Association of Physical Activity and Visual Attention in Older Adults

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Objectives: This study was conducted to examine possible associations between physical activity and visual attention in community-dwelling older adults. **Methods:** Older adults (age 65-95) completed the Useful Field of View (UFOV®) test of visual attention, and they also reported current physical activity levels using the Exercise Participation Questionnaire (EPQ) and the Physical Activity Scale for the Elderly (PASE). **Results:** UFOV® performance was significantly correlated with both measures of physical activity, but some of these effects overlapped with the effects of age. The 21 participants (15%) who reported regular participation on the EPQ were found to have significantly better UFOV® scores than the more inactive participants both before and after controlling for age, gender, and visual acuity. **Discussion:** The preservation of visual attention skills across the life span may be more highly correlated with regular participation in exercise training activities than it is with more general occupational and leisure-related physical activity.

Keywords: *exercise; physical activity; aging; cognition; visual attention*

Several studies have found that age-related deficits in visual attention are associated with an increased risk of motor vehicle accidents and

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other mobility problems among older adults (Ball & Owsley, 1993; Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Goode et al. 1998; Owsley et al., 1998). Enhancing or preserving visual attention skills in later life might lead to a number of benefits including greater independence and a higher quality of life. Although many tests of visual attention have been developed, the behavioral and environmental variables that are associated with preserved attention are largely unknown. Once these associations can be established, subsequent investigations would be justified to determine whether these relationships reflect causal mechanisms that would be useful for enhancing visual attention skills.

Previous cross-sectional studies have indicated that older adults who report regular participation in physical exercise activities perform better, on average, on certain cognitive and neuropsychological tests than more sedentary older adults (Dustman, Emmerson, & Shearer, 1994; Dustman et al., 1990; Shay & Roth, 1992; Stones & Kozma, 1989). Of interest, tests of visuospatial ability and attentional functions appear to be particularly linked to exercise participation in older adults. In one study, physically active older men performed better than inactive but healthy older men on a visuospatial test requiring abilities to perceive complex visual information and accurately reproduce it (Shay & Roth, 1992). Other studies comparing physically active and inactive older adults have found that active participants performed significantly better on tests with high attentional demands such as the Trail Making Test and the Wechsler Adult Intelligence Scale–Revised (WAIS-R) Digit Symbol test (Dustman et al., 1994; Shay & Roth, 1992; Stones & Kozma, 1989). In general, results from several previous studies suggest that regular physical activity may be associated with a preservation of visual processing and attention skills in older adults.

Conceptually, visual attention represents a broad class of cognitive skills that are involved in perceiving, interpreting, and processing information in the visual system. These skills involve searching for and identifying information at the central fixation point, identifying relevant information in the visual periphery, processing this spatial information in an efficient manner, and avoiding becoming sidetracked by distracting visual stimuli. The Useful Field of View (UFOV®) is a computerized assessment of visual attention that takes

into account these various components of visual processing in determining an overall summary score of processing efficiency (Ball et al., 1993). The UFOV® test consists of multiple subtests that assess (a) speed of visual processing, (b) the ability to divide attention, and (c) selective attention abilities. A composite score ranging from 0% to 90% is calculated that represents the amount of reduction or impairment in the size of the useful visual field. Thus, higher scores indicate more limitations or reductions in effective visual attention space. This composite score quantifies the size of the visual area within which targets can capture attention during a brief inspection period. Reductions in the effective size of visual attention have been found to be associated with age (Ball, Beard, Roenker, Miller, & Griggs, 1988; Sekuler, Bennett, & Mamelak, 2000), although many older adults have little deficits in visual attention as measured by the UFOV®.

A 3-year prospective study on 294 older drivers indicated that those with restricted visual attention abilities, UFOV® percentage reduction scores ≥ 40, were 2.3 times more likely to be involved in at-fault automobile crashes than those with stronger visual attention abilities, UFOV® percentage reduction scores < 40 (Owsley et al., 1998). In a retrospective study of older adult drivers, the UFOV® was found to be a more sensitive predictor of state-recorded, at-fault crashes over the previous 5 years than a number of commonly used neuropsychological tests, including clinical tests of visual attention such as the Trail Making Test (Goode et al., 1998).

The purpose of the present study was to conduct an initial cross-sectional examination of possible associations between multiple self-report measures of exercise participation and physical activity level with visual attention as measured by the UFOV®. One hundred and forty community-dwelling older adults were administered the UFOV® and later interviewed about their current exercise and physical activity levels. Because of the previous links between exercise participation and performance on traditional measures of visual attention, it was hypothesized that physical activity levels would also be related to UFOV® performance in this sample. However, the associations between self-report measures of physical activity and UFOV® performance have not been previously examined. Previous studies of the association between physical activity and cognitive performance have also generally dichotomized participants into those who engage in regular vigorous exercise sessions and those who do not engage in such exercise sessions. Lifestyle physical activities such as gardening or yard work are usually not considered to be "exercise" in these investigations. Consequently, we also sought to determine whether visual attention skills as measured by the UFOV® were more highly correlated with measures of vigorous exercise participation or with more general physical activity measures.

Method

PARTICIPANTS

A sample of 140 older adults from the Birmingham metropolitan area served as participants in this project. Participants were originally recruited for participation in a larger project on mobility in older adults conducted at the University of Alabama at Birmingham (UAB). These individuals were members of a community organization of older adult citizens in north central Alabama (UAB Medwise). The participants ranged from 65 to 95 years of age (M = 74.5, SD = 5.4). The sample included 126 White participants (90%), 10 African American participants (7%), and 4 individuals of other minority groups (3%). There were 61 males in the sample (44%) and the remaining 79 participants (56%) were female. The sample was highly educated, with 127 (91%) reporting at least 12 years of education.

PROCEDURE

After receiving an initial description of the study, all participants read and signed an informed consent statement that was reviewed and approved for use by the Institutional Review Board of UAB. No potential participants refused to give informed consent to the study. Next, each participant was tested for corrected binocular visual acuity using the modified Bailey-Lovie chart (Bailey & Lovie, 1980) and contrast sensitivity using the Pelli-Robson chart (Pelli, Robson, & Wilkins, 1988). These measures of visual function were collected due to our interest in evaluating the relationship between visual attention and physical activity, and we wanted to be able to control for the influence

of visual sensory abilities on UFOV® performance. Participants were then administered the UFOV® in individual testing sessions. Measures of exercise participation and other physical activities were obtained later during a telephone interview by a trained research interviewer who was not involved in the UFOV® testing and was unaware of the visual attention or sensory testing results.

MEASURES

Visual acuity. Visual acuity was measured using a modified Bailey-Lovie chart. Participants were allowed to wear glasses or contact lenses to obtain a corrected visual acuity score. Participants viewed a chart of letters from a distance of 4.2 meters, and a visual acuity score was determined by counting the total number of correctly identified letters. Scores were reported using the Sloan scoring system and could potentially range from 0 to 90, with higher scores representing better functioning. The actual scores observed for this sample ranged from 28 to 89 ($M = 68.0$, $SD = 12.5$).

Contrast sensitivity. Contrast sensitivity was measured using a Pelli-Robson chart consisting of 16 groups of three uppercase letters that are constant in size. The groups decrease in contrast by approximately 0.15 log units, ranging from 90% contrast to 0.5% contrast. Participants were asked to identify these letters from a distance of 1 meter. The scoring method described by Elliott, Bullimore, and Bailey (1991) was used, with a possible range from 0.00 to 2.50 and higher scores representing better functioning. The contrast sensitivity scores observed for our sample ranged from 0.75 to 1.95 ($M = 1.67$, $SD = 0.17$).

Useful Field of View (UFOV®). Visual attention was assessed using the UFOV® Visual Attention Analyzer, Model 2000 (Ball & Owsley, 1993). This microprocessor-based instrument uses three subtests to quantify the size and efficiency of one's visual attention field. Subtests were presented on a 20-inch video monitor at a viewing distance of 23.5 cm. The first subtest was designed to measure the stimulus duration required to achieve 75% correct identification of a central visual target. The second subtest, designed to assess the ability to divide attention, required the localization of a simultaneously presented peripheral target (a silhouette of a car) in addition to the identification of the central target. The peripheral target appeared unpredictably at any one of 24 different peripheral locations along eight radial spokes at three eccentricities (10 degrees, 20 degrees, and 30 degrees). The duration of the display was varied to measure speed of processing for this divided attention task. The third subtest, designed to assess selective attention abilities, was the same as the second task with the exception that the peripheral target was embedded in distractors (triangles). Performance on the UFOV® test was then determined as a function of the minimum target duration required to perform the central discrimination task, the ability to divide attention between central and peripheral tasks successfully, and the ability to filter out distracting stimuli.

The primary summary score from the UFOV® is expressed in terms of a percentage of reduction (from 0% to 90%) in visual attention capabilities. In this metric, individuals processing all of the information within the minimum stimulus duration (16 msec) represent 0% reduction, and individuals unable to process even the simplest central target identifications at the maximum duration (500 msec) represent 90% reduction. In general, the summary score provides an index of the size of the attentional window under varying levels of cognitive demand (generated by reduced stimulus duration or other targets competing for attention). Lower reduction scores indicate better and faster processing of visual stimuli presented in the periphery. UFOV® percentage reduction scores in the present study ranged from 12.5 to 65.0 ($M = 31.6$, $SD = 12.8$).

Exercise Participation Questionnaire (EPQ). The EPQ assesses regular participation in physical exercise activities (Roth, Wiebe, Fillingim, & Shay, 1989). Representative activities include running, brisk walking for exercise, participation in sports, and exercise classes. The questionnaire was designed to specifically measure participation in activities for the purpose of exercise or physical training. More casual leisure-related activities (e.g., shopping) or domestic activities (e.g., gardening) are not included or scored. A list of 14 activities was read to the participant during the telephone interview,

and the participant was asked whether he or she regularly engaged in each activity. For each endorsed activity, participants also reported the frequency of participation (number of times per week), the typical duration of the activity per session (in minutes), and the intensity of the activity on a 3-point scale (1 = *low*, 2 = *moderate*, 3 = *high*). Finally, participants were asked how many days per week they participated in moderate- or high-intensity exercise for at least 20 continuous minutes. Interview responses were coded and scored to yield the following measures of exercise participation: (a) number of days per week of moderate or high exercise; (b) total number of minutes of exercise per week; (c) total exercise intensity as indexed by the sum of the days*minutes*intensity rating products across all endorsed activities; and (d) a weighted aerobic composite score based on Cooper's (1982) energy expenditure estimates for each activity. In addition, those who reported at least 3 days of exercise per week for at least 20 minutes in duration at a moderate or high intensity were designated as active participants. A total of 21 of the 140 participants (15%) were classified in the active group.

Physical Activity Scale for the Elderly (PASE). The PASE measures self-reported occupational, household, and leisure-related activities over a 1-week period. Participants were asked about 12 categories of physical activity and asked to report the frequency of their participation in these activities over the preceding 7 days. Scoring procedures were derived from motion sensor counts, physical activity diaries, and a global activity self-assessment (Washburn, Smith, Jette, & Janney, 1993). The PASE generates a single composite score of physical activity that ranges from 0 to 400. Scores for the present sample ranged from 0 to 361.4 (M = 97.3, SD = 61.9). Although the PASE also assesses exercise participation, it provides a more global index of physical activity and mobility than the EPQ because it inquires about a broader domain of physical activities.

STATISTICAL ANALYSIS

Correlational analyses were conducted to assess the relationships between UFOV® performance and scores on the EPQ and PASE. Simple Pearson product-moment correlations were examined first, and

then we examined partial correlations between UFOV® percentage reduction scores and measures of physical activity, with the effects of age on both variables controlled statistically. When comparing UFOV® scores between active (i.e., those who reported 3 or more days of physical exercise per week for at least 20 minutes at a moderate or high intensity) and inactive participants, analysis of covariance was used with age, gender, visual acuity, and contrast sensitivity as covariates. Age and gender were included as covariates to adjust for differences between active and inactive groups on these demographic variables. Visual acuity and contrast sensitivity were included as covariates to adjust for correlations between these sensory variables (rs = –.26 and –.18, respectively) and the UFOV® percentage reduction score. Consequently, these analyses of covariance allowed us to test whether UFOV® performance was uniquely related to physical activity levels after controlling for the potentially confounding effects of age, gender, and fundamental visual sensory functions.

Results

Descriptive statistics including means, standard deviations, and Pearson product-moment correlations are displayed in Table 1. These correlations indicate that visual attention, as measured by the UFOV® percentage reduction score, was modestly correlated with the days, intensity, and aerobic scores from the EPQ and with the summary score from the PASE. The valence of these correlations indicates that those who reported more frequent physical activity tended to have stronger visual attention abilities (i.e., less percentage reduction in the useful field of view).

When partial correlations that controlled for the effects of age were examined, the only statistically significant association between visual attention and physical activity that was found was between the UFOV® percentage reduction score and the EPQ days per week score (r = –.22, p = .01). This indicated a significant association between exercise participation and visual attention even after controlling for the moderate correlations that both variables had with age. The partial correlation between UFOV® and the PASE score was not statistically significant (r = –.10, p = .23).

Table 1
Descriptive Statistics and Bivariate Correlations Between UFOV® and Physical Activity Measures

Variable	M	SD	*Minimum*	*Maximum*	*Pearson Correlation Coefficients* *1*	*2*	*3*	*4*	*5*	*6*
1. UFOV®	31.6	12.8	12.5	65.0	—					
2. Age	74.5	5.4	65	95	.38**	—				
3. EPQ—days/week	0.8	1.7	0	7	–.24**	–.11	—			
4. EPQ—minutes/week	81.8	123.9	0	630	–.14	–.17*	.56**	—		
5. EPQ—intensity	114.1	185.3	0	840	–.17*	–.15	.76**	.93**	—	
6. EPQ—aerobic	8.9	14.3	0	70	–.19*	–.19*	.63**	.82**	.85**	—
7. PASE	97.3	61.9	0	361.4	–.17*	–.22**	.33**	.33**	.36**	.24**

Note. UFOV® = Useful Field of View; EPQ = Exercise Participation Questionnaire; PASE = Physical Activity Scale for the Elderly.
$^{*}p < .05$. $^{**}p < .01$.

Although exercise participation and physical activity were measured on continuous scales, frequency distributions indicated marked skewness for the EPQ variables. In fact, 78 of the 140 participants (56%) reported no regular participation in physical exercise sessions at all as measured by the EPQ. When participants were dichotomized into active (3 or more days of sufficient exercise per week as measured by the EPQ) and inactive (0, 1, or 2 days of exercise per week) groups, a total of 21 of the 140 participants (15%) were classified in the active group. The active group included 13 men and 8 women.

Table 2 summarizes the results of an analysis of covariance that compared the active and inactive participants on the UFOV® percentage reduction score after controlling for the effects of age, gender, visual acuity, and contrast sensitivity. The significant effect for activity status indicates that active participants had better UFOV® percentage reduction scores than inactive participants (adjusted means = 25.6 and 32.7, respectively), even after controlling for these demographic and visual function measures.

Previous work on the validity of the UFOV® has shown that a cutpoint of 40% reduction provides good discrimination between licensed drivers with a recent history of at-fault automobile crashes and drivers with no history of crashing (Owsley et al., 1998; Ball et al., 1993). Using this threshold, 39 participants (28%) were classified as being at risk for crashing and other mobility problems in this study. Of interest, all 39 of the high-risk participants were classified as inactive on the EPQ, and 36 of them reported no exercise participation at all. Thus, whereas none of the active participants was in the UFOV® high-risk category, 33% (39/119) of the inactive participants were classified as at risk for mobility problems according to the UFOV®. Fisher's exact test confirmed that active participants were significantly less likely to be classified as at risk by the UFOV® than inactive participants ($p < .001$).

Discussion

The results of this study showed that performance on a computerized test of visual attention designed specifically to identify older adults who are at risk for automobile accidents and other mobility

Table 2
Results of ANCOVA Comparing Active and Inactive Participants on UFOV® Scores

Effect	*Type III SS*	df	F	p
Age	1517.8	1,134	11.11	.001
Gender	36.7	1,134	0.27	.605
Acuity	198.5	1,134	1.45	.230
Contrast sensitivity	91.7	1,134	0.67	.414
Active versus inactive	884.8	1,134	6.18	.014

Note. UFOV® = Useful Field of View.

problems was related to multiple measures of exercise and physical activity. As predicted, physically active older adults displayed stronger visual attention skills than more sedentary older adults. After controlling for the associations that both visual attention and the physical activity variables had with age, many of the correlations between UFOV® and the physical activity measures were no longer statistically significant. The UFOV® percentage reduction score, for example, was no longer associated with participation in occupational or leisure activities as measured by the PASE after controlling for the effects of age. However, regular participation in moderate- or high-intensity physical exercise, as measured by the EPQ, was still found to be significantly related to visual attention even after controlling for the effects of age and visual sensory functions.

It is noteworthy that this association between exercise participation and visual attention was found in spite of the limited variability observed for some of the measures in this study. Most of the participants (72%) scored in the low risk range for mobility problems as measured by the UFOV® (reduction < 40%), and 56% of the participants reported no regular exercise activity at all. Although these frequencies may be representative of community-dwelling older adults, it is possible that stronger associations would be observed in studies that include more physically active individuals or studies that include more cognitively impaired participants.

Moderate correlations were found between the EPQ measures and the PASE summary score. Whereas participation in exercise sessions for the purpose of physical training is included in both measures, the assessment of these exercise activities is the sole purpose of the EPQ.

The PASE, on the other hand, is a more diverse instrument that captures a much wider range of physical activities. The results of the partial correlation analysis suggest that participation in specific exercise training activities may be more directly related to visual attention skills in older adults than the more general physical activity levels measured by the PASE. When promoting a more active lifestyle for older adults, it may be important to specifically include recommendations for vigorous exercise training sessions. This type of physical activity may provide benefits that are not achieved by more general increases in occupational, domestic, and leisure activities.

It has been suggested that participation in vigorous physical exercise may provide specific neurochemical and cerebrovascular benefits that serve to preserve visual attention functions for older adults (Dustman et al., 1994; Rogers, Meyer, & Mortel, 1990; Chodzko-Zajko, 1991). Our findings are consistent with these hypotheses, but it is important to clarify that cross-sectional analyses from observational studies are not sufficient for confirming causal relationships or for identifying underlying mechanisms. Regular exercise may promote neurological adaptations that preserve visual attention, but it is also possible that those with strong visual attention skills and other cognitive abilities choose to participate in exercise more frequently. This may be particularly true for outdoor activities, such as brisk walking or bicycling, that require adequate visual attention skills to comfortably and safely navigate through the external environment. In addition, there are undoubtedly many other variables that influence both the amount and type of physical exercise participation among older adults (Resnick, 2001).

In addition to the cross-sectional nature of this study, there are other limitations that warrant caution when drawing inferences from the findings. The sample generally consisted of well-educated participants, and only a few of these were members of minority groups. Additional studies would be needed to determine if these findings generalize to more diverse populations of older adults. Only one test of cognitive function was administered, so we were not able to examine in this sample whether our measures of physical activity were correlated with other indices of cognitive ability. The effects observed in this study were generally small when continuous variables were analyzed.

However, when subgroup cross-tabulations were made of the rates of at-risk UFOV® classifications for active and inactive participants, the potential clinical significance of these findings becomes more apparent. None of the active participants fell in the at-risk category, whereas one third of the inactive participants were classified as being at risk. Consequently, physical activity in general, and exercise participation in particular, appear to be significantly related to preserved visual functioning among older adults. Prospective, longitudinal, multivariate studies may now be justified to further clarify the benefits of regular physical exercise participation for preserving cognitive functions across the life span.

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