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Aging and Bilateral Symmetry Detection

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The salience of hilateral symmetry varies as a function of the orientation of the symmetry axis. Vertical symmetry is most salient, followed by horizontal and then oblique orientations. We tested symmetry detection in different age groups to determine whether performance of this intermediate-level visual task is affected by normal, non-pathological aging. We tested forty participants and analyzed the results with respect to age group and symmetry orientation (vertical, horizontal, and 45 degree oblique). There was a vertical symmetry detection advantage for all participants, where sensitivity was highest for vertical symmetry, followed by horizontal symmetry, and then the oblique symmetry. Sensitivity to symmetry did not differ for the two younger age groups (aged 19–39 and 40–60), but declined significantly for the group aged 61–70, and declined again for the oldest group aged 71–80. This age-related difference in sensitivity to symmetry was not reflected in a measure of bias, where there were no differences as a function of age.

THERE are clear age-related declines in visual acuity, contrast sensitivity, temporal-frequency sensitivity, visual fields, and motion sensitivity during normal (nonpathological) aging (Crassini, Brown, & Bowman, 1988; Owsley & Sloane, 1990; Rubin et al., 1997; Spear, 1993). In some cases the changes in lower level visual abilities correlate with age-related deficits in higher level tasks, such as the link observed between poor face recognition and declines in contrast sensitivity (Owsley, Sekuler, & Boldt, 1981; Owsley & Sloane, 1987). In other cases, visual abilities relying on the integrity of the visual system are unaffected by aging, such as in the case of Vernier acuity thresholds (Lakshminarayanan & Enoch, 1995). Thus, deficits in one aspect of vision in elders do not always translate to predictable declines in another area, and we do not understand why this occurs (Hoyer & Plude, 1982; Walsh, 1988).

One possible cause of age-related declines in visual functioning is that processes requiring multiple stages become less efficient with age, whereas those processes relying only on the output of computations completed in the primary visual cortex are unaffected. That is, as more synaptic connections are involved in a sequence of computations required to complete any process, there is a greater chance of an error occurring in that sequence (Habak & Faubert, 2000; Hoyer & Plude, 1982; Walsh, 1988). Thus, processes such as object and face recognition show age-related declines, whereas other visual functions that could be completed in fewer stages, such as static Vernier acuity, are less affected by aging (Lakshminarayanan, Aziz, & Enoch, 1992; Lakshminarayanan & Enoch, 1995; Odom, Vasquez, Schwartz, & Lindbergh, 1989; Whitaker, Elliott, & McVeigh, 1992).

Bilateral symmetry detection is an example of an intermediate level visual task where the structure can be detected by the filtering of the outputs of cells in the striate cortex (e.g., Dakin & Watt, 1994; Gurnsey, Herbert, & Kenemy, 1998; Osorio, 1996; Rainville & Kingdom, 2000). One might expect symmetry detection to decline with age because of changes in the efficiency of low-level visual functions and because of age-related changes in higher cortical functions. Thus, changes in the salience of symmetry with increasing age could provide an index of how long-range visual connections change during the life span.

Bilateral symmetry (where one half of a pattern is a mirror reflection of the other half) salience varies as a function of the orientation of the symmetry axis. Vertical symmetry is most salient, followed by horizontal and then oblique orientations (e.g., Herbert & Humphrey, 1996; Wagemans, 1996). There have been various accounts for this pattern of orientation differences, resting either on the idea that there is a hard-wired preference for vertical symmetry (based on ideas initially proposed by Mach, 1906, and elaborated on by Braitenberg, 1990, and Julesz, 1971). Bilateral symmetry may be detectable based on processes in the primary visual cortex (see, for example, Dakin & Herbert, 1998; Gurnsey et al., 1998; Rainville & Kingdom, 2000), in which case it should be resistant to age-related declines. In contrast, some research on symmetry detection has indicated that top-down influences occur, in that attention and priming influence the salience of symmetry at different orientations (Pashler, 1990; Wenderoth, 1994; Wenderoth & Welsh, 1998). It has been suggested that higher-level factors, such as the observer's frame of reference, affect the selection of a possible symmetry axis (Palmer & Hemenway, 1978; Rock & Leaman, 1963). If such a top-down influence exists, then age-related declines in symmetry detection, associated with changes in higher-level cortical function that result from aging, may occur. To date, there has been no research on symmetry detection in aging.

METHODS

Participants

We recruited forty participants from staff and patients at the Ophthalmology department of the Sir Mortimer B.

Davis Jewish General Hospital in Montreal, Canada. The research followed the tenets of the Declaration of Helsinki. Participants gave informed consent after having the experimental procedure explained to them, and the research was approved by the review boards of the Hospital and University of Montreal. Minimum acceptable corrected acuity (monocular) was 20/30 (1.5 LogMAR). We took the visual acuities from the participants' charts, with their permission. These values represent their best corrected far acuities, and all participants were tested with their best eye and using any needed corrective lens. We tested the acuity of each participant using Snellen and LogMAR charts in the Ophthalmology department of the Sir Mortimer B. Davis Jewish General Hospital. No participants reported any visual or neurological problems. We excluded potential volunteers if they had a history of diabetic retinopathy, glaucoma, or macular degeneration. All participants completed the testing in one visit to the laboratory based in the ophthalmology clinic at the Hospital.

After testing, we divided participants into different groups based on their age: young adults (19–39 years, $n = 10$, mean LogMAR acuity $= 1.13, s = 0.21$); middle-aged (40–60 years, $n = 10$, mean LogMAR acuity $= 1.1, s = 0.21$); young-old (61–70 years, $n = 8$, mean LogMAR acuity $= 1.34$, $s = 0.19$); and old-old (71–80 years, $n = 9$, mean LogMAR acuity $= 1.33$, $s = 0.22$). We did not analyze the results from 3 other participants because performance was at chance for all symmetry orientations (1 in the middle-aged group, and 2 in the old-old group).

Apparatus and Stimuli

We conducted testing using a Macintosh 7200 and Apple high-resolution monitor (Apple Computer, Cupertino, CA). Data collection and stimulus presentation were controlled by Pixx, an application developed by the Vision Laboratory at Concordia University, Montreal, Canada. The viewing distance (114 cm) was maintained using a combination chin/head rest. A fixation cue was presented on the screen between each trial.

The stimuli consisted of asymmetric and symmetric dot patterns presented for 40 frames (0.533 seconds at the refresh rate of 75 Hz) centered on the high-resolution monitor. The patterns were composed of 100 white dots (80 cd/m^2) placed within an invisible circular region 2 degrees in diameter. The monitor screen was dark aside from the patterns, and the contrast was 99% (background screen luminance of 0.5 cd/m^2). The computer generated all patterns at random. The dots could appear anywhere within the circular region. Patterns were symmetric about an axis oriented vertically, horizontally, or at 45 degrees clockwise from vertical (only this one oblique orientation was tested, both to limit the number of trials to be completed in the test session and because there are no indications of differential performance for the left and right oblique orientations in the literature, Herbert & Humphrey, 1996). On symmetric trials, a random pattern of 50 dots was generated and reflected about the axis specified for that block of trials. Schematic versions of a vertically symmetric and an asymmetric pattern are provided in Figure 1A. Note that the dots appeared on the monitor screen as small circular white blobs rather than as square points as in the figure.

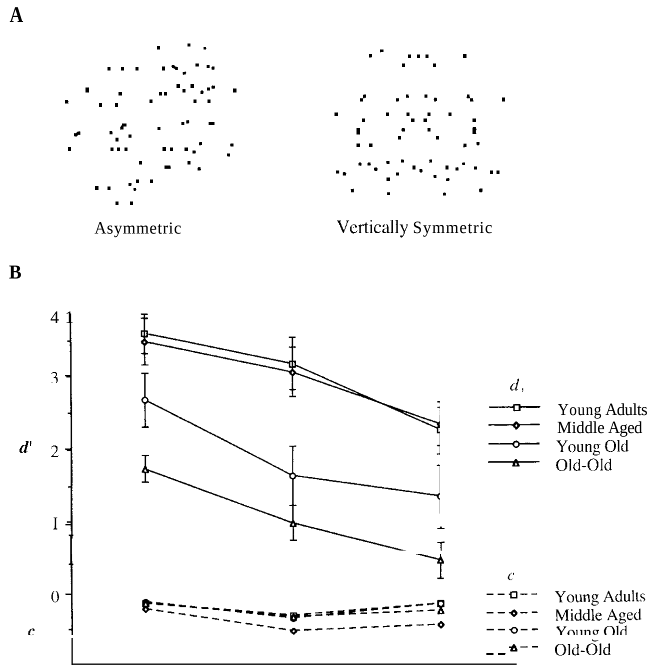

Figure 1. **(A)** Reverse contrast versions of the kinds of patterns presented to subjects. Note that the dots were circular blobs when presented on the cathode ray tube screen. **(B)** Mean d' and c for each age group plotted as a function of the orientation of the symmetry axis. Error bars indicate the standard error of the mean for d'.

Procedure

Testing was monocular using the participant's preferred eye. We presented a total of 60 asymmetric and 60 symmetric patterns in each of three blocks of trials. We tested each symmetry orientation on a different block of trials. On each trial participants had to respond yes or no that the pattern was symmetric. The experimenter (Jason Singh) entered each response on the keyboard. We adopted this procedure because pilot testing indicated that some of the older participants found it difficult to look at the screen, make their judgment, find the right key to press, then return to the task. Trials were self-paced, so we initiated each trial when the participant was ready to respond and was fixating upon the fixation dot placed in the center of the screen between trials. There was no feedback as to whether or not the response was correct.

Each block of experimental trials was preceded by a practice block of 10 trials (5 asymmetric and 5 symmetric, ordered randomly) to familiarize the participants with the task and with detecting symmetry at each particular orientation. We tested each symmetry orientation in a separate block of trials, and participants knew which orientation we were assessing. We also tested vertical symmetry first and randomly selected the subsequent orientations. We did this because naive participants associate vertical symmetry with the concept of bilateral symmetry, so this made explaining the task easier. Each sequence of trials was randomly generated using the presentation software, with the only proviso being that no more than six symmetric or asymmetric patterns could appear in a row.

Results

The symmetry detection performance for each age group is presented in Figure 1B, where d' and c are plotted for each symmetry orientation tested. These two statistics give a measure of sensitivity and bias, respectively. Both are computed from z scores for "Symmetric" responses made by participants. When an individual said "Symmetric" and was correct, the response was defined as a hit. When the response "Symmetric" was given to an asymmetric pattern, it was termed a *false alarm*. Minimizing false alarms and maximizing hits results in a high d' value. Higher d' values indicate greater sensitivity. A d' equal to 1 is equivalent to an overall proportion of correct responses of 70%. The formula for c is analogous to that for d', but rather than taking the difference between the proportions of hits and false alarms, it is computed by taking their sum multiplied by -0.5 (Macmillan & Creelman, 1991). If the hit rate is high and false alarm rate low, c results in a score near 0. Scores less than 0 indicate a preponderance of "Symmetric" responses regardless of trial type (lots of hits and false alarms), and positive values of c occur if there are more "Asymmetric" responses regardless of stimulus type (few hits and few false alarms). In some cases perfect performance was obtained, where the z scores used in calculating d' would be infinite. An arbitrary z score of ± 2.5 was assigned when no misses or false alarms were made so that a d' could be calculated. Thus, the maximum possible d' was 5.

We analyzed the results using a split-plot analysis of variance with Age Group as a between participants factor (4 levels) and Symmetry Orientation as a within-subjects factor (3 levels). For d', there was no significant Age $\times$ Symmetry Orientation interaction, $F(6,66) = 1.6, p > .1$. However, there was a significant main effect for age group, $F(3,33) = 11.2, p < .01$, and a significant main effect for symmetry orientation, $F(2,66) = 42.3, p < .01$. These results confirm the pattern of results illustrated in Figure 1B. Sensitivity did not differ between the young and middle-aged groups, but all other age-group comparisons were significant ($p < .05$, Newman-Keuls test). The old-old group had the lowest sensitivity, the young and middle-aged groups the highest sensitivity, with the young-old group falling between the others. For each group the mean d' differed significantly for each symmetry orientation ($p < .05$). Performance was best for vertical symmetry, followed by horizontal symmetry. Oblique symmetry was most difficult to detect. As reported in the Methods section, average LogMAR acuities increased with age group, but the range of acuities did not differ with age. We reanalyzed the d' data with acuity as a covariate. This analysis showed no significant influence of acuity on d' ($F < 1$), but the significant effect of age remained, $F(3,33) = 19.8, p < .01$.

We repeated the analyses for c. There was neither a main effect of age ($F < 1$) nor an interaction between age and symmetry orientation ($F < 1$). There was a significant effect of symmetry orientation, $F(2,66) = 6.3, p < .01$, reflected in values of c closer to zero for vertical symmetry compared with the other two orientations (which were not significantly different from one another). This analysis revealed that participants were more likely to identify asymmetric patterns as symmetric when looking for nonvertical symmetry orientations.

Discussion

The observed symmetry orientation difference replicates the results of many other studies, and the sequence of orientations was the same for all age groups (sensitivity for Vertical greater than Horizontal, greater than Oblique). If practice affected symmetry detection, the sequencing of trial blocks we used would have minimized the chances of obtaining the vertical advantage. The fact that this advantage was obtained despite testing Vertical first is another indication of the strength of that effect. Whatever the source, this orientation anisotropy does not vary across different age groups. The results demonstrate a decline in the overall ability of participants older than age 60 to see symmetry. However, it must be stressed that although the change in d' for the older groups was significant, it was relatively small. The young-old and old-old participants could still detect symmetry at d' consistent with 70% accuracy.

Although we used participants' far acuities in determining which eye to test and then tested at a viewing distance of 114 cm, we believe acuity is not a significant factor for the following reasons: (a) we asked all participants if they could see the individual dots, and they reported they could; (b) The fixation cue presented between trials was the same size as an individual element composing the patterns, and this dot could be seen by all participants; and, (c) There is evidence that there is little change in the ability to detect symmetry in spatially filtered patterns and blurred patterns (Barlow, 1980; Dakin & Herbert, 1998). Thus, we did not find it surprising that the minor decrease in average acuity for the older participants did not covary with symmetry detection accuracy in this study. Age-related declines in contrast thresholds should have had no effect on the results because the individual dots and the patterns as a whole were suprathreshold. We maximized the contrast by presenting white dots on a black background, and all participants reported being able to resolve the individual dots and the patterns. Although we screened participants using their far acuities and tested at an intermediate distance, the absence of significant influence of acuity on d' argues against differences in acuity accounting for the age-group differences. The sequence of orientation differences did not change across the age groups, arguing against changes in the frame of reference with age. The pattern of these results is consistent with a general decline in performance associated with nonpathological aging. Although low-level explanations cannot be ruled out (the components of the dot patterns *should* be very salient to all participants, but this was not measured explicitly), we speculate that the general decline in performance is consistent with some unspecified changes in intermediate and higher level visual functions with aging. The deficit in symmetry detection for both groups of older participants suggests they have more difficulty matching elements across the symmetry axis. Such comparisons require an intact neural network spanning a few degrees of visual angle, which correlates to a large area in the visual cortex with interconnections between areas separated by relatively large cortical distances.

It is noteworthy that there was no difference in symmetry detection for participants younger than age 60. In combination with evidence that low-level visual abilities are preserved in aging, the observed decline in symmetry detection performance after age 60 suggests that observed difficulties in higher level tasks may result from problems at all stages of visual processing that accumulate with the number of steps required to complete the visual computations (Habak & Faubert, 2000; Hoyer & Plude, 1982; Walsh, 1988). A diffuse neural loss occurring during nonpathological aging would be expected to have a greater effect on higher level tasks than on lower level tasks based on the increasing numbers of neurons and synapses involved in more complicated processing (Spear, 1993; Weale, 1982). Habak and Faubert (2000) showed that the perception of simple motion stimuli (moving gratings) was similar in young and elderly groups, but complex motion perception was worse in the older group (where moving dot textures are presented). Complex motion perception requires more processing steps than are required for perceiving simple motion, and Habak and Faubert argue that this is why the difference as a function of age is primarily seen for certain types of moving stimuli. We speculate that the decline in performance observed in the present study reflects the fact that symmetry detection relies on processes occurring after visual information arrives in the primary visual cortex (Dakin & Herbert, 1998; Gurnsey et al., 1998). This conclusion is speculative and requires further study, because it has been demonstrated that older adults use binocular cues just as well as younger subjects when detecting masked Gabor patterns (Speranza, Moraglia, & Schneider, 1995). That finding is consistent with a conclusion that more central processes related to binocular vision must be intact in the older population. There were some minor differences between the older and younger participants in Speranza and colleagues' study, which is consistent with our finding that older participants could still detect symmetry, just not as well as younger participants.

In conclusion, the salience of symmetry as a function of orientation does not change, because this is most likely a direct result of early visual processing, where different orientations are treated differentially by cortical neurons (Appelle, 1972; Essock, 1980). The differences in symmetry detection across age groups observed in the present study are consistent with normal, but less effective, operation of whatever neural circuitry is involved in symmetry detection.

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