A Relationship between Tolerance of Blur and Personality

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Purpose. To determine whether tolerance of dioptric spherical defocus is related to measures of personality. Clinical observations suggest that there is individual variability in tolerance of blur.

Methods. A computer-controlled Badal optometer was used to measure just-noticeable blur and just-objectionable blur responses to positive lens defocus. Blur tolerance was defined as the difference between these two responses. A personality battery was administered consisting of the NEO-FFI (Neuroticism-Extroversion-Openness–Five Factor Inventory) and the California Adult Q-sort (general measures), as well as individual measures (hypothesis-driven scales) of perfectionism, neuroticism, highly sensitive person, ego resiliency, need for structure, and negative emotionality. Ninety-nine normally sighted subjects (median age, 21 years, median refractive error 0.6 DS) completed both parts of the study.

Results. Within-subject blur tolerance measures with three different pupil sizes correlated highly ($r_s = 0.79-0.86$), implying good repeatability. There was a wide range of individual blur tolerance (0.0–2.7 D). The personality questionnaires exhibited acceptable reliability (Cronbach's $\alpha = 0.67-0.91$). Two perfectionism scales correlated significantly with blur tolerance ($r = 0.25$ and 0.27). The 15 questionnaire items that correlated most with blur tolerance were factor analyzed and yielded two conceptually meaningful factors (both $\alpha = 0.76$). The "low self confidence" and "disorganization" factors correlated positively with blur tolerance ($r = 0.38$ and 0.36, respectively) and their composite correlated with blur tolerance ($r = 0.46$).

Conclusions. These results provide the first evidence of a relationship between personality and tolerance of blur. Tolerance of blur may be related to perception of image quality. If so, personality may influence refractive error correction and development and other choices that are made when presented with degraded images. (*Invest Ophthalmol Vis Sci.* 2010;51: 6077–6082) DOI:10.1167/iovs.09-5013

It is assumed that most people are bothered by blur. However, some may tolerate higher levels of blur than others, such as those with reduced vision[1] and, perhaps, older individuals[2] (Kline DW, et al. *IOVS* 2006;47:ARVO E-Abstract 1203). A common clinical observation is that patients exhibit various levels of tolerance of degraded image quality induced by vision corrective devices. We investigated whether these individual differences in tolerance of blur are related to personality.

In the late 1940s it was noted that personality factors may be implicated when large individual differences in the results of psychophysical measurements are observed.[3,4] Responses were seen to reflect the interplay between perception and individual cognitive and motivational characteristics. More generally, it was believed that individual differences in personality characteristics could influence perceptions of the social and physical environment.[5-7] Contemporary personality research has demonstrated that personality traits exhibit both behavioral and perceptual properties. For example, across several studies, hostile individuals not only exhibited anger and aggressive behavior, but they also perceived ambiguous situations and random individuals much more negatively than did less hostile individuals.[8,9]

Despite the long-held theoretical supposition that personality and perception are meaningfully related, there is a paucity of research on the relationship between personality and visual perception. Over 40 years ago, it was proposed that personality traits correlate with refractive errors.[10] Since then, several research groups have investigated this association with inconclusive results.[11-16] Other possible relationships between personality and vision that have been investigated include choice of refractive correction,[17-21] keratoconus,[22-25] strabismus,[26] binocular rivalry,[27] eye movements,[28-30] and visual stress.[31] However, we know of no studies of the association of personality and the perception, or tolerance, of blur.

Individuals with presbyopia who wear progressive-addition lenses report limits of clear and comfortable vision beyond those expected from blur-detection thresholds,[32] suggesting tolerance of the induced blur. Recently, Atchison et al.[33] and Ciuffreda et al.[34] proposed new operational definitions of perception of blur, ranging from least (just-noticeable[33] or detectable[34] blur, which is equivalent to depth of focus[35,36]) to unacceptable (just-objectionable[33] or bothersome[34] blur). These measures of unacceptable blur may be more relevant to the evaluation of visual function than are blur-detection thresholds (depth of focus). The linear relationship between blur thresholds and letter sizes[33,34] suggests that these judgments were based on the legibility of the letters. The comparable results of the two studies show that such blur tolerance measures can be made reliably in different samples. Neither of

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those studies reported individual differences in blur tolerance, which would be expected if there is a relationship between personality and blur tolerance. In our study, we measured blur tolerance as the difference between the just-noticeable and the just-objectionable levels of blur.

Blurred vision is a suboptimal condition for humans and may be a sign of maladaptive functioning if allowed to persist. We hypothesized that psychologically high-functioning people do not tolerate blur well, whereas low-functioning people may tolerate blur to their detriment because they lack the psychological resources to positively change their environments.

Methods

Subjects

Ninety-nine normally sighted subjects, 62 female, predominantly students at Northeastern University (Boston, MA), completed both aspects of the study. Their age range was 18 to 46 (median, 21) years; the age of four subjects was not recorded (all four were in their early 20s).

The subjects were screened for habitual visual acuity (VA). Inclusion criteria included low cylindrical refractive error (<1.00 DC) in the tested eye. The median VA was −0.06 logMAR (20/17 Snellen; range −0.24 to +0.04 logMAR) and the median spherical equivalent refractive error was +0.60 D (−7.30 to +4.50 DS), as measured on the Badal optometer. There were 44 functional emmetropes, 28 myopes (< −0.50 DS), and 27 hyperopes (≥ +1.00 DS). Seventeen subjects who habitually wore soft contact lenses wore them during the blur-tolerance testing. The lens power was measured in those subjects who wore spectacles, but the spectacles were not worn during blur tolerance testing.

Blur tolerance measurements were performed monocularly (55 subjects were tested on the right eye) without cycloplegia. If both eyes passed the VA criterion, the subject chose the eye to be tested, and if no choice was made by the subject, the examiner chose one eye randomly. The study was approved by the institutional review boards at Northeastern University and Schepens Eye Research Institute, and the assessments were undertaken with the written informed consent of each subject, in accordance with the provisions of the Declaration of Helsinki for research involving human subjects.

Blur Tolerance Measures: Badal Optometer and Procedures

A computer-controlled Badal optometer (Fig. 1) was used to measure *noticeable* and *objectionable* perceived blur.[33] Responses to positive lens defocus were measured while viewing three letters presented on a computer monitor. *Noticeable blur* was described as "the point where you first notice a change in the crispness and sharpness of the letters." *Objectionable blur* was described as "the point at which blur reaches a level that you would refuse to tolerate on a full-time basis. The blur has just reached the point at which it is not acceptable. You would not tolerate spectacles or contact lenses that made you see this way." Special emphasis was placed on the instructions, to ensure that subjects understood the different definitions of blur. Our outcome measure, *blur tolerance*, was defined as the difference, in diopters, between noticeable and objectionable blur responses. As these subjects had active accommodation despite our best efforts to relax it (described later), we were not certain that the subject-reported best focus was the best focus (often found as the midpoint between negative and positive noticeable blur responses when cycloplegia is used), and, therefore, we were not sure that the difference between the subject-reported best focus and the noticeable blur response was a measure of the depth of focus. Thus, this difference between noticeable and objectionable responses was used as our measure of blur tolerance.

A Badal optometer[37] maintains the angular size of the target, despite changes in focus. Our custom-built Badal optometer (Fig. 1) had a movable auxiliary lens that varied the focus of the system while a distant object remained at a fixed location.[36] The optometer, mounted on an optical bench, comprised a Badal system (L1 and L2) and a relay system (L3 and L4), to correct any spherical refractive error. The auxiliary lens (L1), placed on a computer-controlled motorized stage (Velmex, Bloomfield, NY), induced changes in defocus at a speed of 0.12 D/s. Adjustable apertures controlled pupil size (P1) and field of view (P2). An infrared camera was used to obtain and monitor the correct position of the eye and to measure pupil sizes during testing.

Stimuli were Sloan letter[38] triplets, created using true-type fonts provided by Thomson Software Solutions (Hatfield, Hertfordshire, England), that changed randomly for each trial. The black (4.2 cd/m^2) 20/50 letters were presented on a white background (117 cd/m^2) on a 19-inch diagonal CRT monitor (VX920; Gateway, Irvine, CA) that was 7.47 m from the auxiliary lens (6.2 arc sec per pixel). Letters of the body text of a newspaper are about that size (~0.21°). A minimum of 10 practice trials were required before data collection, and the subjects were allowed to do as many additional practice runs as needed, until the subject and operator felt confident. Each trial consisted of a noticeable blur response followed by an objectionable blur response. As the positive-defocus blur slowly increased (0.12 D/s), subjects indicated when they first perceived blur by clicking a mouse. After the noticeable blur response, the auxiliary lens (L1) was moved back (less defocus) by 0.10 to 0.20 D, to avoid responses based on time alone and to allow an objectionable blur response that was the same as the noticeable blur response (i.e., 0 D blur tolerance). The operator frequently gave reminders of the definitions of noticeable and objection-

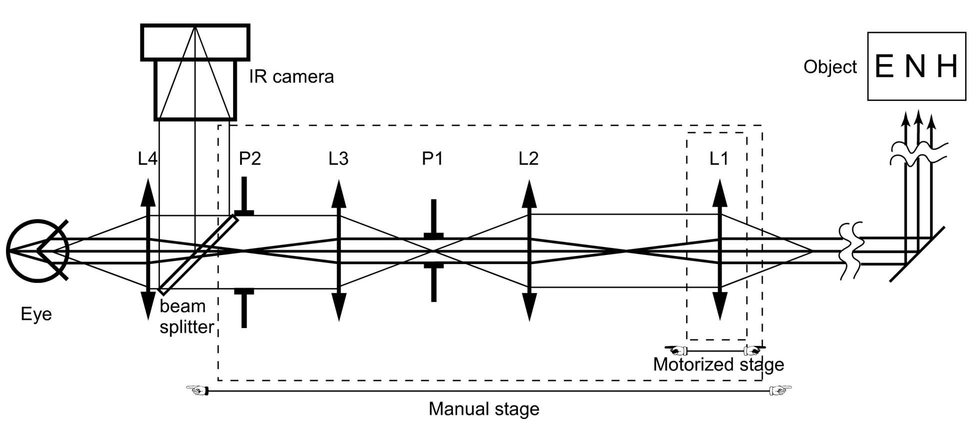

Figure 1. The system used to measure tolerance to blur. The auxiliary lens (L1) and the Badal lens (L2) constitute the Badal optometer. The second focal point of L2 was conjugate with the nodal point of the eye. An objective lens (L3) and an eye lens (L4) constituted the relay system used to correct spherical refractive error by adjustment of the distance between L3 and L4. The (effective) pupil size was controlled by the first aperture (P1), and the field of view was controlled by the second aperture (P2). The position of the eye was adjusted and monitored by using the image of the pupil and the corneal reflections of two infrared (IR) light-emitting diodes (not shown) seen with the IR camera. All lenses were +10-D achromatic doublets. The beam splitter was a glass microscope slide. At 45°, it provided ~90% transmission of visible light from the stimulus to the eye and ~5% of the IR light from the eye was reflected to the IR camera.

able blur. A blur judgment could be repeated (replaced) if there was a problem with the response as indicated by the subject. Subjects were allowed to take breaks if needed. For each entrance pupil size, 10 measurements of blur tolerance were taken. Blur tolerance was measured with one of three entrance pupil sizes: 3.5- and 4.5-mm pupils and natural pupils (measured) in random order. The total time for completion of the blur tolerance test was approximately 30 minutes.

As cycloplegia was not used, there was a risk that blur responses could have been influenced by uncontrolled accommodation. The procedures were designed to minimize the impact of accommodation by ensuring that the accommodation system was relaxed. The subjects were aware of the long viewing distance (7.47 m), and that should have reduced proximal accommodation. In addition, the best spherical correction was found by inducing confirmed positive defocus and then reducing defocus until the subject first reported that the letters were clear. This technique tends to relax accommodation. Further, the slow movement (0.12 D/s) toward positive defocus during blur measurements would induce further relaxation of accommodation. Therefore, once the subject made the first noticeable blur response, the accommodation system should have been fully relaxed. Only positive defocus blur was tested. Blur tolerance was a relative measure of the difference between noticeable and objectionable perceived blur. As confirmation that these procedures had relaxed accommodation, our blur tolerance measures were consistent with those found when cycloplegia was used.[33,34]

Blur tolerance was calculated as the median of the difference in diopters between each pair of noticeable and objectionable blur responses. In a test–retest control study, the coefficient of repeatability (95% confidence limit of difference scores)[39] of blur tolerance was found to be approximately 0.25 D. After the blur tolerance measurements, the subjects were asked to respond to the following question, on a scale of 0 to 5 (where 0 was no difference and 5 was a very large difference): "How much difference do you feel there was in the settings that you just made between the just-noticeable and the objectionable types of blur?" We called these data the subject's introspection score. Pupil sizes were measured several times throughout the testing, a minimum of twice per entrance pupil condition.

Assessments of Personality

A battery of personality questionnaires was administered via computer (MediaLab software; Empirisoft Corp., New York, NY). Participants completed two broadband measures of personality: the NEO-FFI (Neuroticism-Extroversion-Openness–Five Factor Inventory) and the California Adult Q-sort (CAQ). The NEO-FFI[40] is a 60-item questionnaire, with responses rated on a 4-point scale (ranging from strongly disagree, 1, to strongly agree, 4), that assesses five factors that are widely accepted taxonomy of adult personality: neuroticism, extraversion, openness to experience, agreeableness, and conscientiousness. The CAQ[41] consists of 100 statements, each printed on a separate card, that describe a wide range of personality, cognitive, and social attributes. The CAQ was the only measure that was not completed on the computer. Instead, the subjects sorted the cards into nine piles ranging from "least characteristic of me," 1, to "most characteristic of me," 9. The subjects were required to place a predetermined number of statements into each pile (e.g., 5 in piles 1 and 9, 8 in piles 2 and 8, 12 in piles 3 and 7, and so forth). Reliability and validity for the NEO-FFI[40] and the CAQ[42,43] have been demonstrated in numerous studies.

In addition to those exploratory broadband measures of personality, several construct-specific, hypothesis-driven, measures were administered by computer (MediaLab software; Empirisoft Corp.), including (1) ego resiliency,[44] (2) faith in intuition,[45] (3) high degree of sensitivity,[46] (4) need for cognition,[45] (5) need for structure,[47] (6) negative emotionality,[48] (7) neuroticism,[40] and (8) perfectionism.[49] These measures, assessed on the same 4-point scale as the NEO-FFI, have all demonstrated acceptable levels of reliability and validity.[40,44–49]

Data Analyses

A subset of data was not normally distributed and, as a result, nonparametric analyses were used whenever appropriate. There were two outliers (individuals with high blur tolerance values); therefore, all analyses were performed with and without the data from those two subjects (SPSS software ver. 16.0 for Macintosh; SPSS, Chicago, IL, and SAS software, ver. 9.1 for Windows; SAS Institute Inc, Cary, NC).

Results

Blur Tolerance Measures

Blur tolerance measures were consistent with the literature[33,34] and demonstrated interindividual differences, with a wide range of blur tolerance (0.0–3.1 D). Because blur tolerance measures with the three pupil sizes correlated highly (Spearman correlation, $r_s = 0.80–0.86$), blur tolerance was defined as the average of the three pupil sizes for further analyses. These blur tolerance values ranged from 0.02 to 2.66 D (median, 0.48 D), with all but two subjects having blur tolerance less than 1.5 D (Fig. 2).

Mean pupil size measured during the blur tests (scotopic conditions) was 6.3 ± 0.6 mm. Blur tolerance did not correlate significantly with refractive error ($r_s = -0.10$, $P = 0.34$), age ($r_s = 0.09$, $P = 0.7$), or VA ($r_s = -0.06$, $P = 0.5$). As blur tolerance decreased, pupil size increased ($r_s = -0.24$, $P = 0.02$), which suggests that there may have been an interaction between the defocus and ocular aberrations, that are usually larger with larger pupils. As shown in Figure 2, blur tolerance correlated with the introspection grade ($r_s = 0.60$, $P < 0.001$), indicating that the subjects were aware of their relative tolerance of blur. Without the two outliers (high blur tolerance), the correlation between blur tolerance and pupil size decreased slightly ($r_s = -0.21$, $P = 0.04$), and with introspection grade the correlation remained almost the same ($r_s = 0.59$, $P < 0.001$).

Personality Measures

Overall, 17 questionnaire scales or subscales were administered via computer, with responses on a Likert scale. The

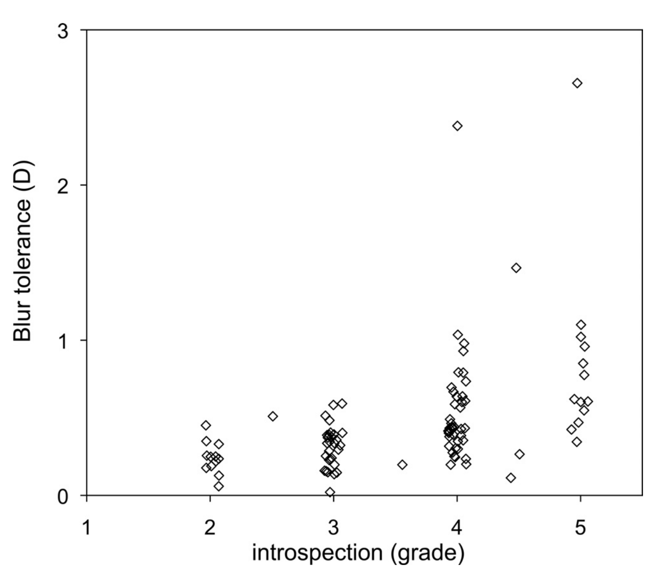

Figure 2. Blur tolerance was correlated with the subject's introspection grade ($r_s = 0.60$, $P < 0.001$). As many data points overlapped, legibility has been improved by applying small random horizontal offsets to the data points. Five subjects reported an introspection grade halfway between two integers (e.g., 2.5 units).

middle column of Table 1 displays the internal consistency of each measure, as assessed by Cronbach's α.[50] All the questionnaires exhibited acceptable reliability ranging from $\alpha = 0.67$ to 0.91. The demonstration of acceptable levels of reliability is important. Low reliability has the effect of attenuating the relationship between a questionnaire and other measures, thus reducing the likelihood of rejecting the null hypothesis. The CAQ has a unique response format that is typically not subjected to internal consistency reliability analysis. However, in its long history of use in personality assessment and research, the CAQ has been shown to possess excellent levels of test–retest and interrater reliability and validity.[42]

Personality and Blur Tolerance

We hypothesized that psychologically well-adjusted individuals would not tolerate blur as well as individuals who were poorly adjusted. To test this hypothesis, the measures described in Table 1 were correlated with blur tolerance. The results are displayed in the right column of Table 1. Only two of the 17 measures correlated significantly with blur tolerance (Pearson correlation, $P < 0.05$), and both measures are subscales from the perfectionism measure. Positive correlations found with the Parental Criticism and Doubts about Action subscales suggest that individuals who believe that their parents are disappointed in them are more likely to tolerate blurred vision than are those who believe their parents approve of their achievements. Likewise, individuals who perceive themselves to be ineffectual[51] are more likely to tolerate blur than those who perceive themselves to be effectual.

The results provide preliminary evidence for the hypothesis that psychological adjustment and blur tolerance are negatively related. Research that explores the relationship between visual characteristics and personality is not common. Therefore, the present study was designed to test hypothesized relationships and to further explore unforeseen empiric relationships between blur tolerance and personality. To accomplish this latter goal, we treated all the items comprising the 17 questionnaires and the CAQ as possible predictors of blur tolerance. From this pool of 312 items, we selected the 15 that correlated most highly in absolute value with blur tolerance (Table 2). The 15 items were subjected to a principal factors analysis with varimax rotation,[52] a procedure for identifying meaningful categories of questionnaire items. Two psychologically meaningful categories, typically referred to as factors, emerged from the analysis. The factor loadings for each one (i.e., the correlation between item and factor) are displayed in Table 2. On the basis of the item content, factor 1 was labeled *low self-confidence* and factor 2 was labeled *disorganization*. Three of the 15 items did not load on either factor.

The seven items comprising factor 1 and the five items comprising factor 2 were standardized and summed, to create composite measures of low self-confidence and disorganization, respectively. The internal consistency reliabilities of the two measures were identical (Cronbach's $\alpha = 0.76$). Both low self-confidence ($r = 0.38$, $P < 0.0001$) and disorganization ($r = 0.36$, $P = 0.0002$) correlated significantly with blur tolerance. The positive correlation between low self-confidence and disorganization ($r = 0.31$, $P = 0.002$) indicated that the measures may assess a common underlying construct. Therefore, the two measures were standardized and summed and the new aggregate score, termed "perceived incompetence," was correlated with blur tolerance ($r = 0.46$, $P < 0.0001$). Without the two outliers (high blur tolerance), the correlations were $r = 0.22$ ($P < 0.05$), $r = 0.28$ ($P < 0.01$), and $r = 0.32$ ($P < 0.001$) for factors 1 and 2 and the composite, respectively. These two exploratory factors predicted blur tolerance better than our originally hypothesized psychological adjustment variables. (By selecting 15 of 312 questionnaire items that correlated highest with blur tolerance, a viable alternative explanation might be that the low self-confidence and disorganization factors were found due to chance more than substance and were unique to the present sample. However, the factors were psychologically meaningful, and these results were replicated in a sample of 86 older adults [age range, 42–86 years] [Woods RL, et al. *IOVS* 2009;50:ARVO E-Abstract 1117]. In that multimeasure study, the low self-confidence and disorganization scales were again the best predictors of blur tolerance. The results, repeated across two divergent samples, indicate that the proffered alter-

Table 1. Reliability and Pearson Correlation with Blur Tolerance of the 17 Questionnaire Scales or Subscales

Questionnaire	Reliability*	Blur Tolerance Correlation
Ego resiliency[44]	0.67	0.07
Faith in Intuition[45]	0.74	−0.06
Highly sensitive person[46]	0.80	0.13
Need for Cognition[45]	0.87	0.05
Personal Need for Structure[47]	0.77	0.05
Negative emotionality[48]	0.90	0.06
Perfectionism: concern over mistakes[49]	0.87	0.18
Perfectionism: personal standards[49]	0.72	0.12
Perfectionism: parental expectations[49]	0.80	0.02
Perfectionism: parental criticism[49]	0.80	0.25†
Perfectionism: doubts about action[49]	0.72	0.27†
Perfectionism: organization[49]	0.91	−0.14
NEO-neuroticism[40]	0.88	0.15
NEO-extraversion[40]	0.78	−0.01
NEO-openness to experience[40]	0.76	−0.04
NEO-agreeableness[40]	0.74	0.01
NEO-conscientiousness[40]	0.85	−0.12

* Cronbach's α.
† $P < 0.05$.

Table 2. Factor Loadings (Correlations) for the 15 Questionnaire Items Most Highly Correlated with Blur Tolerance

Questionnaire Item	Factor 1	Factor 2
I usually have doubts about the simple everyday things I do.	0.56	—
I never felt like I could meet my parents' expectations.	0.76	—
If I fail partly, it is as bad as being a complete failure.	0.65	—
If I do not set the highest standards for myself, I am likely to end up a second-rate person.	0.51	—
I tend to get behind in my work because I repeat things over and over.	0.59	—
I sometimes get myself into a state of tension and turmoil as I think of the day's events.	0.42	—
I rarely feel fearful or anxious.	0.35	—
I never seem to be able to get organized.	—	0.76
I am an organized person.	—	−0.86
I keep my belongings clean and neat.	—	−0.79
I am fastidious, meticulous, careful, and precise.	—	−0.44
I have social poise and presence; socially at ease.	—	−0.37
Is verbally fluent.	—	—
Enjoys sensuous experiences.	—	—
Other people seem to accept lower standards from themselves than I do.	—	—

native explanation cannot account for the findings in the present study.)

Discussion

The most significant finding in this study is the first evidence that tolerance of defocus blur is related to measures of personality. Tolerance of blur was shown to be an individual characteristic that may have important clinical and practical implications. The results support our preliminary specific hypothesis that overall psychological adjustment and tolerance of blur are negatively correlated and imply that some form of maladjustment may be related to blur tolerance. Principal factor analysis revealed two meaningful factors: low self-confidence and disorganization. These factors suggest that people who lack self-confidence require strong evidence of blur before they become annoyed by the blur of an image or that caused by a visual device. Furthermore, disorganized people may tolerate blur because it is simply another manifestation of their untidy personal environments. These two factors predicted blur tolerance better than the hypothesized overall psychological adjustment to sensory inputs.

Tolerance of blur may be related to perception of image quality. If so, personality may influence responses to an imperfect image in many situations, such as refractive error development, refractive error corrections (e.g., progressive addition lenses, multifocal contact lenses, and intraocular lenses, or refractive surgery), and central vision impairments (e.g., macular degeneration), as well as viewing compressed images or videos (e.g., bandwidth-limited content[53–55]). Further work is needed to test whether tolerance of blur, as measured in this manner, is related to tolerance of blur in the real world and whether it is related to satisfaction with real-world situations that induce blur.

The participants in this study were young college students with similar backgrounds. As older people may be more tolerant to blur than younger people[2] (Kline DW, et al. *IOVS* 2006;47:ARVO E-Abstract 1203), we are now investigating personality and blur tolerance in a group of older adults (Woods RL, et al. *IOVS* 2009;50:ARVO E-Abstract 1117).

A possible limitation of this study is that only positive spherical defocus blur was used to evaluate blur tolerance. Atchison et al.[33] found that the differences between noticeable and objectionable blur are the same for positive and negative defocus, and a similar result would be expected for negative defocus. With optical defocus, due to the interaction between each subject's ocular aberrations and the spherical defocus,[56] each subject will have had a different experience in the amount and nature of the blur. It is possible that those subjects who were more tolerant of blur as measured with the optometer experienced less degradation of the retinal image than did other subjects. To address this possibility, we are measuring visual acuity with objectionable blur in a new study (Woods RL, et al. *IOVS* 2009;50:ARVO E-Abstract 1117).

We conclude that blur tolerance may provide a new measure of the impact of degraded images on quality of life. The results in this study provide initial evidence that tolerance of defocus blur is related to personality factors. Further investigation of the relationship between personality and blur tolerance is warranted. If blur tolerance can be predicted with a questionnaire that evaluates personality, such a questionnaire would be useful in a clinical setting to indicate how likely an individual would be to tolerate interventions that may induce blur. Blur tolerance and personality could be related to success with such interventions. Therefore, we are investigating personality factors in a second group to verify the relationship and to develop a questionnaire that could be easily administered in a clinical setting.

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