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Aging and the Perception of Coherent Motion

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AGING AND THE PERCEPTION OF COHERENT MOTION

A Thesis Project
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Master of Science

By
Lindsey M. Shain

May 2018

AGING AND THE PERCEPTION OF COHERENT MOTION

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The aperture problem describes an effect by which a contoured stimulus, moving behind an aperture with both ends occluded, appears to move in a direction perpendicular to its own orientation. Mechanisms within the human visual system allow us to overcome this problem and integrate many of these locally ambiguous signals into the perception of globally coherent motion. In the current experiment, younger and older observers viewed displays composed of either 64 or 9 straight contours, arranged in varying orientations and moving behind circular apertures. Because these lines moved behind apertures, their individual local motions were ambiguous with respect to direction (i.e., subject to the aperture problem). On each trial, motion patterns were displayed for 2.4 seconds, and observers estimated the coherent direction of motion (true motion directions ranged from 0 to 360 degrees). There was a significant effect of direction, such that cardinal directions of pattern motion were judged more accurately than oblique directions. In addition, there was a large effect of aging upon accuracy (the average errors of older observers were 46 and 30.4 percent higher in magnitude than those exhibited by the younger observers for the 64 and 9 aperture conditions, respectively). Additionally, the observers' precision deteriorated markedly as the number of apertures was reduced from 64 to 9. Finally, a statistically significant, albeit negligible relationship was found between orientation discrimination threshold (a behavioral measure of resting gamma amino butyric acid neurotransmitter levels) and ability to accurately estimate coherent direction of motion.

Introduction

Almost constantly, animals move relative to their surroundings, or their environment moves relative to them. The perception of motion is, therefore, an ability that is essential for avoiding danger, detecting food, and navigating safely through the environment. Through the use of photoreceptors in the retina, light signals from the environment are converted into neuronal sensory responses. Specific patterns of photoreceptor activity enable the detection of object motion. Current understandings of the mechanisms by which motion is detected are based on the Reichardt detector model (Reichardt, 1957; Barlow & Levick, 1965; van Santen & Sperling, 1985). This model, depicted in Figure 1, incorporates a delay and compare mechanism in which light is detected (imagine a light object moving against a dark background) by a photoreceptor, but its signal is delayed temporally. The light object moves (e.g., to the right) and is then detected by a second photoreceptor. Because the neural activity from the first photoreceptor was delayed, the two neural signals (from the photoreceptors) arrive simultaneously at a subsequent neural level. This simultaneous activity being detected enables the perception of motion.

The aforementioned model of a motion detector was first developed by Werner Reichardt (1957) based upon studies with beetles. The overall model was later explored by Barlow and Levick (1965), who studied neuronal responses in rabbit retinas. More recent psychophysical studies have further investigated the parameters of this model (e.g., Koenderink, van Doorn, & van de Grind, 1986; Todd & Norman, 1995; van de Grind, Koenderink, & van Doorn, 1985). Notice that the span between photoreceptors and the magnitude of the time delay determine the specific speed of motion that is detected by a particular Reichardt detector. If only one configuration of motion detector existed (i.e., a fixed span and magnitude of temporal delay), human observers (and other animals) would be able to detect only one specific speed. However, these psychophysical studies (Koenderink et al., 1986; Todd & Norman, 1995; van de Grind et al., 1985) have determined that there are multiple spans and temporal delays to enable the detection of a wide range of speeds, and that the delay parameter for a majority of motion detectors tuned for velocities above 10 degrees per second is approximately 50 milliseconds.

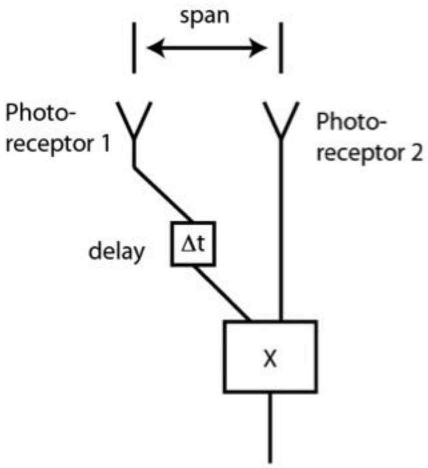

Figure 1. Stimulation of photoreceptor 1 followed by stimulation of photoreceptor 2 leads to simultaneous stimulation of the AND gate (or multiplier). The output of the multiplier indicates presence of rightward motion at a particular speed (span/Δt).

Any motion detector, because it samples motion over a limited (i.e., small) part of the visual field, is subject to the "aperture problem." This is because the detector is effectively "looking" out at the world through an aperture (the diameter of the aperture would equal the span indicated in Figure 1). Consider an extended object contour passing across a motion detector's receptive field (i.e., span). Such a contour would appear to move only in a direction perpendicular to the contour orientation. Because the component of motion parallel to the contour cannot be perceived, the true direction of motion is indistinguishable. Figure 2 demonstrates this effect. It depicts a polygonal figure moving to the right behind an occluding surface; only parts of the object (3 outer boundary contours) are visible through circular apertures. Although the object moves directly rightward, the visible contours themselves only move perpendicular to their own orientations. This "aperture problem" has been appreciated for decades (Marr & Ullman, 1981; Stumpf, 1911; Wallach, 1935).

Due to their small receptive fields, individual motion-sensitive neurons within the visual system are subject to the aperture problem whenever they are activated by a contoured stimulus. Each of these cells can only measure the component of motion perpendicular to a presented edge.

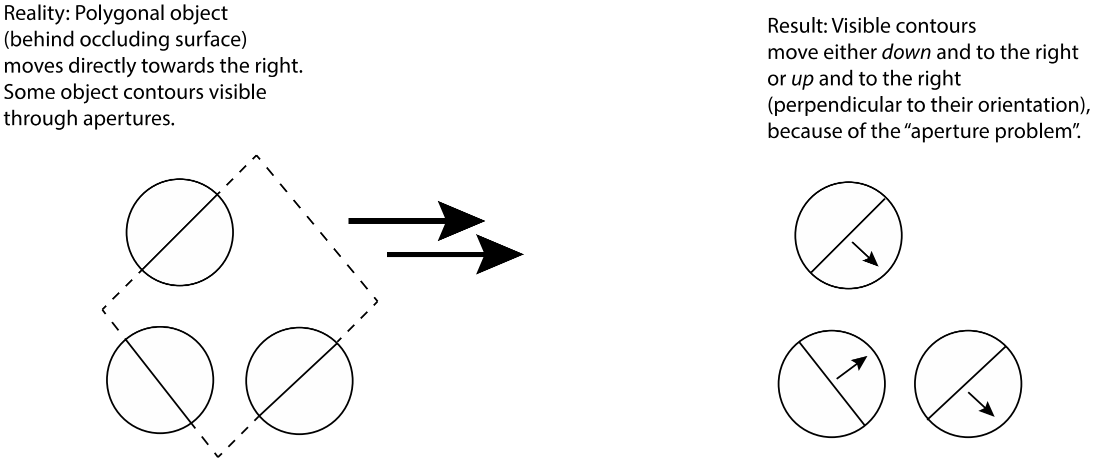

Figure 2. Despite the true rightward direction of motion of the polygonal object shown to the left, each of the three visible contours only moves perpendicular to its own orientation.

Because single motion-detecting neurons cannot detect the true directions of motion of extended object contours, mechanisms must exist within the visual system that reduce the ambiguity so that we can perceive coherently moving environmental objects.

Consider the right half of Figure 2: in this example, there are three local motion signals, but *none* of them correctly signify the direction of object motion. Two motion detectors indicate that the object is moving *down* and to the right, while one detector indicates that the object is moving *up* and to the right. By integrating locally ambiguous motion signals, however, it is possible to determine the actual direction of object motion. One combination rule involves an "intersection of constraints" (IOC, see Adelson & Movshon, 1982). Another possibility involves vector averaging (Mingolla, Todd, & Norman, 1992; Wilson, Ferrera, & Yo, 1992). Notice, for example, that if one averages the two lower local motion signals shown in the figure, one can determine the true direction of object motion (pure rightward motion).

Researchers have studied motion integration using a variety of experimental stimuli, all of which include two distinct motions. One type of stimulus (Mingolla et al., 1992) is similar to that depicted in Figure 2: two distinct motions are presented within a spatial arrangement of apertures. The other commonly used stimulus consists of two superimposed sinewave luminance gratings, where each grating moves in a different direction. Such superimposed gratings are called "plaids." These plaid stimuli can appear as transparent (i.e., one grating appears to slide across the other). Sometimes, however, the two superimposed gratings will appear to move together (i.e., coherently) in a common direction. What is important for either type of stimulus (separate apertures or plaids) is the perceived direction of coherent motion. Does the direction match the predictions of the IOC model (Adelson & Movshon, 1982) or a vector average model (Wilson et al., 1992)? In some conditions, such as for longer presentation duration and higher contrast, the perceived direction of motion approaches that predicted by IOC (Yo

& Wilson, 1992). However, in other cases, such as for shorter presentation durations (of plaids) and when motions are presented in separate apertures, the perceived direction of motion is most accurately predicted by vector averaging (Mingolla et al., 1992; Wilson et al., 1992). This current evidence supports both IOC and vector averaging combination rules. Other research has found that the direction of perceived motion lies in between the predictions of IOC and vector averaging (Ferrera & Wilson, 1990). While it is clear that no single type of combination rule can account for all of the empirical data collected to date, it is nevertheless clear that spatial averaging of locally ambiguous motion signals allows human observers to visually perceive coherent object motion (Amano, Edwards, Badcock, & Nishida, 2009).

Age-related deteriorations have been demonstrated for many aspects of motion perception, such as the perception of speed, the perception of 3-D shape from motion, and the perception of biological motion (Norman, Bartholomew, & Burton, 2008; Norman, Burton, & Best, 2010; Norman et al., 2013; Norman, Clayton, Shular, & Thompson, 2004; Norman, Dawson, & Butler, 2000; Norman et al., 2012; Norman, Payton, Long, & Hawkes, 2004; Norman, Ross, Hawkes, & Long, 2003). In 2007, Bennett, Sekuler, and Sekuler asked older and younger observers to estimate direction of motion. Their stimulus displays consisted of 300 black dots, which were presented against a white background. On any given trial, these points translated in a particular mean direction chosen over the whole range of 360 degrees; each individual point moved in a different specific direction, but, on average, the set of stimulus points moved in a particular mean direction. Because the stimulus displays of Bennett et al. consisted entirely of moving points, there was no “aperture problem.” Nevertheless, this study did demonstrate that a small-to-moderate age-related deficit exists when human adults judge the direction of visual motion. The errors in estimated motion direction were approximately 2.5 and 6.3 degrees for the younger and older observers, respectively.

Additionally, adverse effects of aging have been observed related to the perception of speed. Two experiments by Norman et al. (2003) explored the effects of aging on the ability to perceive and discriminate speed. The stimulus displays consisted of two elongated, moving strips consisting of 100 low-contrast or high-contrast circular spots along the top and bottom of a viewing screen, with a fixation point located in the center. In the first experiment, one of the strips moved at a speed of 1.22, 5.48, or 24.34 degrees/second, while the other strip moved at a slower speed. For each trial, observers were asked to indicate whether the top or bottom strip was moving faster. From the judgements, speed discrimination thresholds were determined. The older observers had higher speed discrimination thresholds than those of the younger observers, indicating reduced levels of performance.

In a 2004 study, Norman, Payton, et al. examined the ability to perceive biological motion. Optical patterns of biological motion were depicted using moving white dots on a black background. These patterns were generated by having a human model wear 13 small light bulbs in the dark while performing various behaviors (walking, jogging, skipping). The duration of the presented biological motions were 120 and 400 msec. While the older and younger observers' discrimination performance was comparable for the longer duration biological motions (400 msec), the older adults' performance was significantly worse for short durations (120 msec). This result demonstrates that the ability to perceive biological motion deteriorates with increased age.

Effects of aging on the ability to perceive 3-D shape from motion have also been documented (Norman et al., 2000; Norman, Clayton, et al., 2004; Norman et al., 2008; Norman et al., 2012; Norman et al., 2013). In a representative study, Norman, Clayton, et al. (2004) asked younger and older observers to discriminate between four different 3-D shapes (sinewave, eggcrate, bullseye, star) defined by 10,000 moving, high-contrast bright points plotted against a black background. The relative movements of the dots defining each 3-D surface were linked to movements of the observers' heads to simulate the motion parallax that occurs in everyday environments. Significant adverse effects of age occurred for all surface point lifetimes (100 msec, 600 msec, & unlimited). Although the surface point lifetimes were limited in two of the three experimental conditions, observers could view the motion parallax stimuli as long as they wanted.

From the previous research of Bennett et al. (2007), Norman et al. (2003), Norman, Payton, et al. (2004), and Norman, Clayton, et al. (2004), it is clear that increased age adversely affects the ability to perform a variety of tasks involving motion, such as judging the speed of motion, discriminating 3-D shape from motion, discriminating activities defined by biological motion, and judging the direction of motion. The age effect obtained by Bennett et al. (2007) for judgements of motion direction, however, is relatively small. Older adults can still (on average) estimate the direction of stimulus motion to within six or seven degrees of the actual direction. This relatively good performance for older adults was obtained for stimulus displays that were not subject to the aperture problem -- there was, therefore, no visual ambiguity about each stimulus point’s individual direction of motion. In everyday life in a cluttered environment, objects (which possess contours) frequently move behind other objects and also behind windows and open doors (i.e., apertures). In addition, since the boundary contours of moving objects are long (i.e., extended) relative to the size of the receptive fields of visual motion-detecting neurons, their detection is subject to the aperture problem.

From previous research (e.g., Mingolla et al., 1992), we know that younger observers can effectively integrate across space to perceive coherent motion direction from a set of locally-ambiguous motion signals, but the same ability has not been examined for older observers. Will the age effect documented by Bennett et al. (2007) generalize to the motions of extended contours which are subject to the aperture problem? The present experiment evaluates and compares this ability in younger and older observers.

Method

Observers

The stimulus displays were shown to 16 younger adults (mean age = 21.9, SD = 2.4, range: 18 – 27 years) and 16 older adults (mean age = 74.3, SD = 6.0, range: 62 – 80 years). Half of the younger and older adults were male, while the remaining half were female. The observers’ visual acuities were good (mean acuity for the younger and older adults was -0.069 and 0.044 logMAR, respectively). All observers gave written consent before participation in the experiment. The experiment was approved by the Western Kentucky University Institutional Review Board.

One potential older observer (female, age = 66 years) was excluded, because she was unable to perceive coherent pattern motion from the individual motions of the spatially-separated line segments. She indicated that the stimulus displays “looked like a kaleidoscope.” However, when tested using a similar display featuring dots rather than line segments (thereby removing the local direction ambiguities), she demonstrated no impairment in judging direction of global motion. This indicates that she both understood the task and had no impairment to general translational motion perception, yet she was, for some reason, unable to integrate the ambiguous motion signals that occur as a consequence of the aperture problem.

Apparatus

The moving patterns were created by an Apple PowerMacintosh G4 computer and were displayed on a 22-inch Mitsubishi Diamond Plus 200 color monitor (resolution: 1280 × 1024 pixels). The viewing distance was 100 cm.

Experimental stimuli

This study utilized a methodology resembling that used by Mingolla et al. (1992). The experimental stimuli consisted of numerous circular apertures displayed on a computer monitor. Two density conditions were used. In one condition, 64 total apertures (8 rows by 8 columns) were shown, while the other condition displayed a total of nine apertures (3 rows by 3 columns). Examples of these stimulus displays are shown in Figure 3.

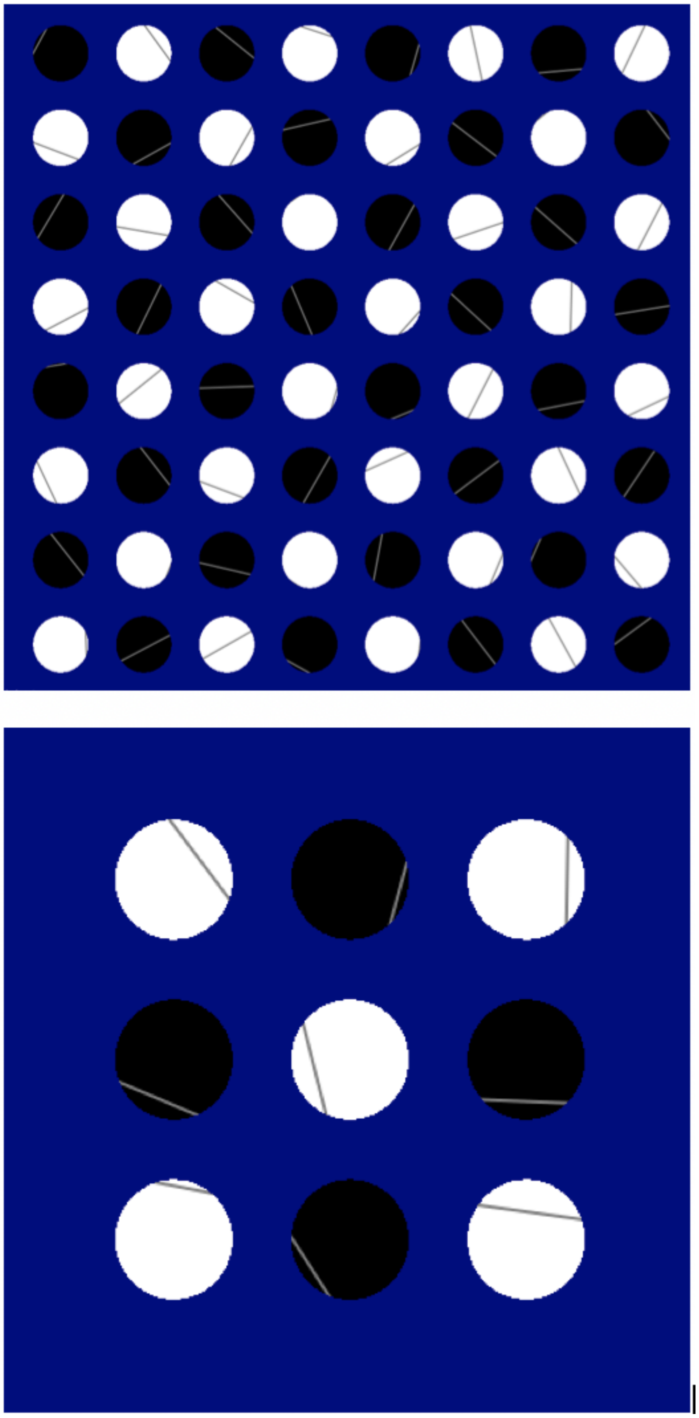

Figure 3. Examples of the 64-aperture (top) and 9-aperture (bottom) stimulus displays. Although the overall pattern moved in one coherent direction, each line segment was randomly oriented such that individual segments appeared to move in different directions (i.e., each line segment is subject to the aperture problem).

Each aperture contained a linear contour in a random orientation. Because of the aperture problem, the contour within each aperture only moved perpendicular to its orientation. However, the aggregate stimulus motion was consistent with the motion of a single pattern that was moving coherently in a particular, or true, direction. The true direction was chosen on each trial from a set of 12 different directions (0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, & 330 degrees from vertical).

In addition, this study utilized a grating orientation discrimination task identical to that used by Norman et al. (2013). Stimuli for this task included sine-wave luminance gratings with a 4-degree diameter, a spatial frequency of three cycles/degree, and 80% contrast (see Figure 4). Each individual grating was displayed in an oblique orientation, such that the average orientation of the bars across all the gratings was 45 degrees clockwise from vertical. On any given trial, two of these gratings were presented sequentially, with a 500 msec inter-stimulus interval. Each individual grating was displayed for 350 msec.

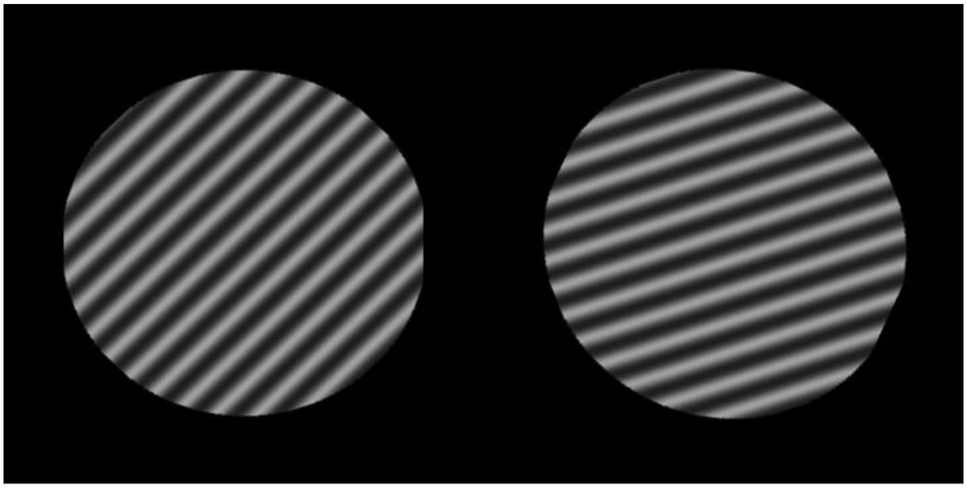

Figure 4. When displayed consecutively, the grating on the right demonstrates a 25-degree clockwise rotation as compared to the grating on the left.

Procedure

Each stimulus configuration in the coherent motion task was displayed to observers for 2.4 seconds. Each of the twelve direction conditions was displayed to observers five times under each of the two aperture density conditions, such that there were 120 trials total (12 x 5 x 2). After viewing each stimulus, the observers were asked to judge the direction of coherent motion by adjusting an arrow's orientation on the computer monitor such that it pointed along the perceived direction of motion. Observers were given the ability to fine-tune their judgments to a precision of one degree.

For the grating orientation task, observers were shown pairs of sinewave luminance gratings. After being presented with each pair, observers were asked to judge whether the orientation of the second grating (relative to that of the first) had rotated either clockwise or counterclockwise. Figure 4 demonstrates a 25-degree clockwise rotation. To begin, the first trial displayed differences in orientation of 10 degrees for younger observers and 25 degrees for older observers. Orientation discrimination thresholds were then found, as described in Experiment 2 of Norman et al. (2013). For all observers, each correct judgment on a given trial lead to a decrease in the difference in orientation between subsequent gratings, whereas each incorrect judgment lead to an increase in this difference. The initial step size was set at 0.35 degrees, which was halved after the first, third, and seventh reversals (i.e., the points at which the observer's performance "reverses," either by making a correct judgment after several mistakes or vice versa). The final threshold estimate was then obtained by averaging the orientation differences for the last eight reversals (there were 10 total reversals in the block of trials).

Results

Individual results for representative younger (CD, age = 22 years) and older adult (JG, age = 75) observers are displayed in Figure 5. Comparing the true global direction of motion with the perceived/estimated direction of motion, the observers' performance is clearly remarkable, with Pearson r correlation coefficients and best-fitting regression line slopes near 1.0. Even in the worst case illustrated, variations in the actual global direction of motion account for around 79% of the variance in the judged directions of motion (i.e., $r^2 = .79$ for older observer JG in the 9-aperture condition).

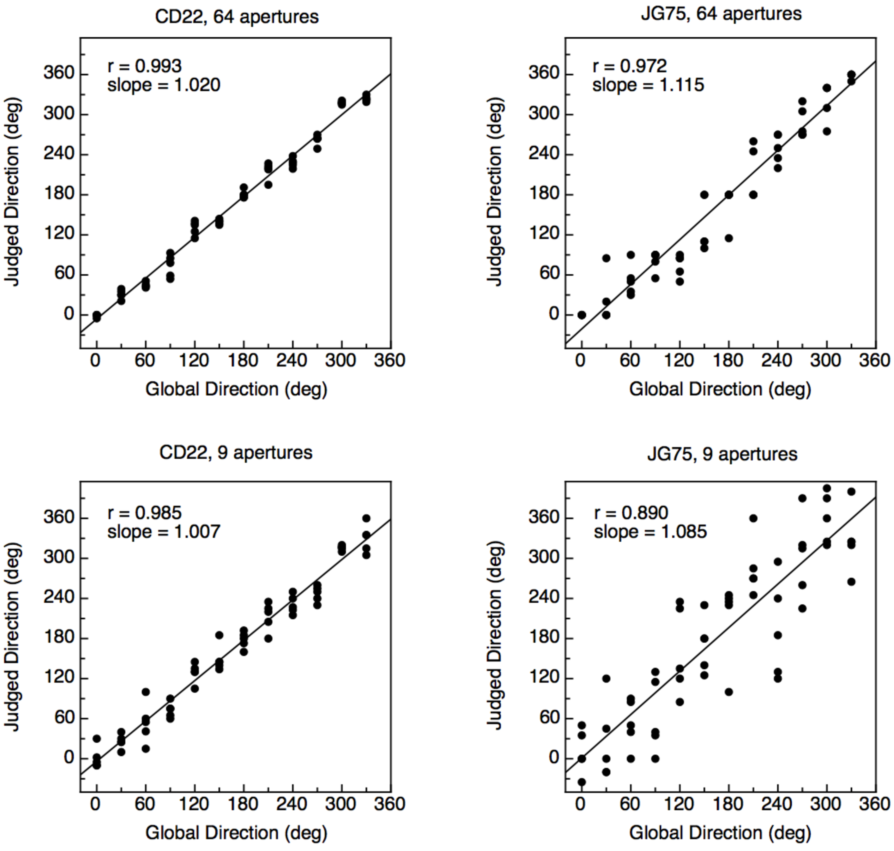

Figure 5. Individual results for a representative younger and a representative older observer. The observers' judged directions of motion for the 64- and 9- aperture conditions are plotted as a function of the actual global directions of motion. The solid line within each plot indicates the best-fitting linear regression line.

Effects related to accuracy and precision of judgments were evaluated using four-way Analyses of Variance (ANOVA). Two within-subjects factors (aperture density and direction of motion) as well as two between-subjects factors (age and sex) were included. A significant effect of aperture density on observers' errors (i.e., difference between actual and estimated directions of motion) was obtained ($F(1,28) = 61.73$, $p < .000001$; $\eta^2_p = .69$). Additionally, there was a significant effect of age ($F(1, 28) = 5.44$, $p = .027$; $\eta^2_p = .16$). Figure 6 illustrates the average errors made by the younger and older observers across both aperture conditions. The older adults' average errors were significantly higher than those of the younger adults, revealing a negative effect of aging on performance. Likewise, performance for the 9-aperture condition was much worse than that obtained for the 64-aperture condition. There was no significant interaction between age and aperture density ($F(1, 28) = .47$, $p = .497$, $\eta^2_p = .02$).

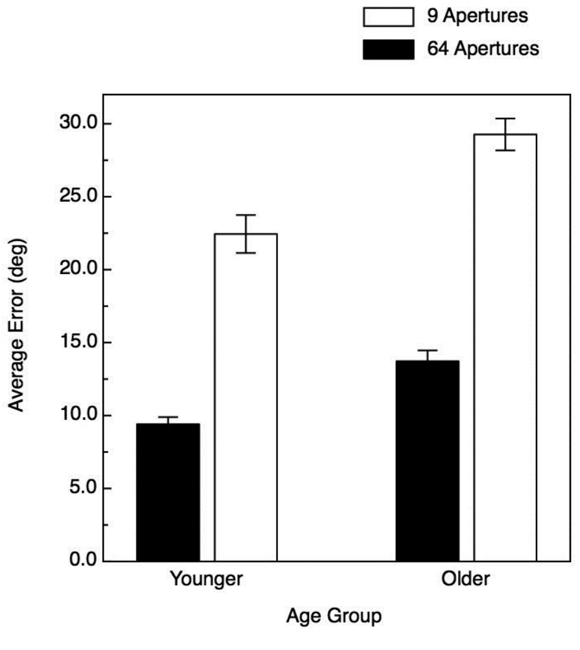

Figure 6. Average errors in direction judgment were significantly higher in the 9-aperture condition; the average error magnitudes were also higher for the older adults. There was no significant interaction between age and aperture density. Error bars indicate ± 1 SE.

As indicated in Figure 7, there was a significant main effect of motion direction (*F*(11, 308) = 7.1, *p* < .0000001; η^2_{p} = .20), such that the judgments were more accurate for the cardinal (i.e., 0, 90, 180, & 270 degrees from vertical) directions as opposed to the oblique directions. Figure 7 also demonstrates a significant interaction between aperture density and direction of motion (*F*(11, 308) = 2.8, *p* < .002; η^2_{p} = .09), indicating that the enhancement in performance for cardinal directions was much stronger for the 64-aperture condition and weaker for the 9-aperture condition.

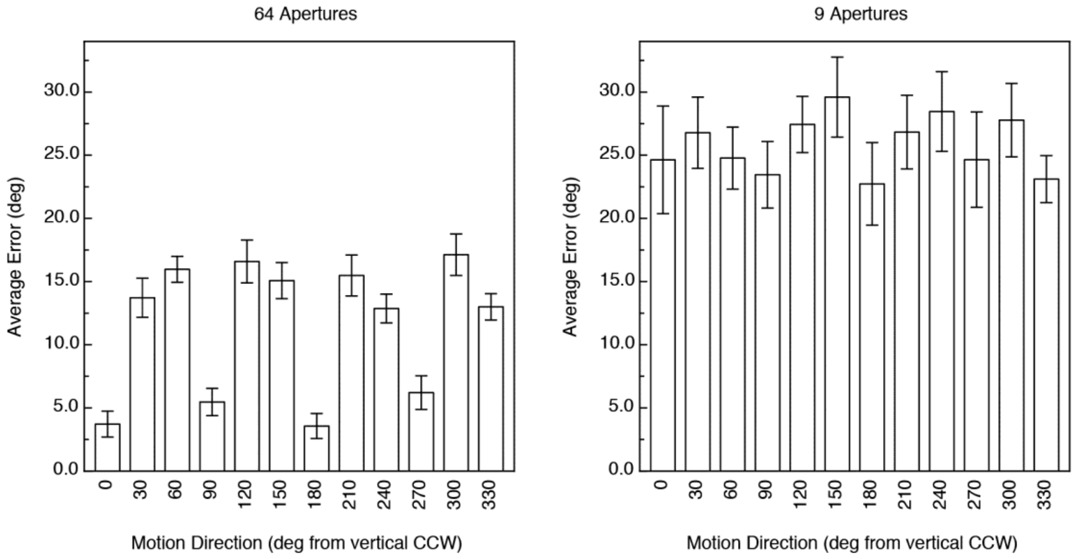

Figure 7. Average errors in direction judgment were significantly higher for oblique as compared to cardinal directions (especially for the 64-aperture condition). The error bars indicate ± 1 SE.

The precision of the observers' judgments was assessed using the standard deviations of the repeated direction estimates. There was a significant effect of aperture density (*F*(1,28) = 47.7, *p* < .000001; η^2_{p} = .63) on precision, but no significant effects of either age or sex. The standard deviations of the repeated judgments in the 9-aperture condition were 2.63 times higher than those obtained in the 64-aperture condition (averages of 20.0 and 7.64 degrees, respectively), revealing far greater precision in the 64-aperture condition.

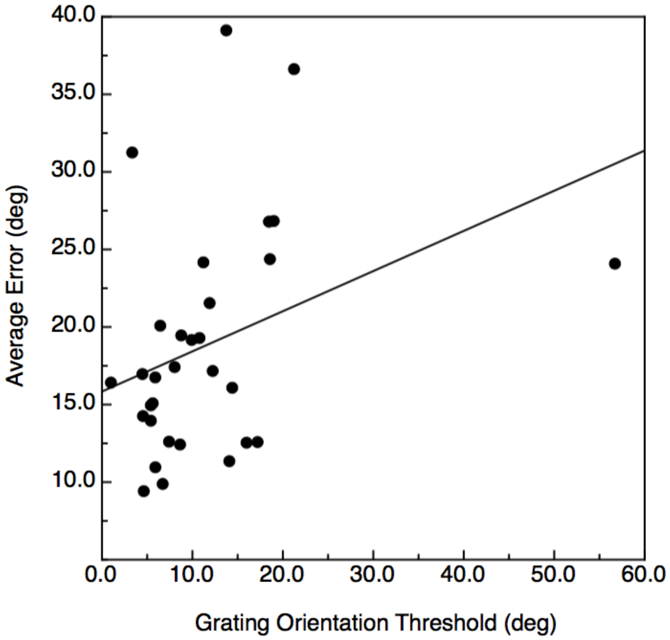

Figure 8. There was a positive and significant relationship between average error in direction judgment and the observers' grating orientation thresholds.

Finally, a positive relationship was observed between average errors in motion direction judgment (across all direction and aperture conditions) and grating orientation thresholds (see Figure 8). A grating orientation threshold was not determined for one younger observer, so the correlation reflects the relationship for the remaining 31 observers. Using a one-tailed test, this relationship was found to be statistically significant ($r(31) = .35$, $p = .028$). These results suggest that as the ability to judge the global direction of motion from locally-ambiguous motion signals decreases, so does the ability to discriminate grating orientation (shown by higher thresholds). Despite the fact that this relationship is statistically significant, it is important to note that the variability in observers' performance on the orientation discrimination task only accounts for 12% of the variability in performance for the direction of motion task (i.e., $r^2 = .12$).

Discussion

Although past research has examined the means by which human observers overcome the aperture problem (Adelson & Movshon, 1982; Amano et al., 2009; Mingolla et al., 1992), this is the first study to demonstrate any effects of aging on this particular ability. This experiment differs fundamentally from previous research demonstrating effects of aging upon the perception of translational motion (e.g., Atchley & Andersen, 1998; Ball & Sekuler, 1986; Bennett et al., 2007; Billino, Bremmer, & Gegenfurtner, 2008; Gilmore, Wenk, Naylor, & Stuve, 1992; Pilz, Miller, & Agnew, 2017; Roudaia, Bennett, Sekuler, & Pilz, 2010; Trick & Silverman, 1991), in that observers in the current experiment were required to effectively overcome the aperture problem in order to accurately assess motion direction. The previous research utilized stimulus displays consisting of moving dots (the individual motion direction of which remains unambiguous). However, this is not representative of solid objects within our natural environment (with internal and external contours), which *are* subject to the aperture problem. Thus, the current experiment fills a void in the scientific literature regarding aging and the perception of motion direction.

Similar to previous studies that found an age-related deterioration in the ability to visually judge the *speed* of motion (Bidwell et al., 2006; Norman et al., 2010; Norman et al., 2003; Raghuram, Lakshminarayanan, & Khanna, 2005; Snowden & Kavanagh, 2006), the current results document an adverse effect of aging upon the ability to accurately judge direction of global pattern motion (see Figure 6). Yet, despite a statistically significant decrease in performance with increased age, it remains clear that older adults can still effectively perceive the global direction of motion from sets of ambiguous motion signals (i.e., error magnitudes are relatively low).

Previous research has often found that observers can more accurately judge the direction of moving points for cardinal than for oblique directions (e.g., Ball & Sekuler, 1986; Gros, Blake, & Hiris, 1998; Krukowski, Pirog, Beutter, Brooks, & Stone, 2003; Loffler & Orbach, 2001). The same effect is demonstrated by the current results (see Figure 7), which extend this “oblique effect” to the ability of human observers to estimate global pattern motion direction from spatially-separated and locally-ambiguous motion signals. Although this effect has been well-documented psychophysically, the exact neurophysiological mechanism is unknown. However, a couple of hypotheses have been proposed. In their 1998 study, Gros et al. demonstrated isotropic motion sensitivity (i.e., no effect of direction for simple motion *detection*). However, similar to the results of the present experiment, their results indicated a greater ability to discriminate motion direction for the cardinal directions. The first of their hypotheses posits that the number of neurons tuned to detect cardinal directions is greater than the number of neurons devoted to detect oblique directions. In their second hypothesis, Gros et al. suggested that those neurons which are maximally responsive to cardinal directions (and directions close to cardinal) are tuned more narrowly than those tuned to oblique directions. This second hypothesis has also been described by Dakin, Mareschal, & Bex (2005) as a likely explanation for the oblique effect found in their results. Investigations into the neural basis of the oblique effect for static stimuli have supported both hypotheses (e.g., Li, Peterson, & Freeman, 2003).

In the cerebral cortex, motion sensitive neurons interact with each other using excitatory and inhibitory neurotransmitters such as glutamate and gamma amino butyric acid (GABA). Given that aging adversely affects GABA synaptic activity (Leventhal, Wang, Pu, Zhou, & Ma, 2003; Liang et al., 2010; Schmolesky, Wang, Pu, & Leventhal, 2000; Yang, Liang, Li, Wang, & Zhou, 2009a; Yang et al., 2009b; Yu, Wang, Li, Zhou, & Leventhal, 2006), one might expect that aging would negatively affect performance for the coherent direction of motion estimation task. Using a grating orientation discrimination task as a behavioral measure of GABA activity (Edden, Muthukumaraswamy, Freeman, & Singh, 2009), the present experiment was able to explore the potentially mediating effects of GABA on the relationship between aging and the ability to perceive global motion direction. Despite a statistically significant relationship between average errors in judgments of motion direction and the observers' grating orientation discrimination thresholds, this outcome (see Figure 8) was not particularly meaningful: variation in orientation discrimination abilities only accounts for about 12 percent of the variance in performance on the global motion direction task. It therefore remains unclear the extent to which reduction in GABA activity is responsible for age-related deteriorations in the ability to perceive the direction of motion from a sample of locally-ambiguous motions.

The results of the present experiment reveal that, despite significant deteriorations in performance with increases in age, older adults retain a substantial ability to effectively perceive coherent direction of *translational* motion from the integration of spatially-separated and locally-ambiguous motion signals. Nevertheless, do the current results for translational motion extend to other forms of motion? Future studies should examine the effects of aging on the ability to overcome the aperture problem for rotation, expansion, and other types of global motion (e.g., Lappin, Norman, & Mowafy, 1991). In addition, the current study showed that the ability to judge coherent direction of motion is adversely impacted by a reduction in the number of locally-ambiguous motion signals (i.e., from 64 to 9 apertures). Future research should explore further reductions in the number of available motion signals, and possibly determine the least amount of locally-ambiguous motions necessary to overcome the aperture problem and effectively judge direction of coherent motion.

In summary, the results of the current study indicate that human observers, both younger and older, retain an amazing ability to integrate widely separated motion signals into a coherent perception of global motion. Despite some degree of deterioration with age, the human visual system is able to solve the aperture problem to a remarkable degree.

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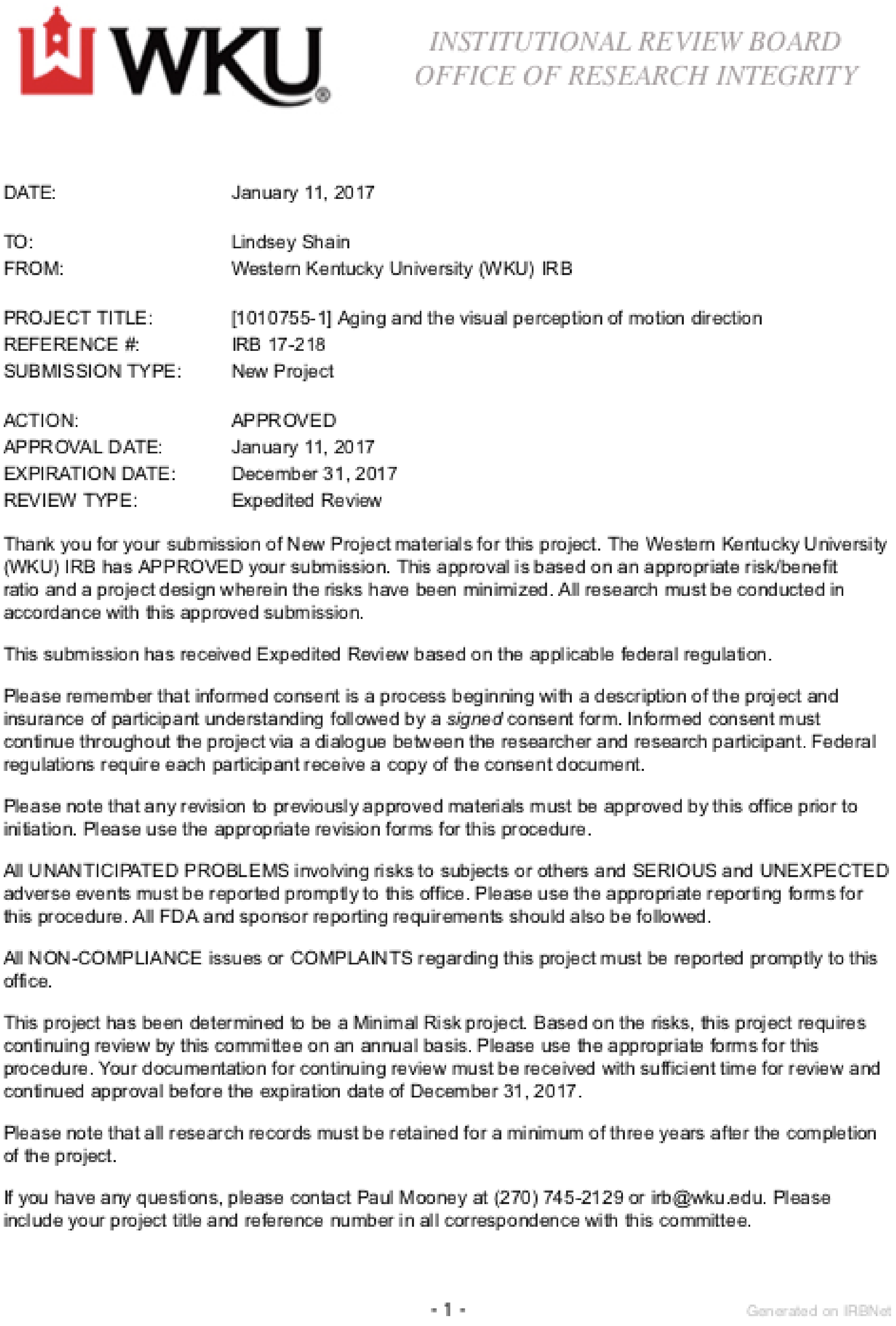

WKU

INSTITUTIONAL REVIEW BOARD
OFFICE OF RESEARCH INTEGRITY

DATE:	January 11, 2017
TO:	Lindsey Shain
FROM:	Western Kentucky University (WKU) IRB
PROJECT TITLE:	[1010755-1] Aging and the visual perception of motion direction
REFERENCE #:	IRB 17-218
SUBMISSION TYPE:	New Project
ACTION:	APPROVED
APPROVAL DATE:	January 11, 2017
EXPIRATION DATE:	December 31, 2017
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 December 31, 2017.

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 Paul Mooney at (270) 745-2129 or irb@wku.edu. Please include your project title and reference number in all correspondence with this committee.