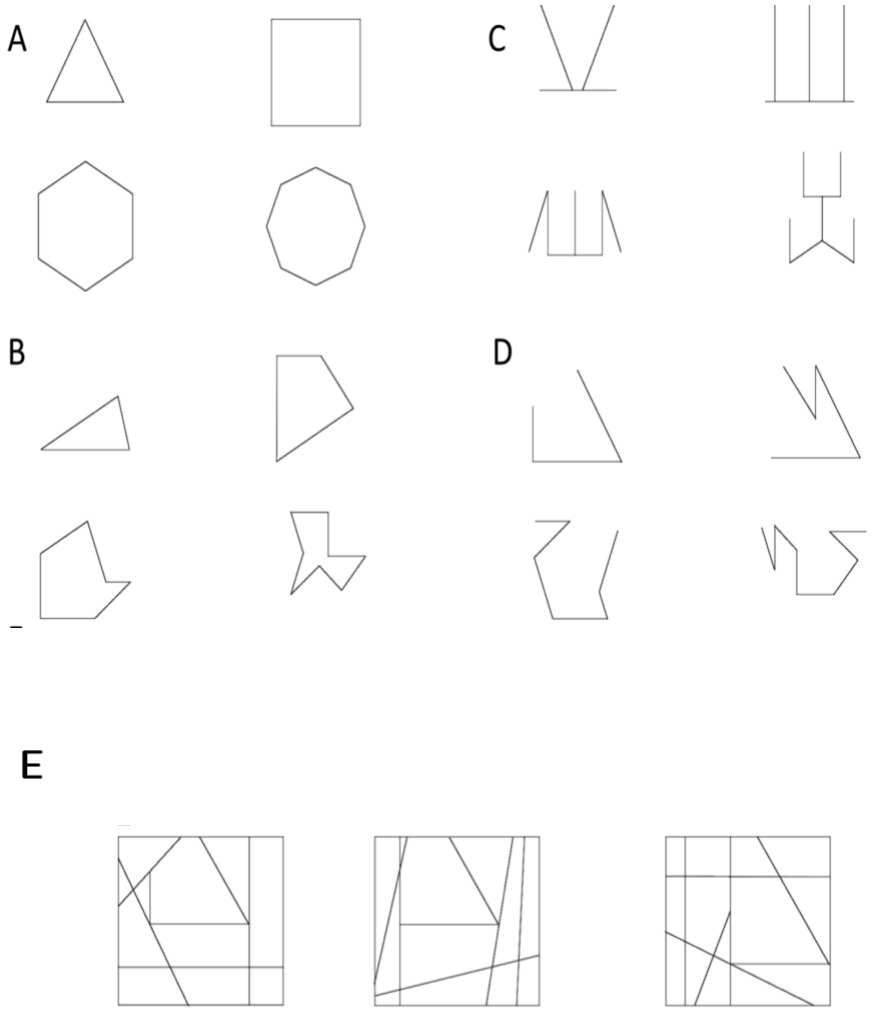
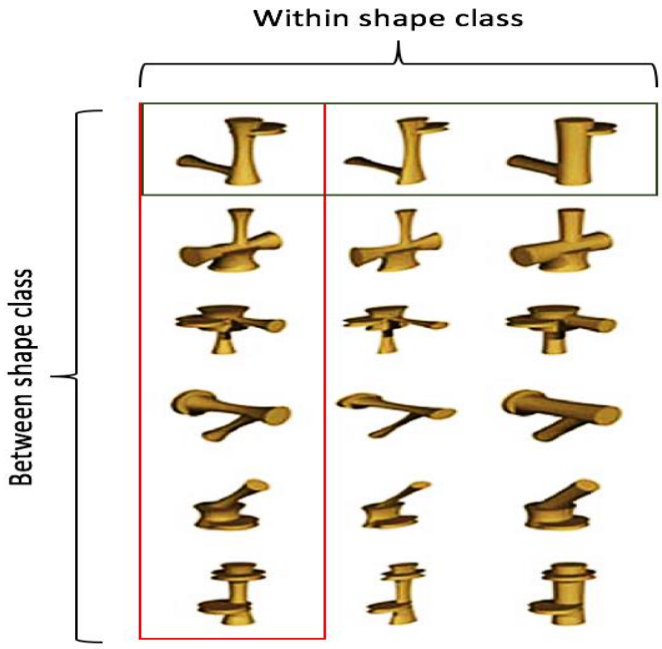


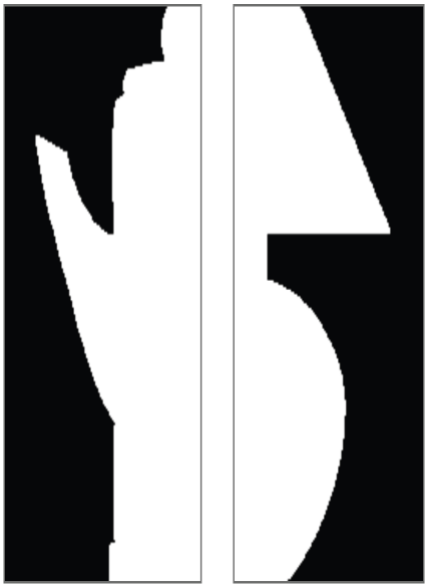
Figure 1. Target and Context stimuli showing from the L-EFT dataset for the Embedded Figures task

Fine Shape Discrimination. This task investigated shape differences with the 'Ziggerins' (Wong, Palmeri, & Gauthier, 2009) stimulus set using a 'match-to-sample' paradigm in a discrimination task. Local part differences and whole shape differences indicate any difficulty in retaining the information of the contour of the figure. A total of 5 stimulus classes along with 2 other within-

class stimulus shapes were used. Between-class shapes differed in global shape and within-class shapes differed in cross-sectional size, size and aspect ratio. (Figure 2) Instructions were provided for a simple matching-to-target task. A sample set of images were generated from the stimulus set (not included in the main experiment) and was designated a practice trial. Image 1 which was considered the "target image" were presented above the alternatives. The three possible matches (Image 2, 3 and 4) were presented at the bottom of the screen equidistant from one another. Trials were counterbalanced so that all correct matches appeared in all three positions equal number of times in a total of 135 trials in a generated random order. All participants received the same order of trials.

Figure- ground segmentation. This task was designed to assesses participants' ability to perceive the shape of an object in the context of other background information when presented with familiar and unfamiliar configurations in black and white 2-region displays. All images were selected from the OMFEA dataset (Peterson & Gibson ,1994). The central contour in each image shape recognition information induce the figural status of one of two sides of the image (left or right) and the participants were asked to choose the one they thought best depicted the shape of an actual "figure". (Figure 3) The participants were told that they were no correct or incorrect responses and that their impressions were the ones of interest. Participants were asked to press either the 'left or right 'arrow' key to indicate the side they thought the shape appeared on. The task had a total of 72 trials with counterbalanced presentations of black and white as well as left and right figural images.





(Left) Figure 2. 'Ziggerins' stimuli showing 5 unique shape class with whole and part variations for the Fine Shape Discrimination task. (Right) Figure 3. Two Image stimuli from the OMFEA stimulus set for the Figure-Ground Segmentation Task

Dot counting. In this task, 1 to 6 dot stimuli were presented to assess group differences in enumeration in a grouping by proximity paradigm. (Figure 4) The dots were circular in shape of about 1.95° in size and were grouped and presented differently in every trial (up to six rows in various combinations). All dots in the same row were grouped tightly and spaced evenly. Positions of dots were randomly jittered to keep participants from being able to predict the locations of the dots. Each presentation of dots was followed by a backward mask about 39° large made up of 500 dots. Participants were asked to count the dots and provide a response of 1-6 on using labeled keys on the keyboard. This task had a total of 192 trials which were counterbalanced and randomized based on dot numbers and dot groupings.

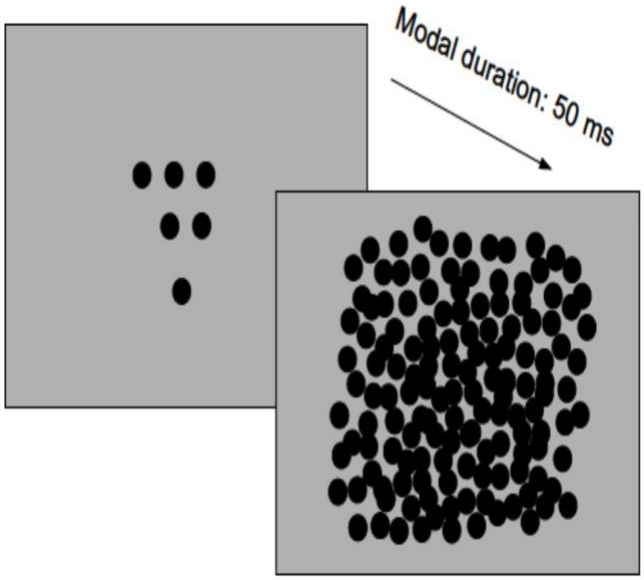


Figure 4. Dot stimuli showing a trial with 6 dots followed by a backward mask for the Dot Counting task

Presentation and response time for each participant was within 60 to 90 minutes with an additional 30 minutes for the pre-experimental procedures. All tasks were programmed using MATLAB (Mathworks), Psychophysics Toolbox (Version 3; Brainard, 1997).

Analyses

Tests of significance investigating the relationships between relevant variables were conducted using MATLAB (Mathworks) and R (R Core Team, 2013) statistical packages.

Pre-experimental questionnaire

Scores from the Geriatric Depression Scale were analyzed for descriptive statistics (means). However, low sample size prevented any further comparisons between participant scores on this scale and their performance in the behavioral experiments.

Perception Experiments

The main experiment consisted of four tests of visual perception- Embedded Figures, Fine Shape Discrimination, Figure-Ground Segmentation and Dot Counting. Scores indicating accuracy were collected for each test separately where correct responses were coded as '1' and incorrect responses were coded '0'. Group means (Experimental and Control) were analyzed for significant differences using independent samples t-tests (treating each test as an individual experiment). Results from the individual t-tests were used to address primary hypotheses about perceptual processes in people with and without PD.

Note about sample sizes. All control participants participated in all portions of the pre-experimental questionnaires as well the four visual perception experiments. All PDs completed the pre-experimental portion of the study. However, due to technical problems during testing, 1 participant from the PD group was unable to complete any of the perception experiments, 1 was only able to complete the Dot Counting task and another 1 could complete the Embedded Figures and Fine Shape Discrimination tasks but not the Dot Counting or the Figure-Ground assignment tasks. In addition, due to time constraints, 1 other participant from the PD group could complete none but the Embedded Figures. The mutual exclusivity of the four tasks and the low sample size, either eliminated the need for or prevented the exclusion of participant data from the study. Therefore, the sample sizes for the individual experiments are different and results were calculated accordingly.

It is unlikely that all statistical assumptions for analysis have been met for this reason. This has been considered in the discussion of results.

Results

Results described are within the scope of the available sample and significance is considered based on the appearance (or lack thereof) of a difference in means.

GDS

Scores for "depressive" answers were allotted 1 point, when participants selected 'Yes' for all statements except for items 1, 4, 15, 21, 27, 29 and 30. Final scores (N = 12; max possible score = 30) ranged from 19 to 4 points with an average of 9.83 points for the PD group and from 10 to 0 points with an average of 3.16 points for the Non-PD group. (Table 1) Overall, ratings for Non-PD participants were less variable than those for PD participants.

	PD				Non-PD		
Questionnaire	Mean	Median	SD		Mean	Median	SD
GDS	9.83	8	6.76		3.16	2	3.6
N = 12							

Table 1. Pre-experimental questionnaire- GDS scores for PD and Non-PD participants

Embedded Figures

Independent samples 2-tailed *t*-tests were used to compare the main performance measures between PDs (n = 4) and healthy control participants(n=6) in the Embedded Figures. Results showed no significant differences in the accuracy of responses given by patients (t=-2.218, $p<0.05($0.058)) and those given by the healthy controls. (Table 2, Fig. 5) Scores also indicate a trend towards greater variability in the PD group than in the Control group.

Group	***Mean***	***SD***
PD	0.94	0.05
Non-PD	0.99	0.01

Table 2 Mean Accuracy and Variability (SD) in the Embedded Figures Task for PD and Non-PD participants

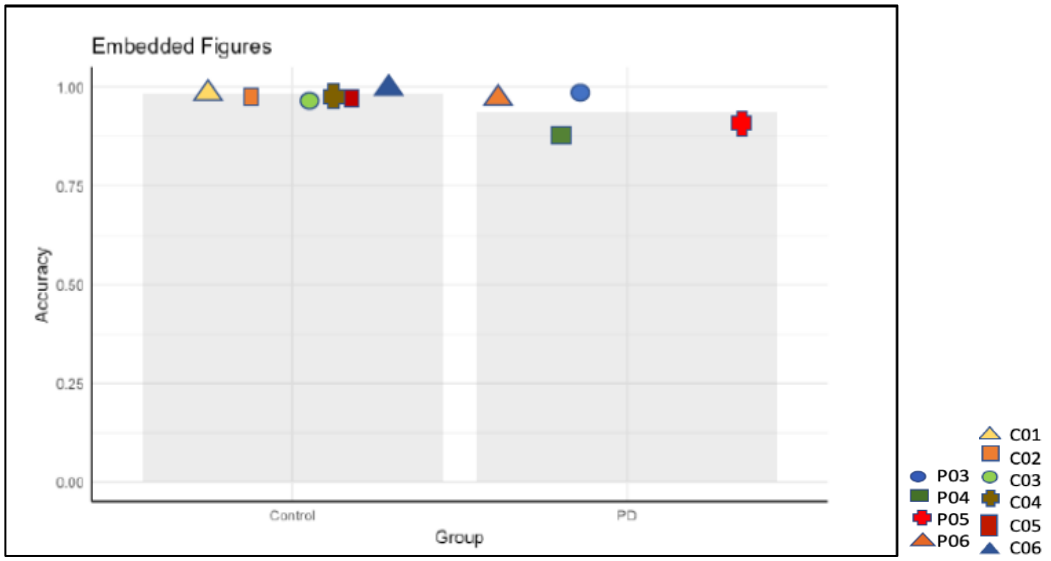


Figure 5. Individual participant means in the Embedded Figures Task for Control and PD group

Fine Shape Discrimination

Independent samples 2-tailed *t*-tests were used to compare the main performance measures between PDs (n = 3) and healthy control participants(n=6) in the Fine Shape Discrimination task. Results showed no significant differences in the mean accuracy of responses given by patients (*t*=-1.482, p<0.05(0.181)) and those given by the healthy controls. (Table 3, Fig. 6)

Group	***Mean***	***SD***
PD	0.94	0.06
Non-PD	0.98	0.03

Table 3. Mean Accuracy and Variability (SD) in the Fine Shape Discrimination Task for PD and Non-PD participants

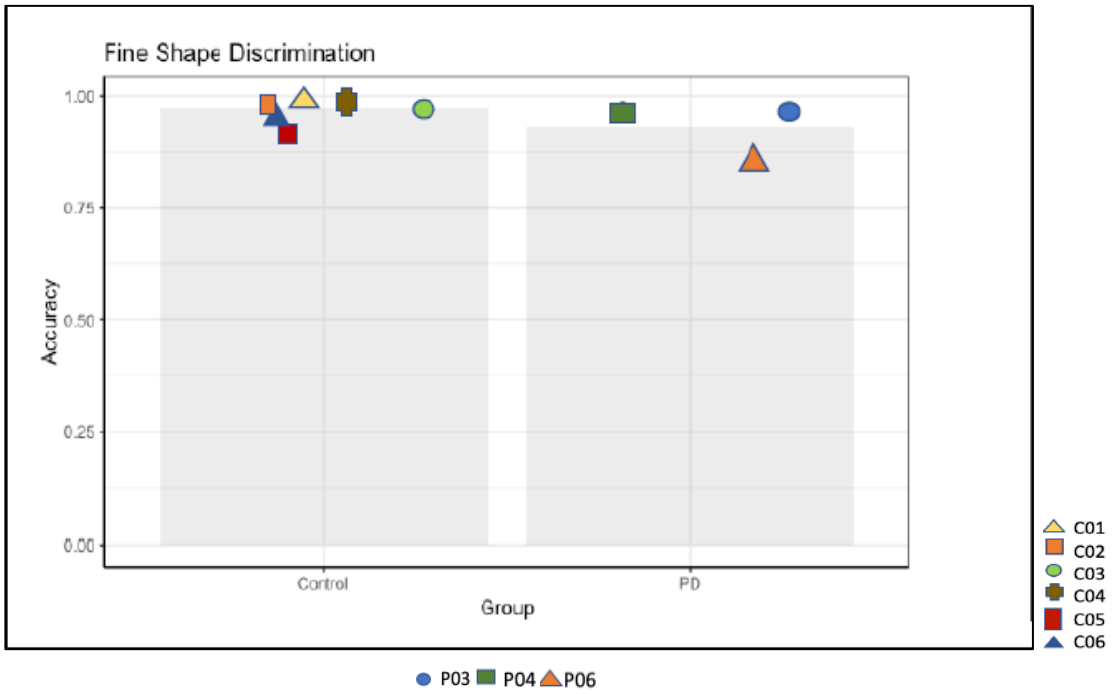


Figure 6. Individual participant means in the Fine Shape Discrimination Task for Control and PD group

Figure-Ground Segmentation

Independent samples 2-tailed t-tests were used to compare the main performance measures between PDs (n = 2) and healthy control participants(n=6) in the Figure Ground segmentation task. Results showed no significant differences in the mean accuracy of responses given by patients (*t*=--0.0117, p<0.05*(0.991)*) and those given by the healthy controls. (Table 4, Fig. 7)

Group	***Mean***	***SD***
PD	0.62	0.24
Non-PD	0.62	0.11

Table 4. Mean Accuracy and Variability (SD) in the *Figure-Ground Segmentation* Task for PD and Non-PD participants

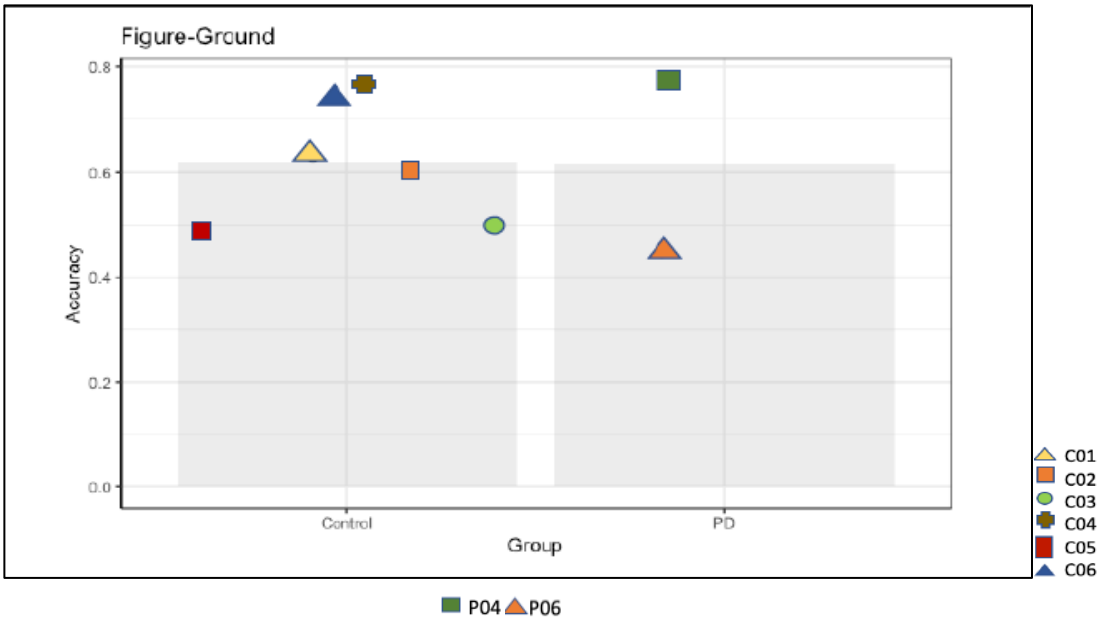


Figure 7 Individual participant means in the Figure-Ground Segmentation Task for Control and PD group

Dot Counting

Independent samples 2-tailed t-tests were used to compare the main performance measures between PDs (n = 2) and healthy control participants(n=6) in the Figure Ground segmentation task. Results showed significant differences between the mean accuracy of responses given by patients (t=-4.316, p<0.05*(0.005)*) and those given by the healthy controls. (Table 5, Fig. 8)

Group	***Mean***	***SD***
PD	0.5	0.02
Non-PD	0.77	0.08

Table 5. Mean Accuracy and Variability (SD) in the *Dot Counting task* Task for PD and Non-PD participants

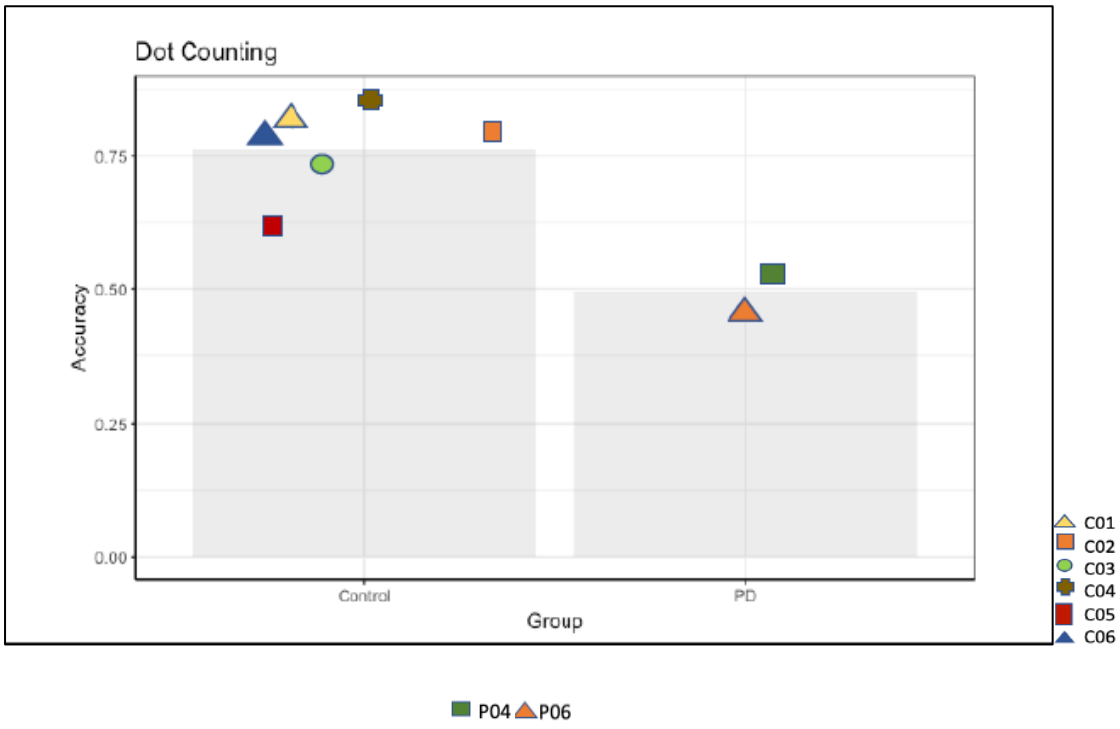


Figure 8. Individual participant means in the Dot-Counting Task for Control and PD group

Discussion

This study investigated whether PD pathology extended to processes involved in the integration of visual information into perceptual wholes using tests of classic gestalt perception principles. Given the evidence for specific grouping and object identification impairments in perceptual tasks that determine how parts and wholes are perceived in the environment, the extent to which performance of participants with PD would differ from healthy controls was studied. Due

to the inconclusive nature of the results, specific hypotheses could not be addressed. However, specific aspects of each task that may have driven performance along with considerations for future questions have been discussed below.

The lack of noticeable differences in PD performance from that of control participants in the embedded figure detection task suggest that PD did not interfere with the effect of embedding strength on accuracy. However, the stimulus features that drive embedding make this task a complex test of discrimination as well as perceptual style. Previous research has indicated that PD patients demonstrate abnormal behavioral patterns in both these aspects. (Weil et al., 2016) Findings from previous studies suggest that performance in such perceptual tasks adhere to very strict conditions of PD dysfunction where disease severity and level of cognitive dysfunction influence the extent to which overall gestalts of target shapes are retained while maintaining their ability to visually match the target to the contexts. (Flowers & Robertson, 1995). This leads to the idea that changing patterns of this impairment may be related to the progression of the disease.

In the fine shape discrimination task, participants were to discriminate between different styles of shapes within a class of unique part-whole structures. No group differences were observed in this task despite variation in cross-sectional shape, size and aspect ratio. In a study done by Laatu and colleagues (2004), PD patients showed no significant differences in an object familiarity tasks when distorted shapes resembled familiar objects. The results from the above-mentioned study as well the current study could indicate an intact ability to perform subordinate level categorizations of shapes. This would be in line with the task performed as the target and matches were always from within the same class of ‘Ziggerins’. Future examinations of discriminations

could perhaps test categorizations on a basic-level to explore the influence of previous experience on representations of object shapes. (Wong, et al., 2009)

Findings from the figure-ground segmentation task provided no evidence of group differences on the assignment of figural status, despite presentations of "novel" along with intact "familiar" objects. This could lead to two possible avenues of exploration that would allow some inquiry into the early recognition process that sub-serve figure-ground segmentation- (1) top-down influences on perception do not differ between PD and controls. This is contrary to findings from the Flowers & Robertson (1995) experiments where PD patients exhibited marked top-down deficits compared to controls even in early stages of the disease; (2) PD patients could have assigned figure status to a different category of stimuli as the controls. Examination of performance specific to whether more "figure" assignments were made when intact familiar configurations were presented or when the part-rearranged novel configurations were presented might be more telling about specific differences in processing of figure-ground information, if any exist. (Peterson & Gibson, 1994)

In the dot counting task, enumeration differences when presented in a grouping by proximity paradigm were tested. Significant group differences were observed in this task when participants were presented 1 to 6 dots. Previous studies that have investigated Dot Counting in populations with PD have found no group differences compared to healthy controls. (Barnes et al., 2003; Bak et al., 2006) This leads to the idea that enumeration (counting) processes (where the dots are traditionally presented in whole chunks) may have been disrupted by the grouped presentation of dots in this task for the PD group. However, further examination is required to

address questions of perceptual attributes that influence preferred grouping styles that in turn may lead to the creation of strong patterns that dominate perception.

The limitations and future ideas for further exploration in this study influence the significance and implications of the findings addressed above. Firstly, the low sample size called the validity of the normality assumptions into question. If such violations exist, then alternative analyses would be required to afford any interpretive value to the results. Secondly, detailed analyses to assess accuracy within each task and their sub-stimulus categories were not conducted. Since all perceptual tasks were driven by intricate principles of grouping, further study would allow a more in-depth study of perceptual organization in this population. For example, key stimulus features like symmetry and closure that influence strength of embedding in a context could be useful in examining sensitivity to embedding in different contexts. Lastly, rigorous clinical assessment for the PD group was missing. Therefore, it is important to consider disease severity and progression of cognitive impairment along with comorbid psychological conditions (like depression) to accurately gather information about the reach of PD pathology. These limitations restricted clarity in the findings from this study and make it difficult to interpret them as final.

Summary & Conclusion

Overall examination of findings gathered from the literature as well as the current study point towards selective differences between PD and healthy control participants in tasks that addressed the dynamic interaction between perceptual grouping and higher-order object recognition. Participants appeared to be relatively unimpaired in tests that assessed the segregation of figures from backgrounds, the perceptual coding of local parts relative to more global wholes, and the construction of shape representations but not in the test that examined perceptual grouping by proximity. Additionally, the relevance of clinical disease progression and cognitive dysfunction on perception in PD was also highlighted. However, insufficient data in terms of sample size as well as clinical assessments limited further inquiry into these differences. Therefore, future work, expanding on these results and addressing these limitations may afford further insight into how PD pathology affects basic organizational efforts of the visuo-perceptual system.

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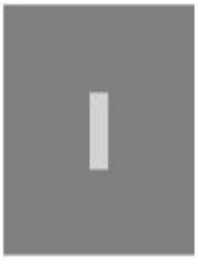
Appendix A

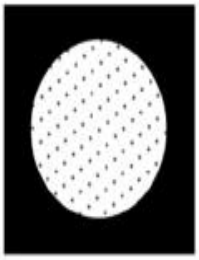
Images of stimuli used in 15 subtests of the Leuven Perceptual organization Screening Test (L-POST)

1 Fine shape discrimination

2 Shape ratio discrimination (Efron)

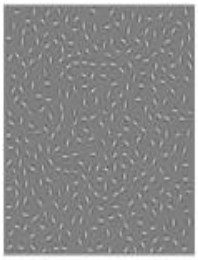


3 Dot lattices

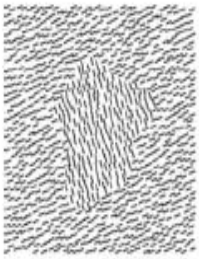


4 RFP fragmented outlines

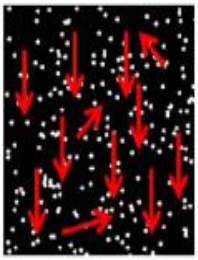
5 RFP contour integration



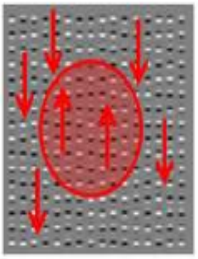
6 RFP texture surfaces



7 Global motion detection

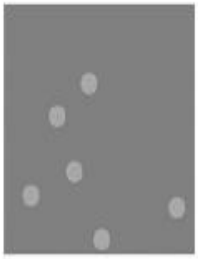


8 Kinetic object segmentation

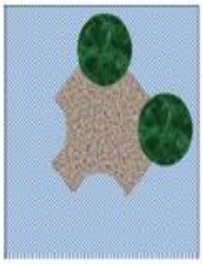


9 Biological motion

10 Dot counting



11 Figure-ground segmentation



12 Embedded figure detection

13 Recognition of missing part

14 Recognition of objects in isolation

15 Recognition of objects in a scene

Appendix B

Example stimuli for Fine Shape Discrimination (Fig. 1), Dot Counting (Fig.2) and Figure-Ground segmentation (Fig. 3) and Embedded Figures (Fig.4) used in the L-POST

Fig. 1

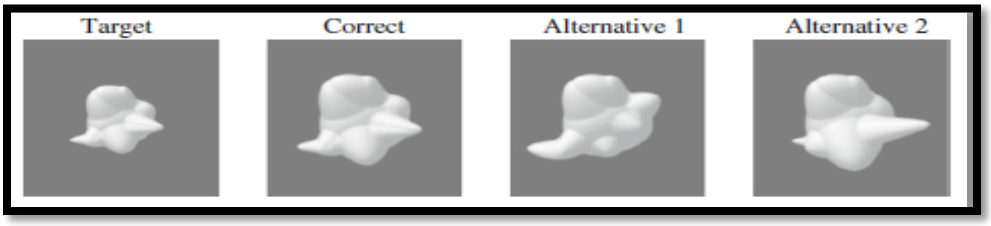


Fig. 2

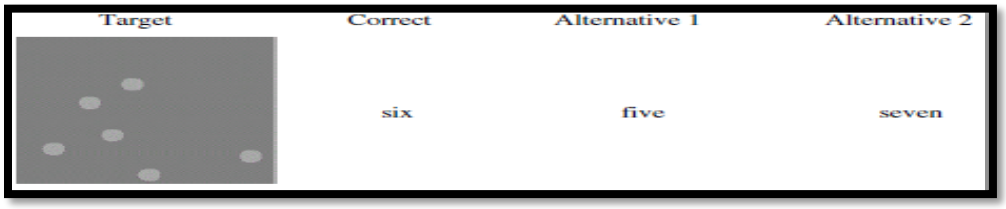


Fig. 3

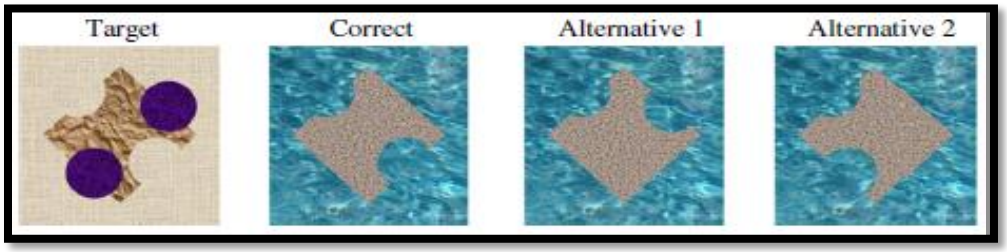
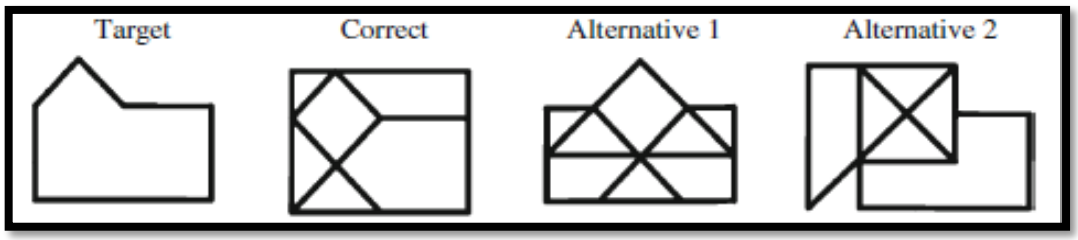


Fig. 4



Appendix C

Geriatric Depression Scale (Short Form)
Self-Rated Version

Patient's Name: _____ Date: _____

***Instructions*: Choose the best answer for how you felt over the past week.**

No.	Question	Answer	Score
1.	Are you basically satisfied with your life?	Yes / No	
2.	Have you dropped many of your activities and interests?	Yes / No	
3.	Do you feel that your life is empty?	Yes / No	
4.	Do you often get bored?	Yes / No	
5.	Are you in good spirits most of the time?	Yes / No	
6.	Are you afraid that something bad is going to happen to you?	Yes / No	
7.	Do you feel happy most of the time?	Yes / No	
8.	Do you often feel helpless?	Yes / No	
9.	Do you prefer to stay at home, rather than going out and doing new things?	Yes / No	
10.	Do you feel you have more problems with memory than most people?	Yes / No	
11.	Do you think it is wonderful to be alive?	Yes / No	
12.	Do you feel pretty worthless the way you are now?	Yes / No	
13.	Do you feel full of energy?	Yes / No	
14.	Do you feel that your situation is hopeless?	Yes / No	
15.	Do you think that most people are better off than you are?	Yes / No	
		TOTAL	

(Sheikh & Yesavage, 1986)

Appendix D

1

PADMAPRIYA MURALIDHARAN

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Education

M.S., PhD | (2014- Present)
Virginia Tech | Psychology (Program: Biological Psychology)

M.A. | (2012- 2014)
University of Pune | Psychology (Program: Clinical)

B.A. | (2009- 2012)
Nowrosjee Wadia College of Arts and Sciences (Affiliated to University of Pune) | Psychology

Software Skills

Data Collection/Analysis: MATLAB, Python | **Graphics Software:** Blender, GIMP, Adobe Photoshop | **Statistical Analysis:** SPSS, R | **Neuroimaging data analysis:** FSL, Statistical Parametric Mapping (SPM), AFNI

Research Experience

Mid-level visual processes in Parkinson's Disease (PD) | August 2016- Present
Conducting a behavioral investigation of PD and mechanisms relevant to global-local interactions in perceptual organization.

Part-whole 2D shape perception- Connectivity analysis | November 2016- March 2017
Analysis of fMRI data collected during shape perception tasks to assess functional connectivity in the whole brain when presented with part-whole contingencies of different 2D shapes.

Gigapixel Display study | November 2014- May 2016
Assisted with a project on Learning with Large-scale Interactive Displays, examining relationships between kinesthetic learning and visuo-spatial navigation.

Preliminary investigation of object recognition and emotion perception deficits in PD | January 2015- May 2016
Designed and executed a behavioral study investigating shape-based object recognition and emotion perception in PD.

Visual Emotion Recognition Study | July 2013- January 2014
Behavioral investigation of group-level lateralization differences in emotion recognition using a divided visual field (DVF) paradigm.

Professional Experience

Graduate Teaching Assistant | August 2014-Present
Duties include structuring course syllabi, developing and delivering course materials to students as well as grading of student quizzes, assignments, and projects.

Conference Presentations

Muralidharan, P., Cate, A.D. (2017) *fMRI investigation of part-whole contingencies using 2-D shapes: A partial least squares analysis*. Poster presented at the Cognitive Neuroscience Society (CNS) Annual meeting in San Francisco, CA.

Muralidharan, P., Cate, A.D. (2016) *Perceptual Organization in Parkinson's disease: The Role of the Basal ganglia in Shape-Based Object Recognition and Emotion Perception.* Poster presented at the Annual meeting for Vision Sciences Society St. Pete Beach, FL.

Other Presentations/Talks

"***Sensorimotor System: Movement and Motor Systems***". Departmental talk, Department of Psychology, Virginia Tech, February 12th, 2016.