Journal of Clinical and Experimental Neuropsychology, 27:529–543, 2005
Copyright © Taylor & Francis Ltd.
ISSN: 1380-3395
DOI: 10.1080/13803390490515432

Psychology Press
Taylor & Francis Group

Reliability and Validity of Useful Field of View Test Scores as Administered by Personal Computer

JERRI D. EDWARDS,[1] DAVID E. VANCE,[2]
VIRGINIA G. WADLEY,[2] GAYLA M. CISSELL,[3]
DANIEL L. ROENKER,[3] AND KARLENE K. BALL[2]

[1]Department of Psychology, The University of Alabama in Huntsville, AL, USA.
[2]Center for Research on Applied Gerontology, Department of Psychology, University of Alabama at Birmingham, Birmirgham, AL, USA.
[3]Department of Psychology, Western Kentucky University, Bowling Green, KY, USA.

The Useful Field of View test (UFOV[1]) is a measure of processing speed that predicts driving performance and other functional abilities in older adults. In comparison to a number of other visual and cognitive measures, the UFOV measure has consistently been found to be the strongest predictor of motor vehicle crashes of older adults. This measure has valuable applications in that computerized, performance-based measures that are predictive of crashes in the elderly population can provide an objective criterion for determining the need for driver restriction or rehabilitation. Administration of the UFOV test has evolved from the standard version (administered via touch-screen with the Visual Attention Analyzer) to two briefer versions, which are administered on a personal desktop computer (PC) using either a touch screen or mouse response option. These new versions of the test are briefer and require less specialized equipment, making the test more portable and practical for use in clinical settings. This study examined the reliability and validity of the scores from these two new versions. Results indicate that test-retest reliabilities of the scores from the UFOV PC versions are high (r's= *0 .884 for mouse and 0.735 for touch), and performance on both PC versions correlates well with performance on the standard version* (r's = *0.658 for mouse and 0.746 for touch). Furthermore, scores were highly correlated (r = 0.916) when participants used either a touch screen or a mouse to input responses. In conclusion, the reliability and validity coefficients are of sufficient magnitude to make the touch and mouse PC versions of the UFOV practical for use in clinical evaluations.*

Introduction

The concept of the useful field of view was originally described by Sanders, who used the term "functional visual field" to define the visual field area over which information can be acquired in a brief glance without eye or head movements (Sanders, 1970). Researchers introduced this concept because although standard acuity and perimetric tests of the visual field were diagnostic of eye disease, such tests failed to capture the degree of difficulty experienced by older adults in everyday activities requiring the use of peripheral vision (Verriest et al., 1985). The term *useful field of view* was first used by Ball and colleagues (Ball,

[1]UFOV is a registered trademark of Visual Awareness, Inc., Chicago, IL
Address correspondence to: Jerri D. Edwards, UAH Department of Psychology, MH 329, Huntsville, AL 35899. Email: edwardjd@uah.edu.
Received 7 october 2003; accepted 23 February 2004

Owsley, & Beard, 1990) and subsequently has come to be widely associated with a specific test administered via computer (the UFOV test, Visual Awareness, Inc., Chicago, IL).

The concept of the useful field of view and its measurement were further refined as research in the areas of visual information processing and cognitive aging advanced during the 1980s and 1990s. For instance, research demonstrated that the diameter of an area that can be visually searched either serially (Scialfa, Kline, & Lyman, 1987) or in parallel (Bergen & Julesz, 1983) is directly related to both target/distractor similarity (conversely known as conspicuity) and stimulus duration. That is, more conspicuous targets can be detected at further eccentricities than less conspicuous targets, given a constant duration, and targets presented for longer stimulus durations can be detected at further eccentricities given a constant conspicuity. Therefore, the size of an individual's useful field of view can be manipulated by varying stimulus duration and conspicuity, as well as central task difficulty. These variables interact with both age and stimulus eccentricity in a variety of predictable ways. The UFOV test was thus designed to capture age-related changes in speed of information processing, proficiency in dividing attention, and ability to ignore irrelevant information (Ball, Roenker, & Bruni, 1990). Three subtests of the UFOV measure an individual's speed of processing across increasingly complex visual displays.

Significance of the UFOV Test

The UFOV test has a number of clinical and practical applications. First, the test may be used in guiding diagnosis and treatment of older adults who are experiencing functional visual problems without a clinical basis as revealed by a standard ophthalmologic exam (Ball & Owsley, 1993). The UFOV test is conceptually distinct from traditional perimetry measures of the visual sensory field. While UFOV test performance obviously relies upon visual sensory input, visual sensory field loss is not a necessary condition for poor test performance (Owsley, Ball, & Keeton, 1995). On the contrary, many older adults who have impairments in UFOV have normal visual function. UFOV test performance relies upon cognitive abilities as well as visual sensory function and is strongly related to cognitive abilities (Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Goode et al., 1998). Thus, the UFOV test relies on the integrity of visual sensory information as well as on an individual's higher order processing abilities (Owsley et al., 1995).

Second, the UFOV test is valuable in that it is related to older adults' everyday functional abilities, including indices of Instrumental Activities of Daily Living (IADLs) (Edwards et al., 2002; Owsley, Sloane, McGwin, & Ball, 2002) and indices of mobility, most notably driving competence (Ball et al., 1993; (Ball et al., submitted); (Myers, Ball, Kalina, Roth, & Goode, 2000); (Owsley, McGwin, & Ball, 1998); (Stalvey, Owsley, Sloane, & Ball, 1999). Many studies have found the UFOV test to be predictive of vehicle crash involvement in older adults (e.g., Ball & Owsley, 1993; Goode et al., 1998; Owsley, Ball et al., 1998; Owsley, Ball, Sloane, Roenker, & Bruni, 1991; Rizzo, Reinach, McGehee, & Dawson, 1997; Sims, Owsley, Allman, Ball, & Smoot, 1998). For example, (Owsley and colleagues (1998))found that even after adjusting for age, gender, race, mental status, medical conditions, and driving exposure, older drivers with a 40% or greater impairment on the UFOV were 2.2 times more likely than those with intact UFOV to incur a crash during three years of follow-up. Furthermore, as compared to a number of other visual and cognitive measures, the UFOV measure has consistently been found to be the strongest predictor of crashing (Goode et al., 1998). In general, older drivers with UFOV impairment are more likely to have a crash and are particularly likely to be involved in at-fault and injurious crashes (Owsley, McGwin et al., 1998).

The UFOV test is of further interest in that older adults' UFOV performance can be improved with speed of processing training (Ball, Beard, Roenker, Miller, & Ball, 1988; Ball & Owsley, 2000; Ball et al., submitted; Edwards et al., 2002; Roenker, Cissell, Ball, Wadley, & Edwards, 2003). To date, research has indicated that such training translates to improved performance on a laboratory measure of timed IADLs as well as to improved on-the-road driving performance (Ball & Owsley, 2000; Edwards et al., 2002; Roenker et al., 2003).

PC Versions of UFOV Test

Since its conception, administration of the UFOV has evolved from the original, computerized version that was administered via the Visual Attention Analyzer, which housed a 20 in. touch screen and included a stationary chin rest situated 28.5 cm from the screen. This version of the test requires 20 to 30 minutes to complete. Given the utility of the UFOV as a diagnostic tool, the need to expand its application to venues outside of research resulted in the development of two new and briefer versions of the UFOV test that are administered via a personal desktop computer (PC). One version utilizes a touch screen monitor (as does the standard version), and the other utilizes a mouse response. Both of these newer versions can be completed in 15 minutes or less. The touch PC version of the test is currently being used in U.S. Motor Vehicle Administrations and was recently used in a nationwide clinical trial of cognitive interventions among a large sample of older adults (Jobe et al., 2001). The mouse PC version is commercially available through the Psychological Corporation.

This article presents an examination of the reliability and validity indices of these newer versions of the UFOV test relative to the standard version, to each other, and to a separate measure of processing speed. Experiments 1, 2, and 3 examine test-retest reliability of scores from the standard, mouse, and touch PC versions of the UFOV test, and Experiment 4 is an examination of validity. For practitioners and researchers familiar with the standard version of the test, these experiments allowed the production of a conversion metric in order to make comparisons between the standard and new PC-version scores (Table 2).

Method

Overview of UFOV Test Versions

The standard and PC versions of the UFOV test (both mouse and touch screen) each include three increasingly difficult, visually presented subtests: stimulus identification, divided attention, and selective attention, as discussed by Owsley and colleagues (1991). The first subtest, which measures processing speed under the lowest demand conditions, requires participants to identify a target presented at a central fixation point on the screen. The target (silhouette of a 2 cm by 1.5 cm truck or car) is presented on a black background in a 3 cm × 3 cm fixation box. The second subtest, which measures processing speed for a divided attention task, involves identification of this central target along with localization of a simultaneous peripheral target (2 cm × 1.5 cm silhouette of a car) presented at one of 8 radial locations. The third subtest, which measures processing speed for a selective attention task, includes these two tasks, but also includes visual distractors (triangles of the same size and luminance as the targets) arranged in concentric circles around the peripheral target. Each trial consists of four display screens: 1) a fixation box, 2) a test stimulus, 3) a full-field, white-noise visual mask, and 4) a response screen. The white-noise visual mask is presented following the stimuli in order to control display duration and to eliminate afterimages.

As summarized in Table 1, the PC versions of the UFOV test are different from the standard version in several ways. In the standard version (Visual Attention Analyzer), the peripheral targets in the divided and selective attention subtests appear randomly at either 10, 20, or 30 degrees eccentricity. In the PC versions of the UFOV, the peripheral target is fixed at approximately 11 cm from the center of the fixation box. In the standard version, the duration of the displays is varied between 16.67 (17) and 250 milliseconds, whereas the touch and mouse PC versions include longer display durations of up to 500 milliseconds. For the standard UFOV version, participants view the monitor from a fixed distance of 28.5 cm by placing their chin in a chin rest. The PC versions do not involve a chin rest, but testers are instructed to seat the participant about 24 in. (60 cm) from the screen. Whereas the standard version uses a touch screen with a 20 in. diagonal viewing area, the PC versions use a smaller 15 in. diagonal viewing area. Unlike the standard and touch PC versions, the mouse PC version requires participants to use a standard mouse to point and click on the targets and their locations. Before taking the mouse version of the UFOV test, participants complete a short, guided-practice program for using the mouse until they demonstrate proficiency. It is important to note that no version of the UFOV test requires the respondent to have any computer experience, nor does prior computer experience enhance UFOV performance in any systematic way.

Visual Attention Analyzer Scoring Algorithm. Scores obtained from the standard Visual Attention Analyzer version of the UFOV are expressed in terms of the percentage reduction of a maximum 35-degree radius field and range between 0 and 30 percent reduction for each subtest. As Ball et al. (1990) have established, each of the three subtest measures independently assesses the factors known to impact the size of the useful field of view. Thus, each of the subtests is scaled on a 1–30 scale and these three scores are summed to represent the overall reduction in the UFOV. As a result, the standard UFOV measure ranges between 0 (can

Table 1
A Comparison of the Three Useful Field of View Test (UFOV) Versions

UFOV Version	Target Viewing Distance	Scoring Method	Possible Range of Subtest Scores	Hardware
Mouse	24 in	75% threshold derived by double staircase method	17 to 500 ms	personal computer 15 in. diagonal screen, standard mouse
Touch	24 in	75% threshold derived by double staircase method	17 to 500 ms	personal computer 15 in. diagonal touch screen
Standard	11 in	Scores are expressed in % reduction that isscaled as a function of display speed and target eccentricity.	0 to 30% reduction	Visual Attention Analyzer 20 in. diagonal touch screen Chin rest

correctly localize peripheral targets at all eccentricities at the briefest stimulus duration regardless of the amount of clutter in the display) and 90 (can neither identify centrally presented targets nor localize peripheral targets at any eccentricity at the longest stimulus duration).

For Subtest 1, the 75% correct threshold in ms is derived by a double staircase method. These scores are translated into a scaled score between 0 and 30 to put them on an equivalent scale with Subtests 2 and 3.

For Subtests 2 and 3, a regression between the eccentricity of the peripheral target and correct performance is determined at several stimulus display durations, which vary across individuals. The beginning display duration is based on Subtest 1 performance, ranging between 40 and 240 ms, in 40 ms increments. The best fitting line reflecting the relationship between eccentricity and localization errors is used to find the eccentricity at which observers can correctly localize the peripheral target at a given duration. This process is repeated at shorter display durations until the minimum duration needed to detect targets at greater than 10 degrees eccentricity is located. The display duration for this level of performance is then scaled into a percentage of UFOV reduction. Again, an individual who can correctly localize targets at all eccentricities at the minimum stimulus duration (40 ms) would receive a score of 0% reduction. An individual who cannot reliably localize the peripheral targets presented at 10 degrees eccentricity at the maximum stimulus duration (240 ms) would receive a score of 30% reduction.

PC Versions Scoring Algorithm. For both the touch and mouse PC versions, scores are expressed as the display duration in ms at which the participant could correctly perform each subtest 75% of the time. A metric for converting scores derived from the percent reduction scoring method (used in the standard Visual Attention Analyzer) to subtest thresholds in ms (used in the PC versions of UFOV) is presented in Table 2. As an example, using this conversion metric, a reduction of 0% for Subtest 2 on the standard version indicates that an individual can perform the task perfectly at 20 ms or less display duration, with targets at 30 degrees eccentricity, while a reduction of 30% for Subtest 2 indicates that the participant could not correctly localize peripheral targets at 10 degrees eccentricity at a display duration of 240 ms.

Thus in the standard version, stimulus duration was fixed, and the eccentricity required to achieve 75% correct performance was determined for that particular duration. In the new versions of the test, eccentricity is fixed, and the duration required to achieve 75% correct performance is determined for that eccentricity. The newer versions can therefore provide a much quicker estimate of UFOV impairment than could be obtained with the original method.

In the PC versions of the UFOV test, the speed of the display duration varies on each subtest between 16.67 (17) and 500 ms by a double-staircase method, in order to derive each participant's 75% threshold score. A score of 500 ms indicates that the participant could not perform the task even at the longest display duration. Just as scores from the standard Visual Attention Analyzer can be converted to millisecond threshold scores, millisecond threshold scores from PC versions of the UFOV can be expressed in terms of percent reduction through use of the conversion metric presented in Table 2.

Experiment 1: Test-Retest Reliability of the Standard Version

Participants

For each of the experiments described in this article community-dwelling adults 50 years of age and older were recruited from a variety of sources. Advertisements were put into newspapers of the communities of Warren County, Kentucky, Jefferson

Table 2
Conversion Metric for Standard and PC Useful Field of View Test (UFOV) Versions

UFOV Task	Standard Version (% reduction)	Touch and Mouse Versions (ms)
Subtest 1	0	0-30
	5	31-40
	10	41-50
	15	51-60
	20	61-70
	25	71-80
	30	>80
Subtest 2	0	<20
	5	21-40
	10	41-80
	15	81-120
	20	121-160
	25	161-200
	27.5	201-240
	30	>240
Subtest 3	0	<40
	7.5	41-80
	12.5	81-120
	17.5	121-160
	22.5	161-200
	25	201-240
	30	>240

County, Alabama, University of Alabama at Birmingham (UAB), and Western Kentucky University in addition to various community newsletters. Lists of licensed drivers aged 55 years and older from the counties of Warren, Kentucky and Jefferson, Alabama were obtained from State Departments of Motor Vehicles, and samples of these drivers received letters inviting them to participate. Participants were also recruited through community organizations and events such as churches, social clubs, and Health Fairs in Warren County, Kentucky and Jefferson and Shelby Counties in Alabama. Finally, members of the Birmingham-Area Medwise organization, a non-profit organization associated with the UAB Hospital System, which offers discounts to senior adults, also received letters inviting them to participate in our studies. These strategies yielded diverse samples of community dwelling elders with education ranging from sixth grade to Ph.D.

Sixty-six older adults from Warren County, Kentucky participated in Experiment 1. These participants had an average age of 71.96 years ($SD = 6.71$), ranging from 56 to 86. The sample included 63 Caucasians, 1 African American, 1 American Indian, and 1 Asian American. Forty-one of the participants were females and 25 were males.

Procedure and Measures

Informed consent was obtained, and participants' binocular far visual acuity (with corrective lenses if applicable) was tested with the Bailey-Lovie chart. Scores ranged from −0.20

to 0.36 LogMAR (*M* = 0.04, *SD* = 0.11). Some of the participants (*n* = 46) were also administered the Pelli-Robson measure of contrast sensitivity. Contrast sensitivity ranged between 1.35 and 1.95 (*M* = 1.70, *SD* = 0.15). Participants performed the standard version of the UFOV test. After a variable interval (*M* = 92.58 days, *SD* = 96.83 days), participants returned for a second visit to retake the standard UFOV test. A sub-sample (*n* = 20) of all participants who completed the test and retest within three weeks was further analyzed to investigate test-retest reliability of scores over a brief period.

Results

The means, standard deviations, and ranges for each subtest and total are presented in Table 3. Test-retest reliability coefficients for UFOV totals and subtests were calculated (see Table 4). Confidence intervals were calculated as outlined by Fan and Thompson and are also presented in Table 4 (Fan & Thompson, 2001). For Subtest 1, the ms threshold was examined since it is common across all three versions of the test. For Subtests 2, 3, and the total, the percent reduction scores were analyzed. The test-retest coefficient for task 1 was deflated due to truncation of scores, which ranged only from 16 to 47 ms. Thus, this correlation coefficient was corrected for deflation due to truncation (Hays, 1994). Overall, the test-retest reliabilities among the subtest scores were moderate, ranging from 0.51 to 0.72. Reliability coefficients were also calculated for the subsample of participants who completed the test and retest within a 3 week period. Test-retest reliabilities of the scores for this sub-sample were similar, ranging from 0.48 to 0.80.

Table 3
Means and Standard Deviations of Useful Field of View Test (UFOV) Performance for Subtests 1, 2, 3, and Total Score, by Testing Occasion

		Test			Retest		
	N	*M*	*SD*	Range	*M*	*SD*	Range
Standard	66						
Subtest 1+		21.85	6.82	16–41	21.03	6.19	16–47
Subtest 1*		0.53	1.55	0–5	0.46	1.69	0–10
Subtest 2*		4.70	5.68	0–30	4.39	6.23	0–30
Subtest 3*		25.30	5.12	17.5–30	23.43	5.77	12.5–30
Total		30.53	8.83	17.5–65	28.29	10.85	12.5–65
Mouse	66						
Subtest 1+		52.45	75.43	16–383	33.50	50.32	16–243
Subtest 2+		153.68	151.71	16–500	86.21	126.44	83–500
Subtest 3+		322.80	143.03	83–500	290.64	141.48	66–500
Total		528.94	317.30	125–1383	410.35	269.22	105–1213
Touch	158						
Subtest 1+		30.46	39.96	16–260	23.37	21.91	16–176
Subtest 2+		143.18	122.49	16–500	106.27	111.77	16–500
Subtest 3+		375.03	117.68	66–500	322.94	131.54	80–500
Total		548.66	228.30	102–1113	452.58	221.26	139–1080

Note: +score is expressed in ms, *score is expressed in percent reduction.

Experiment 2: Test-Retest Reliability of the Mouse PC Version

Participants

Sixty-six community-dwelling, older adults from Birmingham, Alabama and Warren County, Kentucky participated. The participants had an average age of 71.20 years (*SD* = 7.25), ranging from 53 to 87. The sample included 49 Caucasians, 16 African Americans, and 1 Hispanic American. Fifty of the participants were females and 16 were males.

Procedure and Measures

Informed consent was obtained. Participants' binocular far visual acuity (with corrective lenses if applicable) was tested with either the Sloan or Bailey-Lovie letter charts. Scores ranged from –0.10 to 0.51 LogMAR (*M* = 0.09, *SD* = 0.12). Participants performed the mouse PC version of the UFOV test. After an average interval of 10 days (range 4 to 22 days), participants returned for a second visit to retake the mouse PC version of the UFOV test.

Results

Scores were compared for test and retest performance on the Mouse PC-version of the UFOV. Means, standard deviations, and ranges for each subtest and the total scores at both test and retest are presented in Table 3. Correlations and confidence intervals were calculated between test and retest performance for each subtest and total score (see Table 4). All test-retest correlation coefficients were moderately high, ranging from 0.681 to 0.884, indicating that performance was stable over time. In particular, the total UFOV score correlation from test to retest yielded a high test-retest reliability coefficient ($r = .884$).

Experiment 3: Test-Retest Reliability of the Touch PC Version

Method

Participants. Participants included 158 community-dwelling elders residing in Jefferson or Shelby County, Alabama and Warren County, Kentucky. The sample had an average age of 75.10 years (*SD* = 5.80), an average education of 14 years (*SD* = 2.51; range 8 to 20), and was composed of 141 Caucasians, 13 African Americans, 1 Hispanic American, 1 who specified race as "other," and 2 whose racial identity was not reported. Eighty-six of the participants were females and 72 were males.

Procedure and Measures

Informed consent was obtained from the participants. Participants' binocular contrast sensitivity and far visual acuity were measured (with corrective lenses if applicable). Contrast sensitivity was measured with the Pelli-Robson chart. Participants' scores ranged between 1.35 and 1.95 (*M* = 1.65, *SD* = 0.14). Binocular visual acuity was tested using either the Sloan Letter chart or the Modified Bailey-Lovie chart. Participants' far visual acuity ranged between –0.10 and 0.50 LogMAR (*M* = 0.08, *SD*= 0.12).

Participants also performed the PC touch screen version of the UFOV test. After a variable interval (*M* = 34.14 days, *SD* = 22.33), participants again completed the same version of the UFOV test. A subsample (*n* = 50) of all participants who completed the test-retest within three weeks (*M* = 16.58 days; *SD* = 3.93) was further analyzed to investigate the reliability of the UFOV touch version scores over a brief period.

Results

As seen in Table 3, total scores were calculated for test and retest performance on the Touch PC version of the UFOV. Test-retest reliability coefficients with confidence intervals for UFOV totals and subtests were also calculated and are shown in Table 4. Coefficients from each of the subtest scores have sufficient reliability. The test-retest correlation between total scores was acceptable (*r* = 0.735). In summary, test-retest reliability coefficients for the subtests and total appear to be relatively robust over time.

As previously mentioned, a subsample was used to determine the reliability over a time interval of three weeks or less. For this subsample, test-retest correlations with confidence intervals were again calculated between the subtest and total scores on the Touch PC version of the UFOV (see Table 4). All correlations were significant, and the total UFOV score correlation between test and retest was particularly high (*r* = 0.808). Thus, as

Table 4
Reliability and Validity Coefficients of the Useful Field of View Test (UFOV) Versions

Study	*N*	UFOV Subtest 1	UFOV Subtest 2	UFOV Subtest 3	UFOV Total
Test Retest					
Standard					
M = 92 days	66	0.685+	0.669	0.508	0.715
		(0.529–0.793)	(0.508–0.786)	(0.300–0.670)	(0.572–0.814)
M = 18 days	20	0.483	0.866	0.480	0.802
		(0.059 to 0.762)	(0.696–0.945)	(0.040–0.761)	(0.558 to 0.917)
Mouse PC					
M = 10 days	66	0.681	.806	0.847	0.884
		(0.523–0.790)	(0.701–0.879)	(0.757–0.905)	(0.814–0.926)
Touch PC					
M = 34 days	158	0.509	0.581	0.717	0.735
		(0.380–0.617)	(0.470–0.681)	(0.635–0.786)	(0.653–0.797)
M = 17 days	50	0.783	0.716	0.709	0.808
		(0.641–0.872)	(0.544–0.831)	(0.565–0.828)	(0.681–0.888)
Validity					
Mouse to	325	0.488	0.741	0.762	0.772
Standard~		(0.397–0.565)	(0.691–0.790)	(0.711–0.804)	(0.726–0.814)
Touch to	294	0.409	0.863	0.923	0.874
Standard~		(0.319–0.501)	(0.834–0.890)	(0.905–0.938)	(0.846–0.898)
Mouse to	277	0.443	0.886	0.987	0.916
Touch~		(0.345–0.537)	(0.859–0.910)	(0.984–0.990)	(0.894–0.933)

+corrected for truncation, ~corrected for attenuation.

might be expected, a stronger reliability coefficient is obtained when the data are restricted to a shorter test-retest interval. Overall, the test-retest reliability coefficients among the subtests of the touch PC version were high, usually over 0.7, which is within the acceptable range (Carmines & Zeller, 1979; Tabachnick & Fidell, 1996).

Experiment 4: Validity Indices of Mouse and Touch PC Versions of the UFOV

Method

Participants. Three-hundred and sixty-four participants aged 55 years and older were recruited from the communities of Jefferson and Shelby County, Alabama and Warren County, Kentucky. Participants ranged in age from 55 to 93 years ($M = 73.19$, $SD = 6.48$). Education data were available for 222 of the participants, who had an average education of 14 years ($SD = 2.55$; range 6 to 20). The sample included 137 males and 227 females, and was composed of 336 Caucasians, 18 African Americans, 2 Hispanic Americans, 1 Asian American, 1 Native American, and 6 individuals from *other* ethnic backgrounds.

Procedure and Measures. Participants were told that the study involved a comparison of three different versions of a measure of visual attention and processing speed, and informed consent was obtained. Participants' binocular contrast sensitivity and far visual acuity were measured (with corrective lenses if applicable). Contrast sensitivity scores, as measured by the Pelli-Robson chart, ranged between 0.75 and 1.95 ($M = 1.71$, $SD = 0.18$). Binocular far visual acuity was tested using either the Sloan Letter chart or the Modified Bailey-Lovie chart. Scores ranged between −0.18 and 0.75 LogMAR ($M = 0.09$, $SD = 0.13$).

As the study evolved from an examination of any two versions of the UFOV test to an examination of all three, participants performed either two or three different versions of the UFOV test at one sitting. Order of administration of the UFOV test versions and another test of processing speed (described below) was counterbalanced across participants. UFOV test versions included the standard version on the Visual Attention Analyzer, as used in previous research, and the two PC versions.

As noted, participants also completed another PC-based visual search/complex reaction time task, the Road Sign Test, in order to assess convergent validity between each version of the UFOV test and a separate measure requiring speed of processing. This task was chosen due to its face validity with regards to driving. This task required rapid extraction and evaluation of visual information from complex visual displays. If the participant had not already used a mouse, they were given an opportunity prior to this test to practice pointing and clicking with the mouse until they demonstrated proficiency. For the Road Sign Test, participants viewed road signs with and without red slashes. Participants were instructed to ignore the signs with red slashes and to react to the signs without red slashes. The changing displays contained between 3 and 6 signs at a time. Without warning, a display would appear that contained one sign without a red slash. For bicycle or pedestrian signs without a slash, participants were required to click one of the mouse buttons as quickly as possible. For the left or right turn arrow signs without a slash, participants were required to move the mouse in the direction that the arrow pointed as quickly as possible. Prior to the 12 test trials, participants practiced on four trials in order to ensure that they understood the task.

Results

Scores were obtained for the different versions of the UFOV. Means, standard deviations, and ranges for each subtest and total are presented in Table 5.

Due to differences in the scoring methods for the UFOV versions, the following indices were used in validity analyses. Across all three versions, the 75% threshold score for subtest 1, expressed in ms, was compared. For Subtests 2 and 3, the percent-reduction scores from the standard version were compared to the ms threshold for the PC versions.

Correlations were calculated among age, education, visual acuity, contrast sensitivity, the Road Sign Test and each UFOV subtest and total. First, the correlations between the different UFOV test versions were corrected for attenuation as outlined by Carmines and Zeller (Carmines & Zeller, 1979) using the reliability coefficients obtained in Experiments 1 to 3. The correlations corrected for attenuation ranged from 0.44 to 0.98, with Subtest 1 correlations at the low end of this range. These lower correlations among Subtest 1 scores for the three test versions are a function of restricted range. Overall, there was a moderately high level of convergence between the test versions, particularly with regard to Tasks 2 and 3 and the total scores (see Table 4).

Another index of the validity of the newer UFOV versions is that the percentage of individuals with scores in the impaired range versus the intact range was roughly comparable across versions. On the original version of UFOV, an average of 74% scored below 40% UFOV reduction and were classified as low risk (intact), while 26% scored above 40% reduction and were classified as high risk (impaired). Of the individuals characterized as low-risk on the original version, 74% scored as low-risk on the touch version and 70% scored as low-risk on the mouse version. Of the high-risk individuals on the original version, 64% scored as high-risk on the touch version and 70% scored as high-risk on the mouse version. Among those cases changing category from the original version to the

Table 5

Means and Standard Deviations of Useful Field of View Test (UFOV) Versions.

UFOV Tests	Mean	Standard Deviation	Range
Standard			
Subtest 1⁺	23.64	13.05	16–126
Subtest 1*	0.904	2.75	0–25
Subtest 2*	6.03	6.95	0–30
Subtest 3*	22.78	6.30	5–30
Total*	29.71	12.89	5–82.5
Touch PC			
Subtest 1⁺	25.24	29.99	16–293
Subtest 2⁺	103.48	117.22	16–500
Subtest 3⁺	305.54	138.34	50–500
Total⁺	434.27	240.24	82–1173
Mouse PC			
Subtest 1⁺	24.99	33.28	16–346
Subtest 2⁺	112.71	128.90	16–500
Subtest 3⁺	324.44	134.58	80–500
Total⁺	462.14	247.96	112–1346

Note: ⁺score is expressed in ms, *score is expressed in percent reduction.

Table 6
Correlations Among Age, Education, Vision and Road Sign Test Performance and the Total Score for the three Useful Field of View (UFOV) Test Versions.

UFOV Version	Age	Education	Visual Acuity	Pelli Contrast Sensitivity	Road Sign Test
Standard	0.435**	–0.254**	0.326**	–0.300**	0.310**
Mouse	0.474**	–0.199*	0.447**	–0.391**	0.311**
Touch	0.469**	–0.213**	0.378**	–0.370**	0.296**

*$p < .01$, **$p < .001$.

newer versions, most had borderline scores of 35–40% UFOV reduction, indicating that they were at the cut point for a decision of impaired versus intact (i.e., 39% reduction is classified as intact/low risk; 40% reduction is classified as impaired/high risk). Thus, it is not surprising that cases hovering at this cut point on the original version might shift in risk classification on the PC versions of the test. Most likely these results are due to the difference in scaling on the new versions. Further research is necessary to validate the PC versions in predicting crashes.

To examine convergent validity, correlations between the different versions of the UFOV and the Road Sign Test performance were also examined. The correlations between the total score from each version of the UFOV test and the total score on the Road Sign Test (see Table 6) were significant and very similar in magnitude across versions (range 0.296–0.311).

As mentioned, the relationship of the different test versions to age, education, and vision was also examined. The UFOV test was significantly related to age, vision, and education. The magnitude of the correlations was similar for each test version (see Table 6).

Discussion

The results of these experiments indicate that the PC versions of the UFOV assessment represent viable alternatives to the standard UFOV administered with the Visual Attention Analyzer. The scores obtained via administration on each PC version over time correlate significantly, particularly for the total score index. Overall, the findings of Experiments 1 to 3 indicate that the test-retest reliability coefficients of all three versions of the test are of similar magnitude. With regards to Experiment 4, total scores obtained on the PC versions correlate highly with the standard version scores and with each other, indicating acceptable convergent validity across versions.

A limitation of the present study is that the sample sizes of experiments 1 and 2 were relatively small. Prior research with larger samples have demonstrated the test-retest reliability of scores from the standard version of the UFOV test (Ball, Owsley, Beard, Roenker & Ball, 1989). The data obtained in experiment 1 was not intended to again demonstrate the test-retest reliability of this measure, but was necessary to evaluate the new PC versions. Although the sample size of Experiment 2 was also small, the test-retest reliabilities obtained for the mouse PC version were quite similar to those of the PC touch version (Experiment 3), for which sample size was adequate. Furthermore, a strong relationship between performance on the touch and mouse PC versions was demonstrated in Experiment 4.

Across experiments, subtest one of the UFOV test, irrespective of the version, yielded a lower test-retest coefficient than the other subtests. The restricted range and small variability of performance on this relatively easy task compared to the other subtests is the most likely explanation for these results. These results raise the question of whether Subtest 1 is a necessary part of the test. This subtest serves to orient people to the overall task and is sensitive to identifying severely impaired individuals. Although the prevalence of individuals with such a severe level of impairment is low in the population at large, results of this subtest can be of use and interest in particular situations. For example, the California Department of Motor Vehicles uses this subtest to quickly identify severely impaired drivers. At the same time, current research from our laboratory is investigating the feasibility and utility of using Task 2 alone as a brief assessment of UFOV. Task 2 was administered for brevity, for its high correlation with the UFOV total score, and for its known precedence over the other subtests in predicting crash involvement, as determined using the standard version of the UFOV test (Owsley, Ball et al., 1998).

Similar to the results with Subtest 1, the test-retest correlation coefficients for the standard UFOV version tend to be of slightly smaller magnitude, most likely due to the metric of scaling for the percent reduction scores, which can only range between 0 and 30. Finally, the validity coefficients between the mouse and touch PC versions of the task are of slightly larger magnitude than either version shares with the standard version in that these PC versions are scored on the same scale, administered on the same size monitor, and have a larger possible range of score values.

Results indicate that regardless of the version used, UFOV performance is consistently related to age and visual function. UFOV performance is also significantly related to education across versions, but considering the low magnitude of this relationship, the impact of education upon performance is likely to be small. It is particularly of interest that administration of the two PC versions of the test correlated very highly. This finding indicates that requiring the respondent to use a mouse rather than a touch screen does not significantly impact test performance.

In conclusion, the present reliability and validity findings should generalize to populations of community-dwelling adults age 55 and older with relatively intact visual function. To date, the UFOV has been used primarily for the assessment of older adults. Manuals have been developed for determining a participant's driving risk (ranging from very low to very high) based upon the UFOV score obtained (Psychological_Corporation, 1999). This information may be particularly useful for clinicians' use in counseling older patients about driving safety or cessation, and for either reassuring or reinforcing family members' concerns about their loved one's driving risk.

References

Ball, K., Beard, B., Roenker, D., Miller, R., & Ball, D. (1988). Visual search: Age and practice. *Investigative Ophthalmology and Visual Science Suppl., 29*, 448.

Ball, K., Owsley, C., Beard, B., Roenker, D., & Ball, D. (1989). Age and functional vision as related to everyday performance. *Investigative Ophthalmology and Visual Science, 305*, 408.

Ball, K., & Owsley, C. (1993). The useful field of view test: A new technique for evaluating age-related declines in visual function. *Journal of the American Optometric Association*, *64* (1), 71–79.

Ball, K., & Owsley, C. (2000). Increasing mobility and reducing accidents of older drivers. In K. W. Schaie & M. Pietrucha (eds.), *Mobility and transportation in the elderly* (pp. 213–251). New York: Springer Publishing Company, Inc.

Ball, K., Owsley, C., & Beard, B. (1990). Clinical visual perimetry underestimates peripheral field problems in older adults. *Clinical Vision Sciences, 5*, 113–125.

Ball, K., Owsley, C., Sloane, M. E., Roenker, D. L., & Bruni, J. R. (1993). Visual attention problems as a predictor of vehicle crashes in older drivers. *Investigative Ophthalmology and Visual Science, 34* (11), 3110–3123.

Ball, K. K., Roenker, D. L., & Bruni, J. R. (1990). Developmental changes in attention and visual search throughout adulthood. In J. Enns (ed.), *Advances in psychology* (vol.69, pp. 489–508).

Ball, K., Roenker, D., McGwin, G., Wadley, V., Edwards, J., Raleigh, R., & Cissell, G. (submitted). Can high-risk older drivers be identified through performance-based measures in a Department of Motor Vehicles setting? *JAMA, 288*: 2271–2281.

Bergen, J. R., & Julesz, B. (1983). Parallel versus serial processing in rapid pattern discrimination. *Nature, 303*(5919), 696–698.

Carmines, E. G., & Zeller, R. A. (1979). *Reliability and validity assessment* (vol. 17). Newbury Park, CA: Sage.

Edwards, J. D., Wadley, V. G., Myers, R. S., Roenker, D. L., Cissell, G. M., & Ball, K. K. (2002). Transfer of a speed of processing intervention to near and far cognitive functions. *Gerontology, 48*, 329–340.

Fan, X., & Thompson, B. (2001). Confidence intervals about score reliability coefficients, please: An EPM guidelines editorial. *Educational and Psychological Measurement, 61*(4), 517–531.

Goode, K. T., Ball, K. K., Sloane, M., Roenker, D. L., Roth, D. L., Myers, R. S., & Owsley, C. (1998). Useful field of view and other neurocognitive indicators of crash risk in older adults. *Journal of Clinical Psychology in Medical Settings, 5*(4), 425–440.

Hays, W. L. (1994). *Statistics* (5th ed.). Orlando, FL: Harcourt Brace College Publishers.

Jobe, J. B., Smith, D. M., Ball, K., Tennstedt, S. L., Marsiske, M., Willis, S. L., Rebok, G. W., Morris, J. N., Helmers, K. F., Leveck, M. D., & Kleinman, K. (2001). ACTIVE: A cognitive intervention trial to promote independence in older adults. *Controlled Clinical Trials, 22*(4), 453–479.

Myers, R. S., Ball, K. K., Kalina, T. D., Roth, D. L., & Goode, K. T. (2000). The relationship of Useful Field of View and other screening instruments to on-road driving performance. *Perceptual and Motor Skills, 91*(1), 279–290.

Owsley, C., Ball, K., & Keeton, D. M. (1995). Relationship between visual sensitivity and target localization in older adults. *Vision Research, 35*(4), 579–587.

Owsley, C., Ball, K., McGwin, G., Jr., Sloane, M. E., Roenker, D. L., White, M. F., & Overley, E. T. (1998). Visual processing impairment and risk of motor vehicle crash among older adults. *JAMA, 279*(14), 1083–1088.

Owsley, C., Ball, K., Sloane, M., Roenker, D. L., & Bruni, J. R. (1991). Visual/cognitive correlates of vehicle accidents in older drivers. *Psychology and Aging, 6*, 403–415.

Owsley, C., McGwin, G., Jr., & Ball, K. (1998). Vision impairment, eye disease, and injurious motor vehicle crashes in the elderly. *Ophthalmic Epidemiology, 5*(2), 101–113.

Owsley, C., Sloane, M., McGwin, G., Jr., & Ball, K. (2002). Timed Instrumental Activities of Daily Living tasks: Relationship to cognitive function and everyday performance assessments in older adults. *Gerontology, 48*, 254–265.

Psychological Corporation. (1999). *UFOV (Useful Field of View) manual*. San Antonio, TX: Harcourt Brace and Company.

Rizzo, M., Reinach, S., McGehee, D., & Dawson, J. (1997). Simulated car crashes and crash predictors in drivers with Alzheimer's disease. *Archives of Neurology, 54*(5), 545–551.

Roenker, D. L., Cissell, G. M., Ball, K. K., Wadley, V. G., & Edwards, J. D. (2003). Speed-of-processing and driving simulator training result in improved driving performance. *Human Factors 45*(2), 218–233.

Sanders, A. F. (1970). Some aspects of the selective process in the functional visual field. *Ergonomics*, *13*(1), 101–117.

Scialfa, C. T., Kline, D. W., & Lyman, B. J. (1987). Age differences in target identification as a function of retinal location and noise level: Examination of the useful field of view. *Psychology and Aging, 2*(1), 14–19.

Sims, R. V., Owsley, C., Allman, R. M., Ball, K., & Smoot, T. M. (1998). A preliminary assessment of the medical and functional factors associated with vehicle crashes by older adults. *Journal of the American Geriatrics Society, 46*(5), 556–561.

Stalvey, B. T., Owsley, C., Sloane, M. E., & Ball, K. (1999). The Life Space Questionnaire: A measure of the extent of mobility of older adults. *Journal of Applied Gerontology, 18*(4), 460–478.

Tabachnick, B. G., & Fidell, L. S. (1996). *Using multivariate statistics*. New York: Harper Collins College Publishers.

Verriest, G., Bailey, I., Calabria, G., Campos, E. C., Crick, R. P., Enoch, J. M., Esterman, B., Friedmann, A. C., Hill, A. R., Ikeda, M., Johnson, C. A., Overington, I., Ronchi, L., Saida, S., Serra, A., Villani, S., Weale, R. A., Wolbarsht, M. L., & Zingirian, M. (1985). *The occupational visual field.* Paper presented at the 6th International Visual Field Symposium.