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Aging and the perception of speed

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Abstract. Two experiments were conducted to explore the potential effects of aging upon the perception and discrimination of speed. In the first experiment, speed difference thresholds were obtained for younger and older observers for a variety of standard speeds ranging from slow to fast. The second experiment was designed to evaluate the observers' ability to discriminate differences in the speed of moving patterns in the presence of significant amounts of noise (the noise was manipulated by limiting the lifetimes of individual moving stimulus elements). The results of both experiments revealed a significant deterioration in the ability of the older observers to perceive or detect differences in speed. While the presence of noise was found to affect the observers' discrimination performance, it affected both younger and older observers' thresholds in a proportionally equivalent manner—the older observers were no more affected by noise than the younger observers.

1 Introduction

Over the past 20 years, there has been a sustained and growing interest in the perceptual capabilities of older observers—in many studies the perceptual effects that accompany the process of aging have been examined. One focus of research has concerned the perception of motion. For example, there have been studies of contrast sensitivity for static and moving luminance gratings (Owsley et al 1983), the perception of direction of moving patterns (Ball and Sekuler 1986), the perception of coherent motion (Trick and Silverman 1991; Gilmore et al 1992), and the perception of 3-D structure/shape from motion (Andersen and Atchley 1995; Norman et al 2000). There has been little research, however, on how precisely older observers perceive the *speed* of moving patterns.

Despite the fact that the perception of speed has not often been studied in conjunction with aging, it is important to investigate it thoroughly. The failure to adequately perceive the speeds of oncoming vehicles has been implicated as the cause of a significant proportion of all traffic accidents (Hills 1980). B Brown and Bowman (1987) did compare the abilities of younger and older observers to perceive differences in the speed of moving objects (and found no significant difference), but in the single experiment in that study speed discrimination thresholds were obtained for only a single standard speed. Moreover, there was no attempt to assess whether speed discrimination thresholds vary as a function of other important stimulus parameters, such as the presence of noise, etc. Festa and Welch (1997) have recently shown that the ability to detect differences in the speed of moving objects is impaired by the presence of noise (also see Bravo and Watamaniuk 1995). In the following experiments, the primary purpose was to re-examine speed discrimination among the elderly for a wider range of speeds than has been examined to date. An important secondary purpose was to evaluate the robustness of older observers' abilities to discriminate differences in speed when significant amounts of noise are present within moving patterns.

2 Experiment 1

The specific purpose of this experiment was to evaluate the ability of younger and older observers to discriminate differences in speed at a variety of different standard speeds. The standard speeds were chosen to fall within a range of speeds similar to (but wider than) those investigated by McKee (1981).

2.1 *Method*

2.1.1 *Apparatus.* The stimulus displays (1280 × 1024 pixel resolution) were rendered by a dual-processor G4 Power Macintosh (533 MHz) provided with OpenGL and hardware acceleration (Radeon 8500 graphics accelerator, ATI Technologies, Inc.), and were viewed on a 22 inch Mitsubishi Diamond Plus 200 color monitor. The moving displays were viewed by the observers at a distance of 100 cm.

2.1.2 *Stimulus displays.* Two elongated moving strips (each containing either 100 low-contrast circular spots or bright high-contrast points) like those used by Todd and Norman (1995) were displayed on every trial. The diameter of the circular spots was 0.2 deg. The length and width of the strips subtended 21.35 deg and 0.57 deg, respectively, leading to a spot (or point) density of 8.2 deg^2. The moving spots/points were presented against a gray background with a luminance of 5 cd m^{-2}. The contrast of the circular spots (against the background) was always set to be 10 times that of each observer's individual contrast threshold, which was measured with a Pelli–Robson contrast sensitivity chart (Pelli et al 1988). The average contrast threshold for the younger observers was 1.18%, while that for the older observers was 57% higher, or 1.85% (cf Haegerstrom-Portnoy et al 1999; Brabyn et al 2001). The luminances and contrasts within our stimulus displays were measured and verified with a Minolta LS-110 photometer. A static view of a representative stimulus pattern is shown in figure 1.

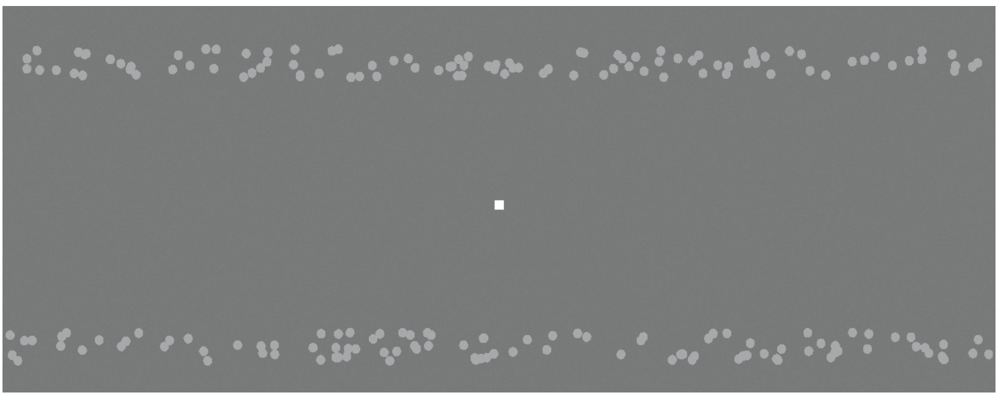

Figure 1. An example of the stimulus displays used in the current experiment. The observers viewed two moving strips of circular spots (depicted) or points translating horizontally with different speeds. The observers' task was to fixate the square fixation marker at the center of the display and judge which of the two strips was moving with the faster speed. The contrast between the circular stimulus elements and the background in this figure is much higher than that used in the actual experiment.

One of the strips moved at one of the three standard speeds (1.22, 5.48, and 24.34 deg s^{-1}—these three standard speeds are evenly spaced in log units), while the other strip moved at a slower speed. The moving elements in both strips translated in a horizontal direction (either from left to right or right to left, determined randomly on each trial) in a continuous motion. When an element in either strip reached the leading edge and thus moved out of the stimulus window, its position was recycled back to the beginning of the window to begin its journey again (although its vertical position was randomly changed at the time of 'recycling' so that the moving stimulus pattern was constantly changing and never repeated itself at any moment of time). The observers were required to maintain fixation upon a small rectangular fixation marker located in the center of the screen.

Each of the strips was offset in a vertical direction from the fixation point by 2.86 deg (this value is intermediate between the two eccentricities used by Todd and Norman 1995). The total angular separation between the two strips was therefore 5.72 deg. The individual frames of the apparent motion sequences were updated at a temporal rate of 60 Hz. The observers could view the moving stimuli for as long as they needed to make a judgment (ie there was no preset time limit).

2.1.3 *Procedure.* The observer's task on any given trial was to indicate which strip's motion was faster, the top or the bottom. No feedback was given regarding the observers' performance. Whether the faster (ie standard) speed was located at the top or bottom was randomly chosen on each trial. The initially large difference in speeds between the standard and test strips was gradually decreased according to the PEST (parameter estimation by sequential testing) adaptive procedure (Taylor and Creelman 1967). This adaptive PEST procedure was used to find the observer's speed discrimination threshold (75% point of the observer's psychometric function) for each of four conditions: moving circular spots at all three standard speeds (slow, medium, and fast) and moving points at the medium standard speed. Separate blocks of trials were run for each of these four conditions—the order of the blocks was determined randomly for each observer.

2.1.4 *Observers.* Thirty-two observers participated in the experiment, sixteen older than 60 years (mean age 72.6 years, $\sigma = 5.5$ years), and sixteen aged 27 years or less (mean age 21.8 years, $\sigma = 2.2$ years). The older observers were screened for the presence of macular degeneration, glaucoma, cataracts, or other retinal or eye problems. All observers' acuity was measured at a distance of 100 cm with the aid of a Landolt C chart specifically created for our viewing distance according to the specifications given by Riggs (1965). The younger observers' mean acuity was 1.0 min of arc^{-1}, while that for the older observers was 0.7 min of arc^{-1} (1.0 min of arc^{-1} is equivalent to 20/20 vision measured at 20 ft (6 m); 0.67 min of arc^{-1} is equivalent to 20/30 vision; older adults' vision is usually not well corrected for a 1 m viewing distance, since traditional bifocals usually correct visual acuity only for extremely near reading distances of 40 cm and for very far distances of 3–6 m—it is a fact, however, that we often view moving objects at moderate distances within several feet of ourselves, for example for purposes of reaching and grasping). In each age group of sixteen, there were eight males and eight females.

In the younger age group, half of the observers viewed the stimulus displays and performed the speed discrimination judgments wearing 0.5 neutral-density filters (Kodak Wratten No. 96) in order to decrease the intensity of the projected moving retinal patterns by two-thirds (they also viewed the Pelli–Robson contrast sensitivity chart wearing the neutral-density filters). Weale (1963, page 168) has shown that the retina of an average 60-year old receives only one-third of the light that the retina of a 20-year old would receive. In our current study, by using the 0.5 neutral-density filters for half of the younger observers, we are making their retinal images similar to those of the older observers. This technique has also been used by Sekuler and Owsley (1982). If there is an age-related effect upon the ability to perceive differences in speed, this manipulation will allow us to determine if the effect is due to optical or neural factors.

2.2 *Results and discussion*

The observers' speed discrimination thresholds expressed as Weber fractions are shown in figure 2. The results for the two younger age groups, with and without the 0.5 neutral-density filters, have been combined, since there was no significant difference between the performance of those groups (two-way split-plot factorial ANOVA, $F_{1,14} = 0.28$, $p > 0.05$). As can be seen from an inspection of figure 2, the obtained discrimination performance was best for both age groups at the middle standard speed. The average Weber fraction for that speed was 5.1% for the younger observers (replicating the earlier results of McKee 1981) and 8.7% for the older observers—the older observers' thresholds were 71% higher than those of the younger observers. The ability to discriminate speed deteriorated at both the low and high standard speeds for both the younger and older observers (cf Orban et al 1984).

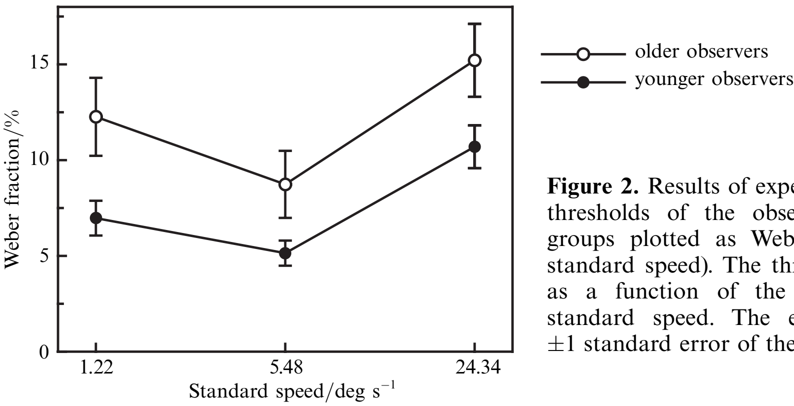

Figure 2. Results of experiment 1: combined thresholds of the observers in both age groups plotted as Weber fractions (% of standard speed). The thresholds are plotted as a function of the magnitude of the standard speed. The error bars indicate ±1 standard error of the mean.

The speed discrimination thresholds shown in figure 2 were subjected to a two-way split-plot factorial analysis of variance (one between-subjects factor: age; and one within-subjects factor: standard speed). There was a main effect of age ($F_{1,30} = 6.8$, $p = 0.014$) and a main effect of the standard speed ($F_{2,60} = 16.1$, $p < 0.0001$). The interaction between age and standard speed was not significant ($F_{2,60} = 0.3$, $p > 0.05$).

Our finding that there are significant differences in the abilities of younger and older observers to perceive differences in speed is different from that of B Brown and Bowman (1987), who found comparable performance. There are a variety of possible reasons for the different results. First, it may be important that our study evaluated the abilities of more observers (thirty-two observers in our experiment versus twenty in the experiment of B Brown and Bowman). A second reason may be the methodology used by B Brown and Bowman: each observer in their study performed only 10 judgments for each of 7 test stimuli in a single block of trials, using the method of single stimuli. Therefore, each observer's psychometric function was determined by only 70 trials. It is common practice for psychometric functions to be based upon 300 (see, for example, McKee 1981; Festa and Welch 1997) to 800 trials (Norman and Todd 1996, 1998). Thresholds derived from psychometric functions based upon only 10 trials per experimental condition (70 trials per psychometric function) are variable and may not be accurate.

The results of the present experiment would seem to indicate that there is an age-related deficit in the ability to perceive differences in the speed of moving objects. We wanted to verify that this is a real effect of aging and determine whether this deficit is stable or would perhaps disappear or be substantially reduced with additional practice with the task. Towards that end, we selected those older observers ($N = 7$) that had the highest thresholds (Weber fractions over 15%) at the fastest standard speed. Those observers participated in three additional experimental sessions to see whether their performance would remain steady over time or would perhaps improve as a result of additional experience in judging speed. The results are shown in figure 3. As can be seen from an inspection of the figure, there was an initial modest improvement in performance (confirmed by a one-way within-subjects ANOVA; $F_{3,18} = 3.4$, $p < 0.05$). It is important to note, however, that this improvement did not continue; performance for the older observers never approached the levels exhibited by the younger observers in the same condition (mean Weber fraction for the older observers in session 4 of figure 3 was 17.9%; that of the younger observers in the analogous condition was 10.7%). A Tukey's HSD a posteriori test of the data in figure 3 showed that the only significant difference was between sessions 1 and 2—there was no significant difference between sessions 1 and 3 or between sessions 1 and 4. The initial improvement due to additional practice between sessions 1 and 2 did not continue, and we must therefore conclude that there is indeed an age-associated reduction in the ability to perceive differences in speed, independent of experience with the task.

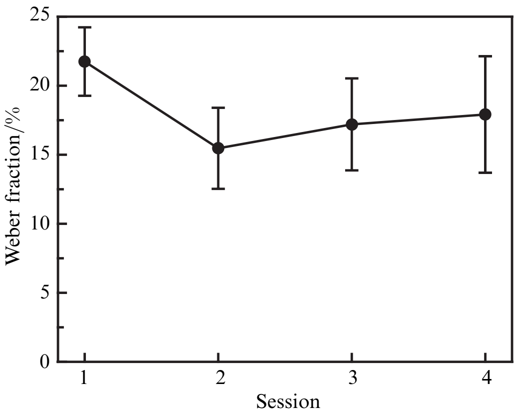

Figure 3. Results of experiment 1: the effects of additional experience and practice upon older observers' speed discrimination thresholds. The error bars indicate ±1 standard error of the mean.

Given that there was some difference in acuity between the younger and older observers, we wanted to verify that the differences in observed acuity could not account for the differences in speed discrimination thresholds that we observed between the two age groups. A plot of speed discrimination thresholds for the fastest standard speed for the older observers as a function of their visual acuity is shown in figure 4. One can readily see that there is no significant relationship between performance on this task and acuity—in fact, the Pearson r correlation coefficient was -0.18, indicating that only 3.2% (r^2) of the variance in the older observers' thresholds could be accounted for by the variability in their acuities.

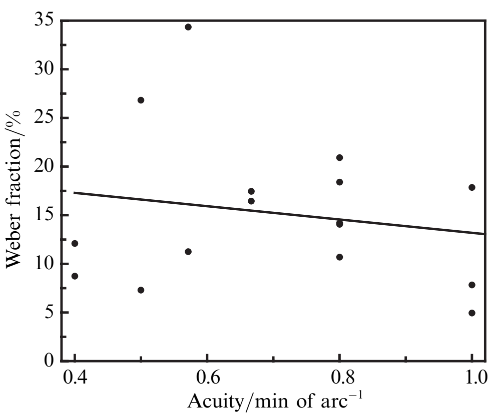

Figure 4. The older observers' thresholds at the fastest standard speed as a function of their visual acuities. The best-fitting regression line is also plotted. Refer to the text for a discussion of the relationship between performance on this task and visual acuity.

The results of this experiment clearly show that the older observers performed more poorly on the speed discrimination task than the younger observers. The results shown in figure 5, however, indicate that within the group of older observers itself, there is no further relationship between the specific individual ages of the observers and their speed discrimination performance. In fact, the Pearson *r* correlation between the individual ages and speed discrimination thresholds (for the fastest standard speed) was -0.027, which is essentially zero. As figure 5 indicates, there are observers in their 80s who have low thresholds (good performance), and there are some observers in their 60s who have high thresholds. While it is true that there is an age-related effect upon speed discrimination (see figure 2), it is not necessarily true that the older one gets, the poorer the ability to discriminate differences in speed.

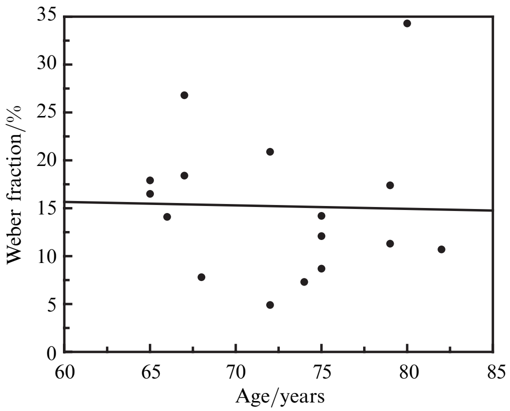

Figure 5. The older observers' thresholds at the fastest standard speed as a function of their specific ages. The best-fitting regression line is also plotted.

Finally, we wanted to evaluate whether there was any difference between speed discrimination thresholds obtained with our low-contrast circular spots and thresholds obtained with the high-contrast points (or dots) that are used as stimuli for many other similar studies (eg Bravo and Watamaniuk 1995; Festa and Welch 1997). Since we collected data for both low-contrast circular spots and high-contrast points at the medium standard speed, a comparison was possible. A dependent-samples *t*-test revealed that the observers' speed discrimination performance was statistically the same for both types of stimuli ($t_{31} = -1.0$, $p > 0.05$).

3 Experiment 2

The results of experiment 1 showed that there are age-related differences in the ability to perceive differences in the speed of moving objects. Andersen and Atchley (1995) and Norman et al (2000) investigated age-related deficits in the ability to perceive 3-D structure and shape from patterns of optical motion. The experiments of Norman et al revealed that older observers have extreme difficulty in perceiving the curvature and shape of 3-D objects defined by motion when noise (manipulated by limiting the lifetimes of individual points in the stimulus pattern; points 'disappear' after a brief lifetime only to randomly appear in new positions) is introduced into the stimulus patterns. The younger observers in the Norman et al study were relatively unaffected by noise. An important unresolved issue from this earlier research concerns the functional location of the presumed defect within the visual system that occurs with age—ie, if older observers cannot tolerate the presence of significant amounts of noise in perceiving 3-D structure-from-motion, is this due to some difficulty at the higher levels of the visual system that process information about depth and 3-D shape, or does the presence of noise disrupt the detection of the differences in speed that would be necessary to enable the perception of 3-D shape from motion? The purpose of this second experiment was to investigate the ability to perceive differences in speed when significant disruptions occur in the lifetimes of moving points over time.

3.1 *Method*

3.1.1 *Apparatus.* The stimulus displays in this experiment were rendered by a Power Macintosh 8600/300 provided with OpenGL and hardware acceleration (Nexus 128 graphics accelerator, ATI Technologies, Inc.), and were viewed on a 21 inch Mitsubishi 91TXM color monitor. The frame refresh or update rate was 50 Hz. All other details were the same as in experiment 1.

3.1.2 *Stimulus displays.* The stimulus displays were identical to the high-contrast point displays used in experiment 1 (the results of experiment 1 revealed that there was no significant difference between speed discrimination thresholds obtained for stimulus displays composed of low-contrast circular spots or high-contrast points). The single standard speed used in this experiment was the same as the middle standard speed used in experiment 1 (5.48 deg s^{-1}). The primary variable that was manipulated in the present experiment was the lifetime of the points embedded within the two moving strips—each point survived for a total of either 2, 4, or 10 frames. At the beginning of a trial, the initial phase of each point's lifetime was randomly determined, so that, at every frame transition, some of the points (but not all) disappeared and were then randomly transferred to a new location within their particular moving strip. Therefore, at every frame transition in the 2-frame lifetime condition 50% of the points disappeared and were randomly repositioned while the remaining 50% 'survived' and moved with the appropriate displacement to a corresponding position in the next frame. In the 4-frame lifetime condition, at every frame transition 25% of a moving strip's points disappeared and were randomly positioned in the next frame, while in the 10-frame lifetime condition this figure was 10%. In other words, the longer the point lifetime, the less noise present within the moving stimuli.

3.1.3 *Procedure.* The observers' task was identical to that in experiment 1: the observers were required to judge which strip (top or bottom) was moving with the fastest speed. Each observer judged the different experimental conditions (those with 2-frame, 4-frame, and 10-frame point lifetimes) in a different, randomly determined order. All other details of the experimental procedures were the same as in experiment 1.

3.1.4 *Observers.* Twenty-eight observers participated in the experiment, thirteen older than 60 years (mean age 69.2 years, $\sigma = 3.9$ years), and fifteen aged 31 years or less (mean age 24.6 years, $\sigma = 2.6$ years). All observers' acuity was once again measured at a distance of 100 cm with the Landolt C. The mean acuity of the younger observers was 0.97 min of arc^{-1}, while that of the older observers was 0.62 min of arc^{-1}.

3.2 *Results and discussion*

The manipulation of the amount of noise by limiting the lifetimes of individual stimulus points (that were subsequently re-plotted in new, randomly chosen positions) over time had large effects. In fact, for the point-lifetime conditions of 10 frames, 4 frames, and 2 frames, we were unable to determine reliable thresholds for 7%, 21%, and 54% of the observers, respectively. In particular, many observers in both age groups, young and old, had difficulty with the stimulus displays containing the movements of points that survived for only two consecutive frames (in this condition, 69% of the older observers and 27% of the younger observers were able to reliably perform the task at reasonable levels of performance). The results for those observers who could reliably perform the speed discrimination task are shown in figures 6a and 6b for the older and younger observers, respectively.

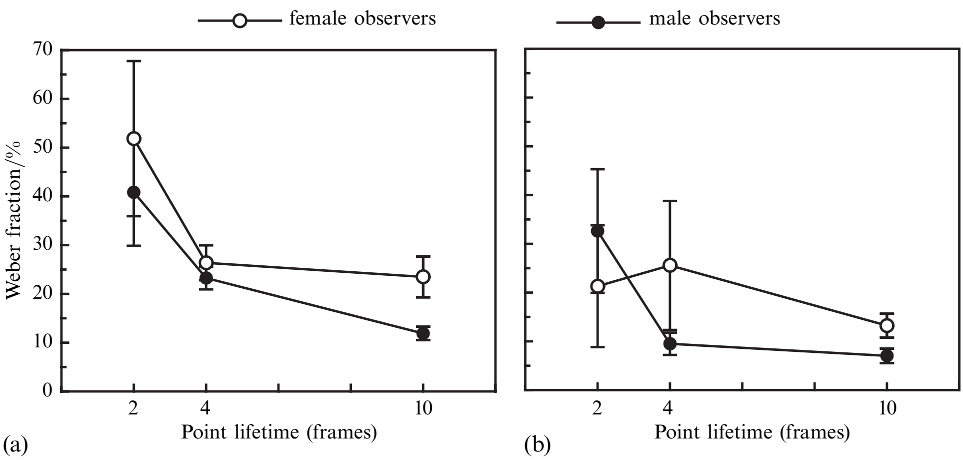

Figure 6. Results of experiment 2: combined thresholds of (a) the older observers and (b) the younger observers plotted as Weber fractions (the performances for males and females are plotted separately). The thresholds are plotted as a function of the lifetimes of the moving points in frames. The error bars indicate ±1 standard error of the mean.

One can readily see from an examination of figures 6a and 6b that the performance was best (ie Weber fractions were lowest) for the 10-frame point-lifetime condition, and deteriorated in the 4-frame and 2-frame point-lifetime conditions. This deterioration of performance with increases in noise and reduction in the lifetimes of moving points is similar to that observed in previous studies (De Bruyn and Orban 1988; Snowden and Braddick 1991; Bravo and Watamaniuk 1995; Festa and Welch 1997). This effect of the increasing amount of noise was verified by a Friedman two-way analysis of variance by ranks ($\chi^2_{r2} = 35.5$, $p < 0.001$). One can also see in figure 6a for the older observers (but not in figure 6b for the younger observers) an effect of sex—older males had consistently lower Weber fractions than older females. This effect of sex is significant for the 10-frame point-lifetime condition (as assessed by the median test, $\chi^2_1 = 4.7$; the Fisher exact probability test was used to estimate the exact probability, $p = 0.013$).

The overall results for the younger and older observers collapsed across sex are shown in figure 7. One can clearly see the effects of the manipulation of point lifetime as well as the effect of age. This effect of age was confirmed by the median test ($\chi^2_1 = 12.0$, $p < 0.001$). Notice that the effects of age are roughly constant and do not interact with the effects of variations in point lifetime. One can see this clearly in figure 8, in which the ratios of the Weber fractions for the 2-frame and 10-frame

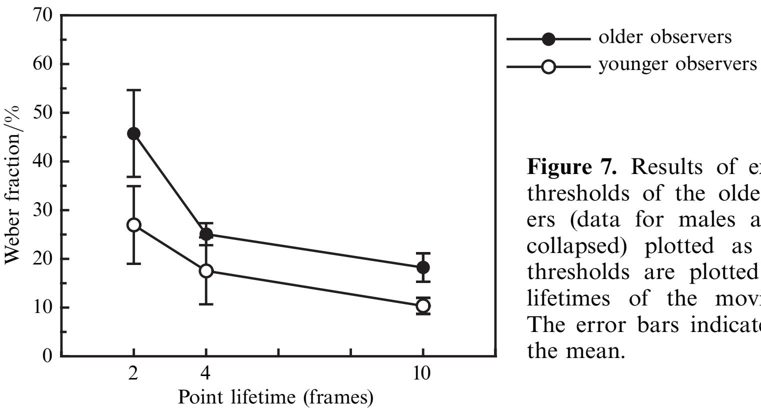

Figure 7. Results of experiment 2: combined thresholds of the older and younger observers (data for males and females have been collapsed) plotted as Weber fractions. The thresholds are plotted as a function of the lifetimes of the moving points in frames. The error bars indicate ±1 standard error of the mean.

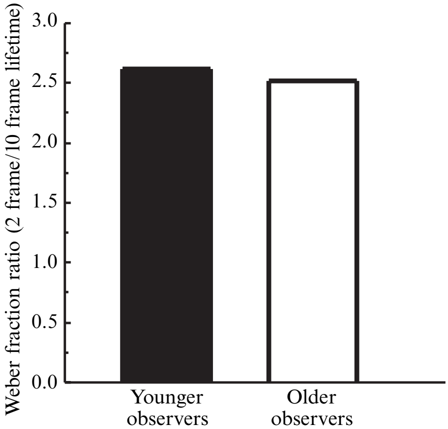

Figure 8. Results of experiment 2: the ratio of thresholds for the 2-frame and 10-frame point-lifetime conditions for both younger and older observers. One can see that for both groups the thresholds for the 2-frame point-lifetime condition were approximately 2.5 times higher than those for the otherwise equivalent 10-frame point-lifetime condition.

point-lifetime conditions are plotted for both younger and older observers. The increased amounts of noise present within the 2-frame point-lifetime stimuli relative to that present within the 10-frame point-lifetime stimuli made it much more difficult for the observers to precisely judge differences in speed—the Weber fractions for this 2-frame point-lifetime condition were on average about 2.5 times higher than the analogous Weber fractions for the 10-frame point-lifetime condition. Increases in the amount of noise (from 10-frame to 4-frame to 2-frame point lifetimes) had proportionally equal negative effects upon both younger and older observers (see figure 7).

4 General discussion

Past research has shown that the ability to detect movement is an important component of our perceptions, that we perceive movement (speed and direction) directly (ie it is not estimated from separate sensations of time and distance). In particular, in 1875, Exner (as cited by Boring 1942) found that, if two spatially adjacent electrical sparks were presented 14 ms apart in time, clear directional motion could be seen, even though 45 ms was required for observers to judge the temporal order of the two sparks (which spark came first). In this case, the observers could see phenomenal movement, even under conditions where they could not make judgments about differences or order in time. Later research supported Exner's conclusion that human observers perceive movement and velocity in a direct manner and that visual mechanisms exist that detect velocity (direction and speed) per se (see Wertheimer 1912/1965; J F Brown 1931; Lappin et al 1975; McKee 1981).

Over the past 100 years, there has been a sustained interest in the psychophysical investigation of speed; a significant number of psychophysical studies have been conducted that have explored how precisely human observers can judge differences in speed (eg Bourdon 1902; J F Brown 1931; Gibson et al 1957; Notterman and Page 1957; Brandalise and Gottsdanker 1959; Mandriota et al 1962; Lappin et al 1975; McKee 1981—much of the earlier research was reviewed by R H Brown 1961). A common paradigm was for the observer to adjust the speed of one moving stimulus until it appeared to match that of another moving stimulus (ie the standard). The Weber fractions that were obtained ranged from about 1% of the standard speed (J F Brown 1931) to 23%–24% (Notterman and Page 1957; Mandriota et al 1962), and depended upon such factors as the magnitude of the standard speed, whether the two moving stimuli to be compared were presented simultaneously or successively, etc. In light of the results of these previous investigations, the results of our younger observers seem to be in the middle of the range and are probably closest to the Weber fractions obtained by McKee (1981)—to illustrate, the average Weber fraction for our younger observers in experiment 1 at the middle standard speed was 5.1%, while the Weber fractions for McKee's observers (see her figure 2, page 494) ranged from 3% to 9% of the standard speeds. This similarity in overall quantitative results is striking, especially since our observers were not practiced psychophysical observers (ie they had never before participated in a psychophysical experiment nor did they receive a significant number of practice trials in the current experiments) and they did not receive feedback during any experimental session. McKee's observers were more experienced and did receive feedback; nevertheless, we obtained Weber fractions that were similar to those of her observers.

The results of both of the present experiments showed that there are large age-related deficits in the ability of human observers to perceive and discriminate differences in the speed of moving objects. We observed this age-related effect in every condition in both experiments. In experiment 1, half of the younger observers viewed the experimental stimuli wearing 0.5 neutral-density filters. In effect, this made them 'visually old', by making their projected retinal stimuli equivalent to that of a 60-year old (see Weale 1963; Sekuler and Owsley 1982). However, this manipulation had no effect—younger observers wearing the neutral-density filters did not perform more poorly than the rest of the younger observers. Thus, it seems clear that the age-related effects demonstrated in experiments 1 and 2 are not a consequence of the reduced retinal illumination that affects the aging eye, but rather are related to some degradation in the visual neural processes responsible for the perception of speed per se. The results of our experiments on aging and the discrimination of speed are similar to results obtained in past research on threshold motion detection [ie the minimum oscillatory motion that was just detectable—see Buckingham et al (1987)]. Buckingham et al also found age-related differences in motion perception. Our results extend their findings to the perception and discrimination of speed.

In addition to demonstrating age-related differences in the ability to discriminate differences in speed, we also found a sex-related difference in experiment 2—older females performed more poorly (ie had much higher Weber fractions) than older males in the 10-frame point-lifetime condition (the highest performance condition). This effect has been noticed before for other motion-related tasks, namely for the detection of correlated motion (Gilmore et al 1992; Andersen and Atchley 1995). Our findings extend this result to the perception of speed of 2-D patterns. Interestingly, while Andersen and Atchley found that older females performed more poorly at detecting the presence of a correlated motion signal within a noisy 2-D pattern, they found no evidence for a sex-related deficit in the perception of 3-D surfaces defined by motion.

In our second experiment we required observers to discriminate differences in speed for noisy moving patterns where the lifetimes of individual points were limited to 2 frames, 4 frames, or 10 frames. Our results show that the presence of noise has a definite negative impact upon the observers' speed discrimination thresholds, but this noise had a proportionately equal effect for both the younger and older observers (see figure 7). Thus, the presence of noise affects the relative performance of younger and older observers differently, depending upon whether the motion-associated task involves judging 2-D structure or 3-D structure. While the noise in this study (judging the speed of 2-D patterns) had proportionally equal effects upon the younger and older observers, this was not true in our earlier study of aging and the perception of 3-D structure/shape from motion (Norman et al 2000). In that study, limiting the lifetimes of moving points to only 2 successive views had a selective devastating effect upon the older observers' ability to perceive the curvature of 3-D surfaces defined by motion. The conclusion of Andersen and Atchley (1995) would seem to be true—they suggested from the results of their study on aging and perception that "different processes underlie the analysis of 2-D and 3-D motion". From the results of our study, we would tend to agree.

In conclusion, the results of both experiments clearly indicate that older observers have difficulty in comparing the speed of two continuously moving patterns, regardless of amount of noise or whether the overall speed is slow, medium, or fast. Since our observers were required to maintain steady fixation during the task, this age-related decrement in performance is likely attributable to a decreased sensitivity of the neural mechanisms involved in the estimation of speed. However, since the motions to be judged were extended in time (we gave the older and younger observers as much time as they needed to make a judgment in order to maximize their performance), the possibility of the observers making eye movements cannot be entirely ruled out. If pursuit tracking did occur, any age-related deficit in this ability could have contributed to the difference in speed discrimination performance that was observed between the young and the elderly. Future research will be needed to determine the precise relative contributions of sensory and motor factors to the observed age-related deficits in judging the speed of moving objects.

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