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Aging and Visual Spatial Integration

Alexia J. Higginbotham
Western Kentucky University, alexia.higginbotham205@topper.wku.edu

AGING AND VISUAL SPATIAL INTEGRATION

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Alexia J. Higginbotham

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AGING AND VISUAL SPATIAL INTEGRATION

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Dr. J. Farley Norman, Director of Thesis

Dr. Andrew Mienaltowski

Dr. Matthew Shake

Dean, Graduate School 4/18/19
Date

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Department of Psychological Sciences Western Kentucky University

The current study evaluated the ability of 20 younger and 20 older adults to discriminate shapes depicted by Glass patterns. On any given trial, observers identified a particular pattern as either possessing a radial or concentric organization. Detecting a shape defined by a Glass pattern requires the successful detection of the orientations of its constituent local dipoles. In addition, long-range processes are needed to integrate the spatially separated dipoles into perceivable contours that have a particular (e.g., radial or concentric) organization. In the current experiment, the shapes were defined by either 40 or 200 oriented dipoles spread over an area with a diameter of either 6 or 25 degrees visual angle. Three amounts of visual noise were added to the patterns to manipulate task difficulty: 1) no added noise points, 2) low amounts of noise (a 1:1 ratio of randomly-placed noise points and signal dipoles), and 3) large amounts of noise (a 5:1 ratio of randomly-placed noise points and signal dipoles). The results of the current study indicate that human observers, both younger and older, possess an effective ability to integrate visual information across space (using Glass patterns as stimuli). There is a small age-related deterioration in discrimination performance and this is most likely due to the deficits in orientation discrimination that accompany reductions in inhibitory GABA activity in visual cortex.

Introduction

How do we gain knowledge about the external world? For millennia, scholars have explored this question by trying to understand our perceptual experiences. The main objective of all perceptual research is to understand the input aspect of human cognition (Uttal, 1983). Undoubtedly, the most dominant piece of perceptual information for humans is visual.

Furthermore, research on vision and aging has increased dramatically over the past few decades (Owsley, 2016). This research is important because changes in the functionality of the visual cerebral cortex have the potential to negatively impact our ability to perform common everyday tasks such as recognizing objects and driving. Such impairments can have a profound impact upon the quality of life and well being of the older population (65+) (Andersen, 2012; Owsley, 2016).

The ability of humans and animals to detect and recognize form is one of the enigmas of visual perception (Cao, Lisani, Morel, Muse, & Sur, 2008). In order to create the perception of a whole global form, the neural circuitry within the visual cortex combines information from several parts of the visual field in such a way as to detect features that are larger than the receptive field of a single cell (Carlson, 2014). Form is often difficult to study because changing one attribute of global arrangement often affects other features. For example, elongating a continuous line (with appreciable thickness) on a computer monitor can only be done by adding to the number of pixels being illuminated. Thus, a long line has greater area than does a short one. One way to study form effectively is to use dots. A line of five dots may be elongated, for example, from one to four centimeters without changing the number of pixels that are illuminated in a computer display (Uttal, 1983).

Glass patterns (Figure 1) (Glass, 1969; Glass & Pérez, 1973) are a type of dot pattern that has been used as a tool in psychophysical research to study how the brain integrates individual pieces of information across space to perceive a global form (i.e., performs spatial integration).

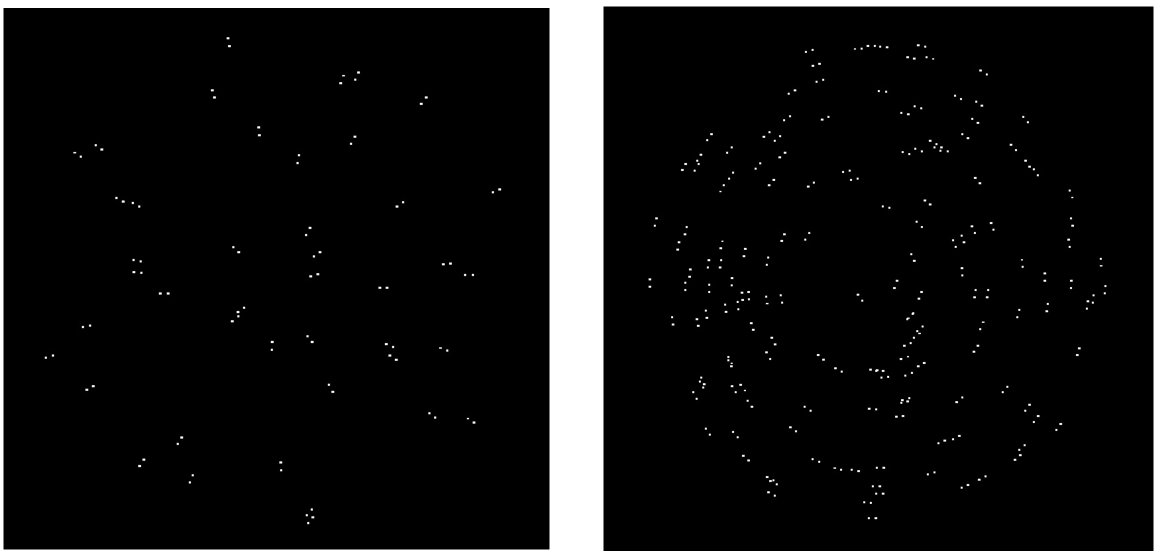

Figure 1. Radial Glass pattern with no noise (left), and concentric Glass pattern with no noise (right).

The literature reviewed here will discuss the visual system, Glass patterns, and the effects of age upon spatial integration. In particular, a description of Glass patterns and how they were developed will be provided. Also, to demonstrate that Glass patterns are a viable resource to study the functionality of striate and extrastriate visual cortex, neurophysiological evidence will be assessed. Furthermore, a brief explanation of how aging affects visual processing and the perception of global form from Glass patterns will be included. Finally, this literature review will conclude by pointing out gaps in the literature regarding spatial integration.

GLASS PATTERN ORIGIN & DESCRIPTION

Glass pattern origin. Glass patterns have been used in psychophysical and neurophysiological studies to examine form-detecting mechanisms and how the visual system combines elements into the perception of a global form. These patterns received their name from an American scientist, Leon Glass, who applied statistical methods to the study of visual perception (Glass, 1969; Glass & Pérez, 1973). The original Glass patterns were made from random dot patterns created by spraying black paint from an aerosol can onto white paper (Glass, 1969). He realized that a circular global pattern was perceived when a transparency of the random dot pattern was superimposed on itself and rotated (Glass, 1969). For each dot within the pattern there is a corresponding "partner" dot (that creates a dipole) that lies along the circumference of a circle centered at the point of rotation. The visual system is able to detect these correlations among noise (additional unpaired dots), integrating individual dipoles across an entire image to create the perception of a whole form. Glass believed that these patterns would be useful for studying the neural basis of form perception (Glass, 1969). While there was no direct evidence of this at the time, he turned out to be correct.

There are four common types of Glass patterns that have been extensively used in research: concentric, hyperbolic, radial, and parallel (Lewis et al., 2004; McKendrick & Battista, 2013; Ohla, Busch, Dahlem, & Herrmann, 2005; Weymouth & McKendrick, 2012; Wilson & Wilkinson, 1998). The lower the obtained threshold (the least number of signal dipoles needed to detect a pattern embedded in noise), the better the performance (e.g., Macmillan & Creelman, 1991). The concentric pattern's detection threshold has been found to be the lowest, followed by the radial, hyperbolic, and parallel (Wilson & Wilkinson, 1998). McKendrick and Battista (2013) found a strong correlation between concentric and radial Glass pattern detection performance (r=.70, $p < 0.001$). In addition, fMRI (functional magnetic resonance imaging) and single unit recording studies show that there is an area in human/primate cortex (e.g., MST, middle superior temporal area) that responds selectively to concentric and radial motion (Morrone et al., 2000; Saito et al., 1986). The similarity in how concentric and radial patterns are perceived is important because it demonstrates that similar visual mechanisms respond to both types of patterns.

Validity of glass patterns to study visual cortex. Glass patterns are ideal for studying form perception because they allow an assessment of how global form perception is affected by manipulations of local orientation (Vreven & Berge, 2007). As we will see, the visual system (e.g., neurons in cortical area V1) is sensitive to the orientations of local elements within a visual pattern. There have been many methodologies used to verify that Glass patterns represent a useful way to study the function of striate and extrastriate areas within the visual cortex. Such methods include: single unit recording (Smith, Bair, & Movshon, 2002), event-related brain potential (ERP) measures (Ohla et al., 2005), repetitive Transcranial Magnetic Stimulation (rTMS) (Pavan, Ghin, Donato, Campana, & Mather, 2017), magnetoencephalography (MEG) (Swettenham, Anderson, & Thai, 2010) and functional magnetic resonance imaging (fMRI) (Mannion, Kersten, & Olman, 2013).

All of these neurophysiological techniques confirm that Glass patterns primarily activate the intermediate level (i.e. V4 and V5) of visual processing in the pathway leading from striate cortex (V1) to inferior temporal cortex (IT). The functions of these visual processing areas will be discussed in more detail in the next section.

HUMAN VISUAL PROCESSING

The human visual system is one of the most complex visual systems among animals and is not particularly confined to a specific region of the brain. To discuss all the functions of the visual system would go beyond the domain covered by this literature review. A brief explanation of the current understanding of visual processing is provided, with an emphasis on the areas where spatial integration occurs to perceive global form.

Two-stage processing model. In 1981, David Hubel and Torsten Wiesel won the Nobel Prize for physiology or medicine for furthering our understanding of the brain mechanisms of visual information processing. They found that cortical neurons in the cat and monkey visual cortex are arranged in a precise manner and that cells with similar functions, like partiality for certain orientations of lines, are coordinated into a columnar architecture in the striate cortex (cortical area V1) (Hubel & Wiesel, 1968). Their work helped us understand how cortical neurons encode visual features that help us perceive the world. However, their findings concerned only an early stage in form perception. Hubel and Wiesel discovered neurons (simple and complex cells in V1) that detected local contours with particular orientations, but it was unclear how the form of entire objects could be perceived.

Although investigations of neurons in the visual cortex have demonstrated neuronal sensitivity to specific line and edge orientation, it is less understood how this information is used to recognize global form. Glass' work suggested two stages of processing: an initial stage of local cue detection (e.g., detecting oriented dipoles) and a second stage of integrating the local cues (i.e., multiple dipoles) to perceive a global form (Glass, 1969; Glass & Pérez, 1973). We are now aware that form information is processed mostly in the ventral visual pathway, where information from V1 is carried to intermediate areas of extrastriate visual cortex (e.g., V4 and V5) and the inferior temporal cortex (IT) (Ghose & Ts'o, 1997; Kelly, Bischof, Wong-Wylie, & Spetch, 2001; Nankoo, Madan, Spetch, & Wylie, 2012; Wilson & Wilkinson, 1998; Wilson, Wilkinson, & Asaad, 1997). The inferior temporal cortex (IT) is considered to be the final stage in the ventral cortical pathway. Anatomical and lesion studies have indicated that areas V4 and V5 form the major intermediate level of the form vision pathway from V1 to IT (Wilson et al., 1997). The literature review will next address the process of spatial integration, including the importance of excitation and inhibition that occurs in this intermediate visual level to perceive form.

Spatial integration: excitation & inhibition. The perception of global structure in Glass patterns requires both neuronal excitation and inhibition. The neurophysiological mechanisms underlying the perception of Glass patterns have been studied by Grossberg and Mingolla (1985). They explained how we can perceive contours that aren't explicitly there (e.g., the radial and concentric contours visible within dotted Glass patterns) by proposing a neural network model that incorporates a Feature Contour System (FCS) and a Boundary Contour System (BCS). The first step occurs in the FCS where local competition takes place. Different neurons detect the differently oriented features (e.g., dipoles in a Glass pattern) that must eventually be combined to produce recognizable contours. At each specific location in the visual field, many orientation-sensitive neurons in V1 compete with each other (i.e., each individual neuron attempts to inhibit all of the other neurons tuned to different orientations). The outcome of the competition determines the eventual winner. Once the winning orientation at each specific place within the visual field is determined by the FCS, then the BCS is activated. The BCS uses a process called oriented cooperation. During oriented cooperation, neurons tuned to similar orientations at different locations in the visual field facilitate (i.e., excite) each other so that we perceive whole contours and global forms that aren't completely there in the physical stimulus (e.g., the concentric and radial contours visible within Glass patterns). Inhibition and how it declines with increasing age will be discussed next.

Many changes to vision and visual processing occur across the normal adult lifespan. Although the mechanisms underlying age-related changes in perception are still being studied, the visual neurophysiology of aged primates has revealed reduced neuronal function in striate and extrastriate cortical areas (Leventhal, Wang, Pu, Zhou, & Ma, 2003; McKendrick, Weymouth, & Battista, 2013; Schmolesky, Wang, Pu, & Leventhal, 2000; Yu, Wang, Li, Zhou, & Leventhal, 2006). Older adults perform worse than their younger counterparts on many perceptual tasks, including orientation discrimination (Betts, Sekuler, & Bennett, 2007). These performance deficits appear to be linked to age-related changes in cortical inhibition. The age-related reduction in inhibition abolishes the selectivity of visual neurons to orientation (Leventhal et al., 2003). Many recent studies have demonstrated that aging leads to reductions in inhibitory GABA (gamma amino butyric acid) activity in visual cortex (Leventhal et al., 2003; Liao, Han, Ma, & Su, 2016; Norman et al., 2013; Pinto, Hornby, Jones, & Murphy, 2010). Leventhal et al. (2003) were able to reverse the normal effects of aging and restore normal neuronal functionality in old monkeys by applying GABA (or muscimol, a GABA agonist) directly to striate cortex (V1).

AGING AND GLASS PATTERN DETECTION

Understanding visual decline as we age is useful for predicting the impact of age-related changes to performance on everyday tasks. Numerous studies have measured the effects of aging on visual tasks designed to assess the function of various parts of the early through intermediate object perception pathway. Human perceptual studies show small to moderate changes in orientation discrimination (Betts et al., 2007; Casco et al., 2017). In addition, the ability to detect and discriminate patterns comprised of local elements declines, and is more susceptible to the effects of surrounding clutter (or noise) (Casco, Robol, Barollo, & Cansino, 2011; Del Viva & Agostini, 2007; McKendrick et al., 2010; Roudaia, Farber, Bennett, & Sekuler, 2011; Weymouth & McKendrick, 2012). We can conclude that healthy normal aging results in a decreased ability to discriminate global form from local elements embedded in noise (McKendrick & Battista, 2013).

Additionally, there have been Glass pattern detection studies that examined early and middle childhood (6-9 years), early adulthood (17-29 years), middle-adulthood (30-59 years), and older adulthood (62-78 years) (McKendrick & Battista, 2013; McKendrick et al., 2013). Newborn babies have been found to be capable of perceiving the global structure of a form (Lewis et al., 2004). Sensitivity to global structure in Glass patterns was significantly worse in 6-year-olds than in adults (17-29) (Lewis et al., 2004). Furthermore, it was found that sensitivity to Glass patterns reaches adult levels sometime between 6 and 9 years of age. It has also been found that older adults (62-78) perform significantly worse on Glass pattern detection tasks than younger adults (17-29)

(Weymouth & McKendrick, 2012). Primate neurophysiology of aged animals shows neural functioning changes consistent with reductions in inhibitory function as well as increased spontaneous neural firing in older primary and extrastriate visual cortex. On average, older observers required larger numbers of signal dipoles (relative to noise dots) than younger observers to detect form in Glass patterns.

The implications of this research are simple: if you cannot see or discriminate form well, it is harder to perform everyday tasks. For example, in a drawer containing many objects, it will be harder to find a specific desired item as we get older. As we age, we can presume that our ability to see form in clutter declines, as shown by the research described in the previous paragraphs.

The current scientific literature helps us to understand changes in the ability to perform spatial integration as humans age (using Glass patterns as a tool), but there are gaps that need to be addressed. The particular issues to be addressed include: failure to thoroughly investigate the effects of varying levels of signal-to-noise ratio, and the problem associated with the size of the Glass pattern stimuli.

Many previous studies have explicitly manipulated signal-to-noise ratios (Kelly et al., 2001; Maloney, Mitchison, & Barlow, 1987; Ohla et al., 2005; Prazdny, 1984; Seu & Ferrera, 2001; Vreven & Berge, 2007; Wilson et al., 1997; Wilson & Wilkinson, 1998). However, these studies did not evaluate aging. Given the reduction in orientation sensitivity that accompanies aging, it would be expected that the successful perception of Glass patterns would decline with age, with the greatest declines possibly occurring under conditions with smaller signal-to-noise ratios. However, these expectations are simply speculation at this point and we are unaware of the true abilities of younger adults and older adults regarding the perception of Glass patterns with varying signal-to-noise ratios. In contrast, studies of Glass patterns that have evaluated the effects of aging did not explicitly manipulate signal-to-noise ratios.

A final concern is that the stimuli typically used are simply too small. The diameter of Glass patterns used in past research does not exceed a visual angle of 6 degrees. If the point of using Glass patterns is to evaluate the human ability to integrate information across space, this is not much space to integrate. Our field of view greatly exceeds 6 degrees. An increased size (diameter) of Glass patterns would permit a better evaluation of the human ability to integrate visual information across space.

There is a need for a more thorough investigation to evaluate the effects of aging while varying signal-to-noise ratios and dipole density. Two sizes of Glass pattern stimuli will be utilized to help determine the extent to which declines in orientation sensitivity and spatial integration capability are responsible for the previously obtained age deficits in perceiving global forms from Glass patterns.

Method

Experimental stimuli and Apparatus

The visual stimuli were generated by an Apple dual-processor Power Macintosh G4 computer. with ATI Radeon 9000 hardware-accelerated graphics and displayed using a 22-inch Mitsubishi Diamond Plus 200 monitor (1280 x 1024 pixels).

In the experimental stimuli, the dipoles (pairs of points) defining the global shapes were embedded in “noise” patterns of dots. The visual stimuli were radial and concentric patterns. The dots (dot size was 2 pixels) were white on a black background. Examples of each pattern are included in Figure 1 without noise to show the patterns clearly. When noise is added to the experimental stimuli, noise points were placed randomly within the area containing the global form. There were two levels of dipole density (40 and 200 dipoles), three levels of noise (no noise, 1x (low noise), and 5x (high noise) the amount of dipoles), and two levels of Glass pattern size (visual angles of 6 and 25 degrees). Some examples of Glass pattern stimuli embedded in noise are provided in Figure 2.

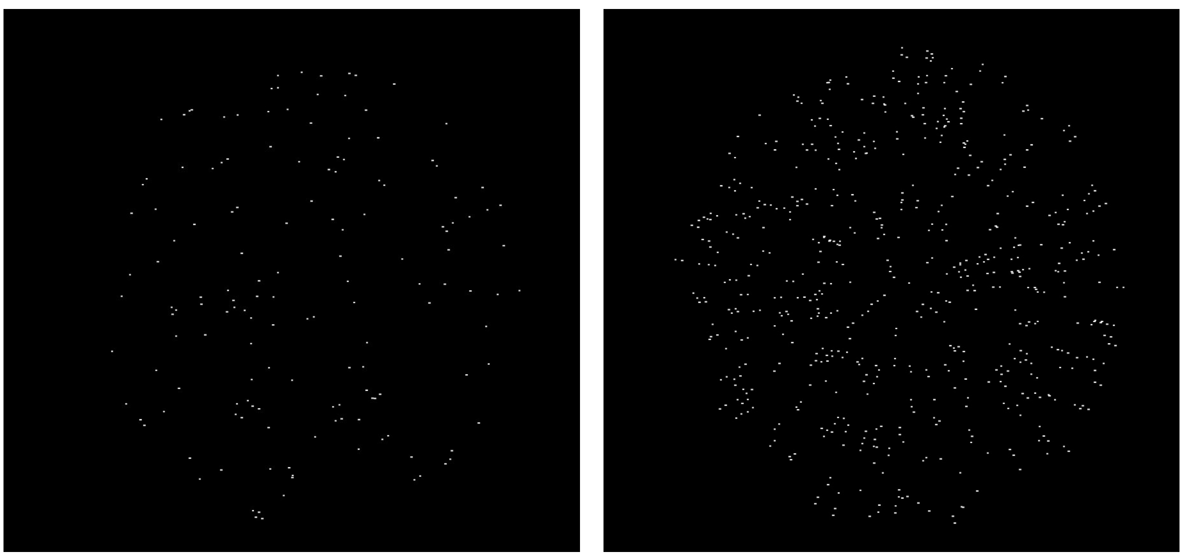

Figure 2. Concentric pattern with 25 dipoles and 100 unpaired noise points (left), and radial pattern with 200 dipoles and 200 unpaired noise dots (right).

Participants

There were two groups of participants consisting of 20 younger adults (*M* = 21.1 years old, *SD* = 2.0, range = 18 to 25) and 20 older adults (*M* = 73.6 years old, *SD* = 5.9, range = 62 to 81). The participants’ visual acuities were good: the mean acuity for the younger and older adults was -0.05 and 0.01 LogMAR (log minimum angle of resolution), respectively. All participants gave written consent before participation in the experiment. The experiment was approved by the Western Kentucky University Institutional Review Board.

Procedure

The participants were tested individually in the Gustav Fechner Vision and Haptics laboratory at Western Kentucky University. At the beginning of the session, the participants completed an informed consent form and had their visual acuity tested. After these preliminary procedures, they were given instructions for the task. First, they were shown examples of what concentric and radial patterns look like without noise (like the stimuli shown in Figure 1). They were told that their task was to identify the pattern as being radial or concentric. On any given trial they would see either a concentric or radial pattern embedded within noise dots; the participants then completed forty practice trials (without noise) and could not proceed to the experiment until their performance reached 90% correct recognition accuracy. The participants were given auditory feedback regarding their performance during the practice trials.

The research design used here is quasi-experimental due to the inability to manipulate participant age. As described earlier, a one-interval recognition task (Macmillan & Creelman, 1991) was used. The specific design is a 2 (Age: younger vs. older adults) x 3 (Noise: no noise vs. 1x vs. 5x) x 2 (Dipole density: 40 dipoles vs. 200 dipoles) x 2 (Glass pattern size: 6 degrees vs. 25 degrees) mixed factorial. Age is a between-subjects variable, whereas dipole density, noise level, and pattern size are within-subjects variables. On each trial the computer randomly displayed either a radial pattern or a concentric pattern. There were twelve stimulus conditions, with forty trials per condition, creating a total of 480 trials per participant. For the 40 dipole condition, the number of unpaired noise points varied as follows: 0 (no noise), 40 (1x), and 200 (5x). For the 200 dipole condition, the number of unpaired noise points varied as follows: 0 (no noise), 200 (1x), and 1000 (5x). Separate blocks of 240 trials each were conducted for the small (6 deg) and large (25 deg) Glass patterns. The order of the large and small stimulus blocks was counter-balanced across participants. Within each block the order of specific stimuli (number of noise dots, numbers of dipoles in the Glass pattern) was randomly determined.

For both practice and test trials, the stimuli appeared on the monitor for 500 ms (the same presentation time as used by McKendrick, Weymouth, & Battista, 2013). Before the stimuli appeared, a fixation cross was displayed in the center of a black screen and reappeared after every trial. The participant had an unlimited time to indicate whether they perceived a concentric or radial pattern. As soon as the experimenter pressed a response key, the next trial was initiated. Feedback was not given on test trials. After the experiment was completed, participants were informed of their performance and thanked for their participation.

Results

The primary results of the experiment are shown in Figures 3, 4, and 5. Figures 3-5 plot pattern discrimination performance in terms of d' (the signal detection measure of perceptual sensitivity, see Macmillan & Creelman, 1991). Figure 3 plots older and younger adults' d' as a function of noise-to-signal ratio (i.e. number of noise points relative to dipoles). While younger adults performed numerically better than the older adults in all conditions, performance for both age groups declined with increasing noise-to-signal ratios. The largest difference in performance between the older and younger adults occurred when there were equal amounts of signal dipoles and noise dots (i.e. low noise condition).

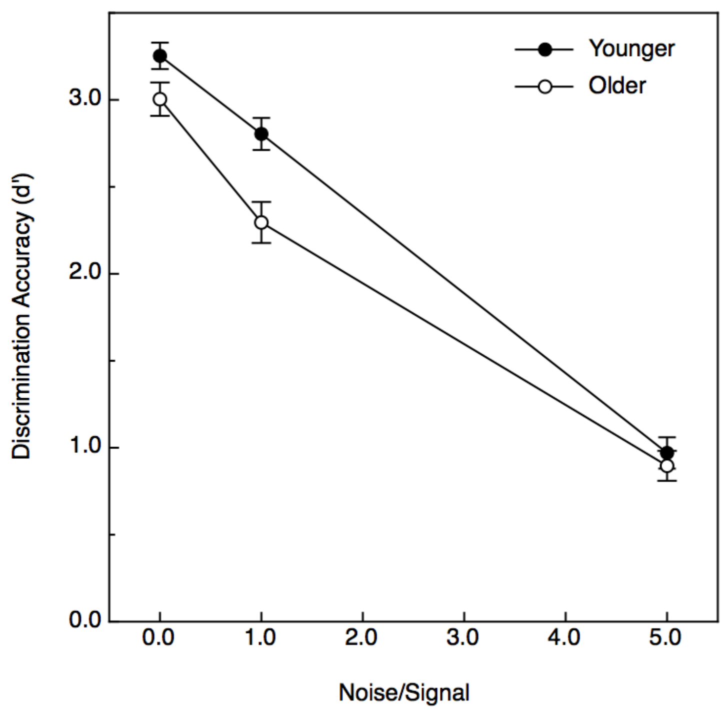

Figure 3. The younger and older adults' results (mean d' for each condition) are plotted as a function of noise-to-signal ratio. The open circles and closed circles indicate the older and younger adults' average performance, respectively. Error bars indicate ± 1 SE.

Figure 4 plots younger and older d' as a function of pattern size. The performance of the younger adults was slightly better for the small pattern size (6 deg), when compared to the large pattern size (25 deg). While the younger adults performed better overall, the older adults were less affected by the change in pattern size.

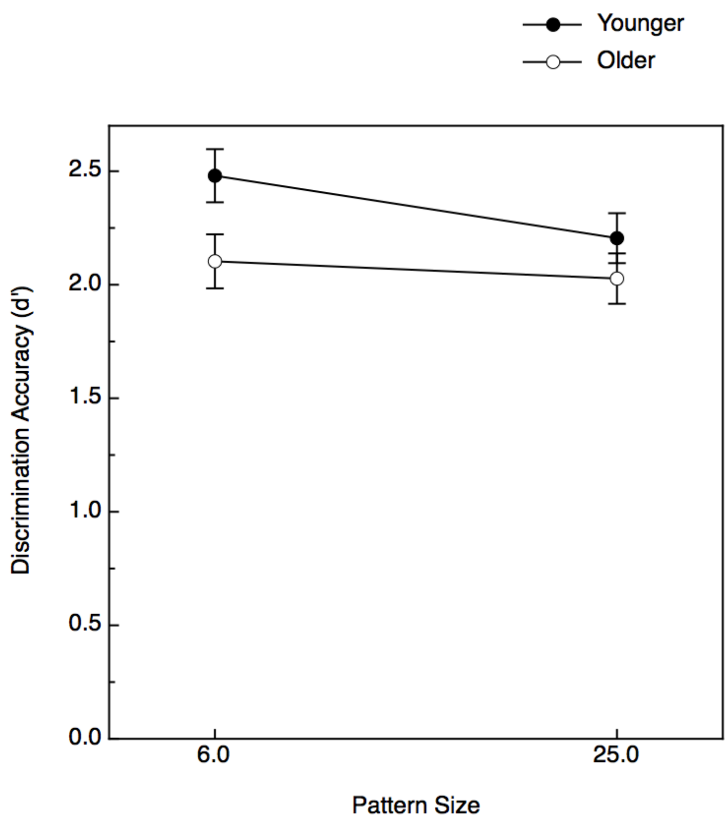

Figure 4. The younger and older adults' results (mean d' for each condition) are plotted as a function of pattern size (6 deg & 25 deg). The open circles and closed circles indicate the older and younger adults' average performance, respectively. Error bars indicate ± 1 SE.

Figure 5 plots the participants' performance as a function of both the number of dipoles and the amount of noise. There was a small interaction present: for the no noise and low noise (i.e. 1x amount of noise-to-signal) conditions, the patterns containing 200 dipoles produced to the best performance. For the high noise (i.e. 5x amount of noise-to-signal) condition, the patterns containing 40 dipoles produced the best performance.

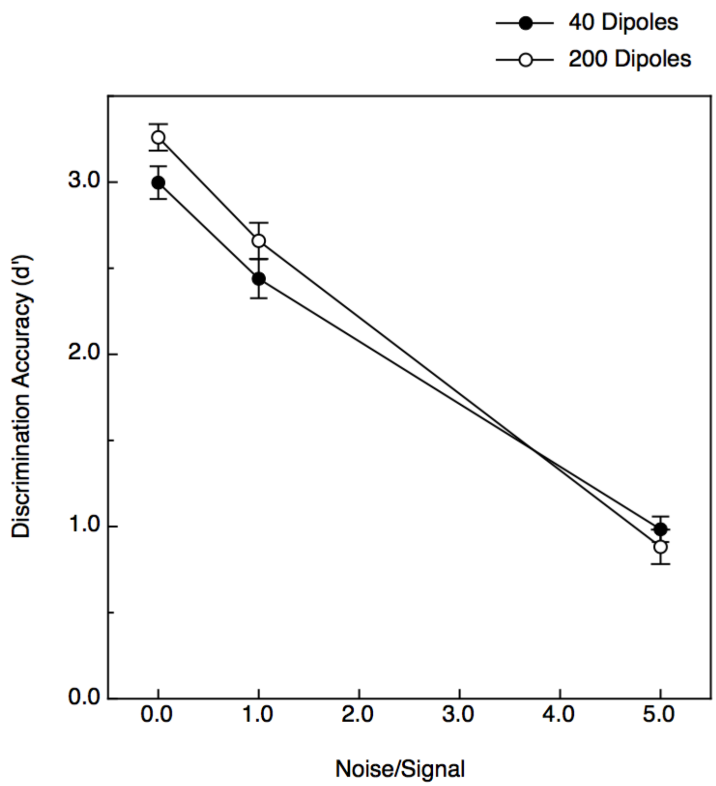

Figure 5. The participants' results (mean d' for younger and older adults) are plotted as a function of both the number of dipoles and the amount of noise. The closed circles indicate the average participants' performance for patterns containing 40 dipoles embedded in noise (i.e. no noise, 1x noise, and 5x more noise than signal). The open circles indicate the average participants' performance for patterns containing 200 dipoles embedded in varying amounts of noise. Error bars indicate ± 1 SE.

A four-way split-plot analysis of variance (ANOVA, one between-subjects factor: age (younger vs older); three within-subjects factors: pattern size (small: 6 deg vs large: 25 deg), dipoles (40 vs 200), and amount of noise points (0, 1x, and 5x the amount of signal dipoles) was conducted upon the participants' discrimination accuracies (i.e. d' values). As illustrated in Figure 4, there was a significant main effect of pattern size ($F(1, 38) = 5.811$, $p = .021$, $\eta_p^2 = .133$). Performance for small patterns (6 deg) was 8.3 percent higher than performance for large patterns (25 deg). Figure 5 illustrates a dipoles x noise interaction ($F(2,76) = 4.864$, $p = .01$, $\eta_p^2 = .113$): for no noise and low noise conditions, patterns containing 200 dipoles produced the best performance. For the high noise condition, patterns containing 40 dipoles produced the best performance. In addition, Figure 5 illustrates main effects of the amount of noise ($F(2, 76) = 390.110$, $p < .000001$, $\eta_p^2 = .911$) and the number of dipoles ($F(1, 38) = 4.568$, $p = .039$, $\eta_p^2 = .911$). This means simply that the higher the noise-to-signal ratio, the worse the performance. Furthermore, the performance for patterns containing 200 dipoles was 5.9 percent higher than for patterns containing 40 dipoles. Finally, there was a small age x noise interaction ($F(2, 76) = 3.627$, $p = .031$, $\eta_p^2 = .087$), as portrayed in Figure 3. For the no noise and high noise conditions, the younger adults' performance was 8.3 percent higher than that of the older adults. The largest difference in performance between the age groups was for the low noise condition where the younger adults' performance was 22.2% higher.

In addition to evaluating the participants' perceptual sensitivities, response biases (c values, see Macmillan & Creelman, 1991) were also determined. As depicted in Figure 6, there was a bias to respond radial (positive c values) when the patterns contained 40 dipoles and a bias to respond concentric (negative c values) when the patterns contained 200 dipoles. The patterns containing 40 dipoles produced the highest response bias (to respond radial) in the low noise condition. The patterns containing 200 dipoles produced the highest response bias (to respond concentric) in the high noise condition.

A four-way split-plot analysis of variance (ANOVA, one between-subjects factor: age (younger vs older); three within-subjects factors: pattern size (small: 6 deg vs large: 25 deg), dipoles (40 vs 200), and amount of noise points (0, 1x, and 5x the amount of signal dipoles) was conducted upon the participants' response biases (i.e. c values). As illustrated in Figure 6, there was a significant dipoles x noise interaction ($F(2,76)$ =

3.657, p = .030, η_p^2 = .088) and a significant main effect of the number of dipoles (F(1, 38) = 28.847, p = .000004, η_p^2 =.432).

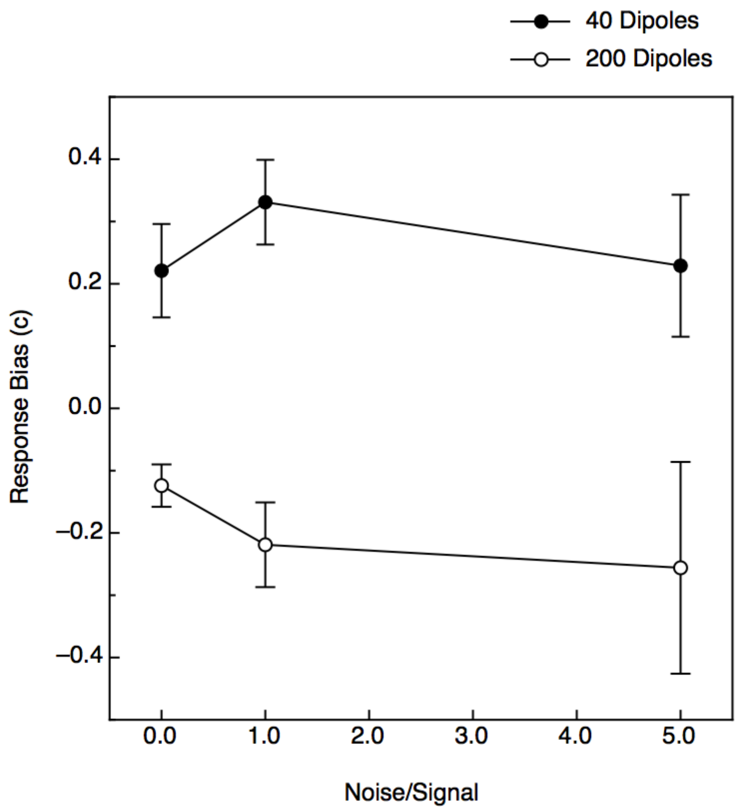

Figure 6. The participants' response biases (mean c values for younger and older adults) are plotted as a function of both the number of dipoles and the amount of noise. The closed circles indicate the participants' average response biases for patterns containing 40 dipoles. The open circles indicate the participants' average response bias for patterns containing 200 dipoles. Negative c values correspond to a bias to respond concentric. Positive c values correspond to a bias to respond radial. Error bars indicate ± 1 SE.

Discussion

The current study used Glass patterns to investigate the effects of aging on visual spatial integration. There have been well-documented findings in psychophysical research that the perceptual system becomes less efficient with age (Owsley, 2016; Andersen, 2012). However, there are certain visual and perceptual tasks for which older adults perform similarly to younger adults. Older adults perform similarly to younger adults in judging length (i.e., visually or haptically) (Norman, Holmin, & Bartholomew, 2011; Norman, Wheeler, Pedersen, & Dowell, 2018), discriminating 3-D shape (Norman et al., 2006), discriminating biological motion (Norman, Payton, Long, & Hawkes, 2004), and perceiving optical slant from texture (Norman, Crabtree, Bartholomew, & Ferrell, 2009). Similarly, it was found in the current experiment that while younger adults did perform statistically better than older adults (at least in the low noise condition), it is important to note that the difference was relatively small. Both age groups were affected adversely by the increases in noise, but the older adults were affected slightly more. The largest age-related difference in performance occurred in the low noise condition. This is not particularly surprising, given the large amount of research that shows (with other types of stimuli) 1) that the ability to detect and discriminate patterns composed of local elements declines with age, and 2) that older adults are more susceptible to the effects of surrounding clutter (or noise) (McKendrick et al., 2010; Roudaia, Farber, Bennett, & Sekuler, 2011; Casco, Robol, Barollo, & Cansino, 2011; Del Viva & Agostini, 2007; Weymouth & McKendrick, 2012). Furthermore, McKendrick and colleagues (McKendrick & Battista, 2013; McKendrick, Weymouth, & Battista, 2013; Weymouth & McKendrick, 2012) have demonstrated that there is a statistically significant adverse effect of increasing age upon the ability to perceive global structures depicted by Glass patterns. However, the coherence thresholds they report give us minimal information about the effects of noise and no information regarding perceptual sensitivity (their coherence thresholds were 16.2 and 28.6 percent for younger and older adults, respectively). Maloney et al. (1987) evaluated perceptual sensitivity (i.e., d’) for the perception of Glass patterns as a function of noise (in younger adults) and found similar results to the current study: d' decreases with increasing amounts of noise.

Overall, the current participants performed slightly better for the 6 degree pattern size. Past research suggests that orientation sensitivity deteriorates in the periphery (Spinelli, Bazzeo, & Vicario, 1984). This could help explain why the participants' performance declined with an increase in pattern size. The large pattern size (25 deg) creates a larger image on the retina, resulting in more dipoles imaged in the periphery than would occur for the small patterns (6 deg). As depicted in figure 4, an unexpected finding was that older adults were less affected by the change in stimulus size compared to the younger adults. While the explanation for this finding is not clear, this finding does indicate that deteriorations in spatial integration are not responsible for the age-related declines shown in figure 3. The significant main effect of age is most likely due to the decline in orientation detection that occurs with increases in age. Perceiving Glass patterns requires the determination of the orientation of the signal dipoles. During the process of integrating local orientation signals into a global percept, if there is a failure to determine the orientation of signal dipoles, then the required orientation information cannot reach higher visual areas (e.g., V4 and V5). This results in a failure to perceive the global pattern. If the age-related declines in the current experiment were due to the ability to spatially integrate information, then there should have been worse performance for the older adults when they viewed large pattern sizes (25 deg). In terms of Grossberg and Mingolla's (1985) neural network model (i.e., for explaining how we can perceive contours that are incomplete), the functionality of the Boundary Contour System (BCS) seems to be preserved quite well throughout the lifespan. The small age-related deficit observed in the current experiment is probably due to deterioration in the functionality of the Feature Contour System (FCS), where local competition between orientation detectors is taking place. Research indicates that deficits in orientation discrimination are likely due to age-related changes in cortical inhibition (Leventhal et al., 2003), specifically age-related reductions in inhibitory GABA activity in visual cortex (Leventhal et al., 2003; Liao, Han, Ma, & Su, 2016; Norman et al., 2013; Pinto, Hornby, Jones, & Murphy, 2010). Reductions in inhibition in older adults' V1 and/or V2 visual areas reduces the selectivity of visual neurons to orientation, making it more difficult to perceive the global contours needed to recognize Glass patterns (i.e. concentric or radial).

In summary, the results of the current study indicate that human observers, both younger and older, possess an effective ability to integrate visual information across space (using Glass patterns as stimuli). The small deterioration in performance that occurs with aging is most likely due to the deficits in orientation discrimination (i.e., degradations in quality of the knowledge of stimulus orientation) that accompany reductions in inhibitory GABA activity in visual cortex.

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Appendix

INSTITUTIONAL REVIEW BOARD
OFFICE OF RESEARCH INTEGRITY

DATE:	September 12, 2018
TO:	Alexia Higginbotham
FROM:	Western Kentucky University (WKU) IRB
PROJECT TITLE:	[1319896-1] Aging and the visual perception of global shape
REFERENCE #:	IRB 19-077
SUBMISSION TYPE:	New Project
ACTION:	APPROVED
APPROVAL DATE:	September 12, 2018
EXPIRATION DATE:	August 15, 2019
REVIEW TYPE:	Expedited Review

Thank you for your submission of New Project materials for this project. The Western Kentucky University (WKU) IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by a *signed* consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

This project has been determined to be a Minimal Risk project. Based on the risks, this project requires continuing review by this committee on an annual basis. Please use the appropriate forms for this procedure. Your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date of August 15, 2019.

Please note that all research records must be retained for a minimum of three years after the completion of the project.

If you have any questions, please contact Robin Pyles at (270) 745-3360 or irb@wku.edu. Please include your project title and reference number in all correspondence with this committee.