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The impact of blurred vision on cognitive assessment

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The purpose of this study was to systematically assess the effect of blurred vision on several nonverbal neuropsychological measures commonly used as part of test batteries to assess the cognitive status of different patient populations. A total of 30 highly educated and healthy participants aged between 21 and 33 years were placed in one of three blurred vision groups, defined by their maximal visual acuity (20/20 or control group, 20/40, and 20/60). Blurred vision was simulated using positive diopters at a distance of 40 cm, the same distance as that at which tests were administered. Each participant was then assessed on a predetermined battery of nonverbal and verbal neuropsychological tests demanding different levels of acuity for optimal performance (i.e., tests whose items varied in terms of size and spatial frequency characteristics). In general, blurred vision significantly affected performance on nonverbal tests defined by small-sized/high-spatial-frequency items to a greater extent than on tests defined by larger sized/lower spatial-frequency items. As expected, blurred vision did not affect verbal test performance (Similarities, Information, and Arithmetic WAIS subtests).Our results are a clear indication of how even a "minimal" loss of visual acuity (20/40) can have a significant effect on the performance for certain nonverbal tests. In conclusion, such inferior performance is hypothetically interpretable as reflecting impaired cognitive functioning (i.e., attentional) targeted by a specific task (i.e., visual search) and suggests that the precision of the cognitive assessment and subsequent diagnosis are significantly biased when visuo-sensory abilities are not optimal, particularly for older patient populations where blurred vision resulting from correctable visual impairment is quite common.

INTRODUCTION

An effective and comprehensive cognitive assessment entails the use of verbal and nonverbal neuropsychological tests that are administered and scored on the presupposition that the patient being assessed has intact sensory abilities (Wechsler, 1997). However, an assessment is often carried out without knowledge of the patient's visual acuity and/or contrast sensitivity at the time of evaluation. Although it is both common practice and common sense to instruct the patient to wear his/her corrective lenses before the assessment, information regarding whether or not the patient's corrected acuity at the time of evaluation is optimal is often overlooked or not known. In addition, it has also been documented that a precise self-assessment of visual acuity is sometimes not possible for either younger (Skeel, Nagra, van Voorst, & Olson, 2003) or older (Klein, Klein, Lee, & Cruickshanks, 1999) persons. Without knowledge of the patient's visual capabilities before assessment, a poor score obtained on a nonverbal test may at least in part be attributable to nonoptimal visual acuity during assessment and not be a precise measure of the cognitive capacities targeted by that particular nonverbal test.

This argument can be applied to any patient undergoing a neuropsychological assessment as loss of visual acuity can be caused by a variety of reasons and be manifested at different ages. However, in addition to patients who have sustained traumatic brain injury (TBI; see Skeel et al., 2003), we suggest that this argument is very applicable to

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elderly patients being evaluated for cognitive status. Large-scale epidemiological studies investigating the prevalence of correctable visual impairment in the elderly have demonstrated that approximately 20% of the elderly participants aged 75 years and over had acuities of worse than 20/40, an estimate considered to be conservative by the authors (Evans et al., 2002). As summarized by Evans & Rowlands (2004), most epidemiological studies suggest that between 10 and 50% of the elderly (65 years and over) participants sampled in each study presented visual acuity of 20/40 or worse. Although the prevalence varied, it can be argued that an important percentage of older patients (approximately 1 out of 5) necessitating cognitive assessment probably present a visual impairment that may impact their performance on nonverbal tests.

When a patient does not present an ocular pathology (i.e., glaucoma, age-related macular degeneration, etc.), loss of visual acuity is most often the result of either refractive error (lack of proper optical correction) or cataracts (clouding of the lens). Such visual loss, referred to as correctable visual impairment (CVI), leads to blurred vision that affects the efficiency with which visual information is processed. Blurred vision caused by refractive error has been demonstrated to affect performance on certain neuropsychological tests. For example, Kempen, Kritchevski, and Feldman (1994) demonstrated that blurred vision resulting from noncorrected near vision (Snellen acuity of 20/50) decreased performance on Benton's Facial Recognition (FR) and Visual Form Discrimination (VFD, but not for Judgment of Line Orientation (JLO; see Benton, de Hamsher, Varney, & Spreen, 1983, for test description). These results were interpreted as evidence that reduced acuity significantly affects performance on neuropsychological tests whose items are defined by both detailed and low-contrast information (i.e., FR and VDS tests). Van Boxtel et al. (2001) demonstrated that normal age-related loss in visual acuity, contrast sensitivity, and color weakness differentially affected performance on certain conditions of the classic Stroop Color–Word Test, suggesting that decreased performance of elderly patients on the Stroop test may at least in part be related to a normal decline in age-related visual function. Most recently, Skeel et al., (2003) assessed the effect of decreased visual acuity on a battery of nonverbal neuropsychological measures where participants were grouped in noncorrected near visual acuity categories defined as perfect (Snellen 20/20), mildly impaired (Snellen 20/25), moderately impaired (20/30–20/50, or severely impaired (<20/70) vision. Results demonstrated that performance was significantly impaired for certain tests necessitating higher levels of acuity to be completed—that is, Digit Symbol Coding subtest of Wechsler Adult Intelligence Scale–third edition (WAIS-III; Wechsler, 1997) and Trail B subtest of Trial Making Test (Reitan, 1992)—even when the decrease in acuity was minimally affected (i.e., between 20/30 and 20/50). However, other tests hypothesized by the authors to be affected by reduced acuity were not (i.e., the d2 Test of Attention; Brickenkamp & Zillmer, 1998).

Whereas previous studies assessed the impact of naturally occurring blurred vision on neuropsychological test performance, the present study is the first to systematically assess the impact of different levels of acuity loss on nonverbal test performance by simulating blurred vision. In addition, this study also differs from previous ones in that the effect of blur was assessed for a larger sample of nonverbal measures, including those currently used as part of batteries assessing different aspects of cognitive functioning (i.e., WAIS-III and the Delis–Kaplan Executive Function System, D-KEFS). Participants are randomly placed in one of three "target blur" conditions (best Snellen acuity of 20/20, 20/40, or 20/60) and are asked to complete a predetermined battery of tests (intersubject condition). Once they have completed the battery under their respective target acuity, they are assessed on modified versions of the Digit Symbol Coding and Symbol Search WAIS subtests under the other (or nontarget) blur conditions (i.e., 20/20 and 20/60; please see Method section, *Intrasubject testing: Digit Symbol Coding/Symbol Search WAIS subtests*). This intrasubject manipulation attempts to simulate a scenario where the acuity of an older patient declines as a function of time but his or her cognitive status remains constant. Such a situation is plausible given the fact that visual change is accelerated with age, and patients are often reassessed for cognitive status on a yearly basis.

Two important questions are addressed by the present study: (a) which nonverbal neuropsychological measures are affected by correctable visual impairment, and (b) at what exact level of refractive blur does subsequent task performance mimic impaired cognitive functioning targeted by the task used. Based on previous results, it is hypothesized that blurred vision will impact the performance on tests characterized by small-sized/high-spatial-frequency items to a greater extent than on those defined by larger sized/lower spatial-frequency items (i.e., Kempen et al., 1994; Skeel et al., 2003). It is also hypothesized that tests requiring visual

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scanning to be completed (i.e., cancellation tasks) will also be largely affected by reduced visual acuity (Skeel et al., 2003).

METHOD

Participants

A total of 30 observers (18 male, 12 female) aged between 20 and 33 years (mean age = 23.6 years; *SD* = 2.93) were recruited within the University of Montreal, École d'Optométrie (School of Optometry). All participants were either emmetropes (persons with uncorrected 20/20 vision) or had corrected-to-normal vision (20/20) or better when tested. None of the participants reported having any systemic or ocular pathology affecting visual field and/or acuity or any known neurological condition. A total of 28 of the participants had either a Bachelor's degree or were enrolled in a university-level program. French was the mother tongue of all except one of the participants, and therefore assessments were for the most part carried out in French using the WAIS-III version for Canadian francophones (Wechsler, 2005). Participation was voluntary and lasted approximately 3 hours per session.

Acuity measures and manipulations

A licensed optometrist (L.B.) carried out acuity measures and dioptic refraction in a well-illuminated room. Binocular far visual acuity was assessed using a standard Snellen acuity chart at a distance of 10 feet. Binocular near visual acuity was measured with a near Snellen equivalentvisual acuity chart (Inami & Co., Ltd) at a distance of 40 cm. Participants were randomly placed in one of three experimental blur groups differing in best visual acuity: 20/20 (controls), 20/40, and 20/60. Positive (plus) lenses of different diopter strengths were used to blur the binocular near visual acuity of each participant to the target acuity (plano diopters were worn for participants in the 20/20 or control group). In order to ensure that the participant did not see or memorize the letters contained in subsequent acuity chart lines during the blurring procedure, initial elevated diopter strength was used (resulting in ≈20/200 near acuity) and decreased until the target acuity level (either 20/40 or 20/60) was met for each participant. Trial lenses were worn directly over the habitual corrections in trial lens clips or in trial lens frames if the participants did not wear eyeglasses (i.e., were emmetropes or wore contact lenses). For some participants, particularly those in the 20/40 or 20/60 blur groups, an amelioration in acuity is presented over time due to accommodation, a common occurrence in younger observers. For this reason, acuity was assessed every 30 minutes in order to ensure constant target visual acuity throughout each testing session. If necessary, target visual acuity was maintained constant during each assessment by increasing diopter strength.

Neuropsychological testing

Each participant was administered a predetermined neuropsychological test battery that included the following measures:

1. *Wechsler Adult Intelligence Scale–3rd edition (WAIS-III;* Wechsler, 1997): Picture Completion (PC), Digit Symbol Coding (CD), Matrix Reasoning (MR), Picture Arrangement (PA), and Symbol Search (SS) subsets (Performance scale); Information (I), Similarities (S), and Arithmetic (A) subtests (Verbal scale). Verbal subtest performance was measured to control for the possible effect of blurred vision on general cognitive functioning and to provide a partial measure of the overall cognitive functioning of the participants. In addition, Canadian WAIS-III norms were used to obtain scaled score equivalents of raw scores for each WAIS-III subtest.
2. *Delis–Kaplan Executive Function System (D-KEFS*; Delis, Kaplan, & Kramer, 2001): Complete Trail Making Test subtest; Visual Scanning (VS), Number Sequencing (NS), Letter Sequencing (LS), Number–Letter Switching (N-LS), and Motor Speed (MS).
3. *The Mesulam and Weintraub Cancellation Tasks (MWCT;* Mesulam, 1985): Letters–Structured (L-S), Letters–Unstructured (L-U), Forms–Structured (F-S), and Forms–Unstructured conditions.

The aforementioned tests were chosen based on (a) the frequency of inclusion in neuropsychological test batteries for assessing the cognitive functioning of different patient populations and (b) the varying visual characteristics defining each test (i.e., size and spatial frequency of test items). After being blurred to target acuity, participants were seated comfortably at a table where they were presented each test on a support inclined at approximately 35 deg. This was done to ensure that the "target blur" was constant throughout the testing

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session and across the testing material (test surface always perpendicular to fixation). It also aided participants in maintaining a constant viewing distance of 40 cm from the test material. All assessments were carried out in the same environment and were supervised by a licensed neuropsychologist (A.B.). The raw scores for each participant were then converted into their respective standardized score (when possible) for each measure and used for statistical analysis.

Intrasubject testing: Digit Symbol Coding/ Symbol Search WAIS subtests

After participants had completed the predetermined test battery with their target acuity (i.e., 20/40), performance was assessed on modified versions of the Digit Symbol Coding and Symbol Search WAIS subtests under the other or nontarget blur conditions (i.e., 20/20 and 20/60). A between-subjects counterbalancing procedure was used to distribute the potential influence of order effects across testing sequence equally. To do so, one of three treatment sequences (i.e., ABC, BCA, CAB), where A = 20/20 condition, B = 20/40 condition, and C = 20/60 condition) was assigned to each participant before the experimental session for both the modified Digit Symbol Coding and Symbol Search tests, depending on his or her initial target acuity. For example, if a participant's target acuity was 20/40 (BCA sequence was used), he or she would complete the 20/40 condition (or B), followed by the 20/60 (or C) and 20/20 (or A) condition, respectively. In addition, "Example" and "Practice" items for each test were completed without blurring, regardless of the participants' initial target acuity, in order to insure that the participants' ability to understand the task instructions was not affected by acuity level.

The modified Digit Symbol Coding version was like the original except that the legend was modified to create new symbol–number pairings (i.e., the circle symbol paired with "1"), and the numbers above each empty response box were rearranged across each line in random order. The frequency with which a certain number appeared within each line was controlled for in the modified versions (i.e., the number "2" always appeared four times in the first response line, twice in the second, three times in the third, etc.). As for the modified Symbol Search subtest, symbols in the target (two-item) and search (four-item) group for each line were rearranged in such a way that the same number of lines in each page contained target symbols in the search symbol group. Therefore, 7 out of the 15 lines presented on the first of the page of the modified Symbol Search subtests were "yes" responses.

The performance of each participant was measured on the modified versions of the Digit Symbol Coding and Symbol Search WAIS subtests at all blur conditions (20/20, 20/40, and 20/60). These subtests were chosen for the following reasons: (a) Performance is minimally affected by learning for these measures (i.e., prior knowledge or strategy should not affect retest performance); and (b) each subtest is defined by small-size, high-spatial-frequency items whose perception should be affected by blurred vision. In addition to the intersubject performances acquired by the predetermined test battery, intrasubject performance on these two tests allowed us to evaluate the effect of increasing blurred vision (change in refractive error as a function of time) on the same measure for the same participant (unchanged cognitive status).

RESULTS

WAIS-III subtests: Intersubject results

Figure 1 shows the mean scaled scores for each WAIS subtest as a function of visual acuity group (20/20/, 20/40, and 20/60). Each bar in Figure 1 (and in all subsequent figures) represents the mean scaled score for 10 participants; standard error bars are also shown for each group. As mean differences between WAIS subset performance is not informative in the context of the present study, separate single-factor between-subject analyses of variance (ANOVAs) were carried out to assess the effect of decreased visual acuity on performance for each WAIS subset. In addition to *F*-ratio values, omega-squared values (ω^2) are included as a additional measure of treatment effect size. Analysis revealed that blurring vision (decreasing near visual acuity) significantly impaired performance on all the nonverbal subtests tested except for Matrix Reasoning: PC, $F(2, 27) = 4.588$, $p = .019$, $\omega^2 = .193$; CD, $F(2, 27) = 11.191$, $p < .001$, $\omega^2 = .405$; MR, $F(2, 27) = 0.270$, $p = .765$, $\omega^2 = -.051$; PA, $F(2, 27) = 5.809$, $p = .008$, $\omega^2 = .243$; SS, $F(2, 27) = 6.331$, $p = .005$, $\omega^2 = .262$. Pairwise comparisons revealed that performance on the CD and SS subtests was decreased even when a "minimal" loss of acuity (20/40) was simulated: CD, $p = .003$; SS, $p = .012$; Bonferroni correction at alpha level of .0167. For the other subtests, performance was significantly affected at the 20/60 level of acuity. As expected, blurring did not significantly affect performance on the verbal measures tested (S, I, and A subtests; $p > .05$).

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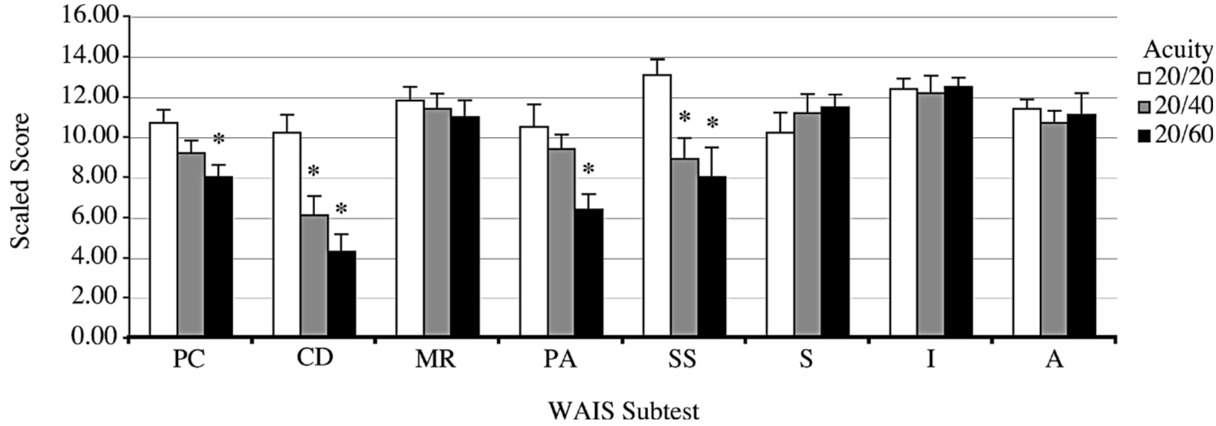

Figure 1. Intersubject mean scaled scores ($n=10$) for Picture Completion (PC), Digit Symbol Coding (CD), Matrix Reasoning (MR), Picture Arrangement (PA), Symbol Search (SS), Similarities (S), Information (I), and Arithmetic (A) WAIS subtests as a function of visual acuity group. Asterisks (*) denote significant difference relative to control acuity (or 20/20) performance. Standard error bars are shown.

For all significant results, the effect size (ω^2) was greater than .15, suggesting a relatively "large" effect of decreased acuity on performance (Cohen, 1977).

Digit Symbol Coding/Symbol Search subtest: Intrasubject results

Each bar in Figure 2 represents the mean scaled score for 30 participants as a function of blur condition for both Digit Symbol Coding and Symbol Search WAIS subtests. A repeated measures ANOVA revealed that on average, the performance of each participant decreased significantly as a function of visual acuity on both subtests: CD, $F(2, 58)=54.01$, $p < .001$; SS, $F(2, 58)=22.05$, $p < .001$. Informal observation of the individual data indicated that order effects were minimal, as only one of the participants (for the Digit Symbol Coding test only) presented a greater scaled score for the 20/40 condition than for the 20/20 or control acuity condition. All other participants, for both Digit Symbol Coding and Symbol Search subtests, consistently scored lower in the blur conditions (20/20 or 20/60) than in the 20/20 condition. Therefore, the mean scaled scores presented in Figure 2 are an accurate indication of how each participant performed on an individual basis.

D-KEFS trail making test

The normative scaled scores for each D-KEFS test condition as a function of visual acuity group are

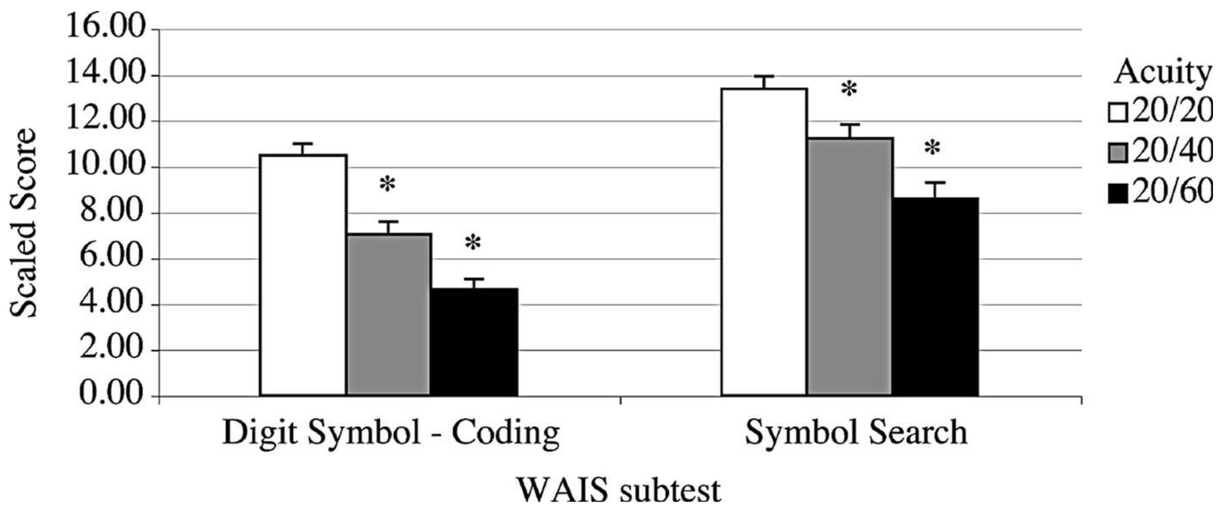

Figure 2. Intrasubject mean scaled score ($n=30$) for modified versions of the Digit Symbol Coding (CD) and Symbol Search (SS) WAIS subsets. Asterisks (*) denote significant difference relative to control acuity (or 20/20) performance. Standard error bars are shown.

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shown in Figure 3. Analyses demonstrated that decreased visual acuity affected performance on the VS, NS, and LS D-KEFS test conditions: $F(2, 27) = 6.264$, $p = .005$, $\omega^2 = .259$; $F(2, 27) = 8.945$, $p = .010$, $\omega^2 = .346$; $F(2, 27) = 5.15$, $p = .012$, $\omega^2 = .217$, respectively, at an acuity level of 20/40; VS, $p = .003$; NS, $p = .011$; LS, $p = .011$; Bonferroni correction at alpha level of .0167. N-LS and MS conditions were not affected by blurred vision: $F(2, 27) = 0.960$, $p = .393$, $\omega^2 = -.003$; $F(2, 27) = 0.54$, $p = .9475$, $\omega^2 = -.016$, respectively. For all significant results, the effect size (ω^2) was relatively "large" (Cohen, 1977).

MWCT

Time to completion (seconds) and total errors committed (omissions + false positives) for each MWCT condition are shown as a function of visual acuity group in Figure 4. Separate single-factor between-subject ANOVAs demonstrated

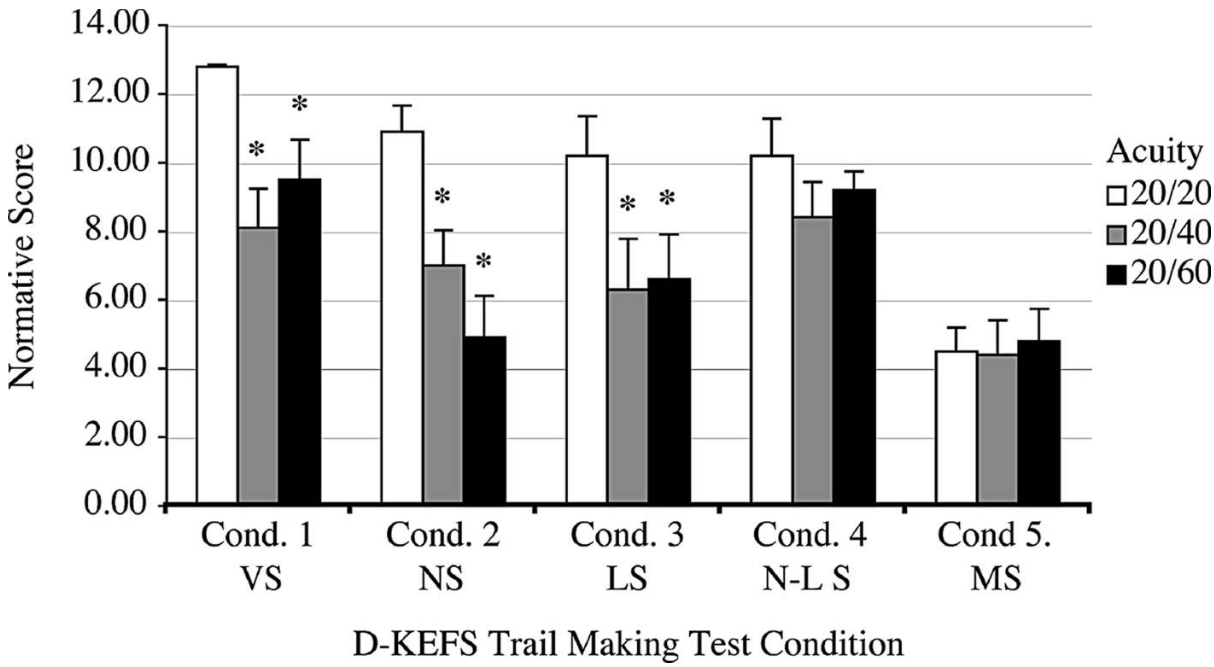

Figure 3. Intersubject normative scaled scores for Visual Scanning (VS), Number Sequencing (NS), Letter Sequencing (LS), Number–Letter Switching (N-LS), and Motor speed (MS) Trail Making Test conditions of the Delis–Kaplan Executive Function System (D-KEFS) as a function of visual acuity group. Asterisks (*) denote significant difference relative to control acuity (or 20/20) performance. Standard error bars are shown.

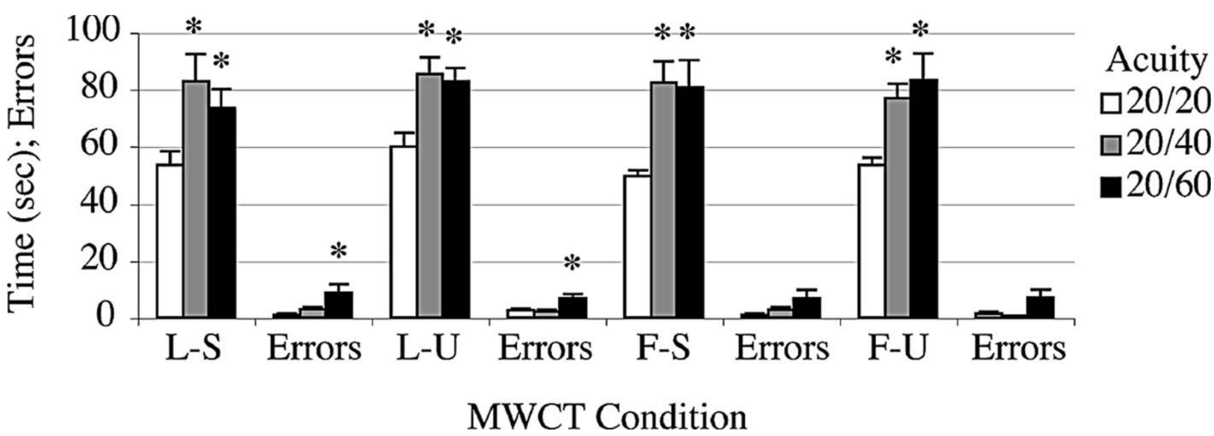

Figure 4. Intersubject time to completion (s) and errors for the Letters-Structured (L-S), Letters-Unstructured (L-U), Forms-Structured (F-S), and Forms-Unstructured (F-U) conditions of the Mesulam and Weintraub Cancellation Tasks (MWCT) as a function of visual acuity group. Asterisks (*) denote significant difference relative to control acuity (or 20/20) performance. Standard error bars are shown.

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that decreased visual acuity affected time to completion performance for the all conditions: L-S, $F(2, 27)=4.352$, $p=.0230$, $\omega^2=.183$; L-U, $F(2, 27)=7.661$, $p=.002$, $\omega^2=.308$; F-S, $F(2, 27)=6.810$, $p=.0040$, $\omega^2=.279$; F-U, $F(2, 27)=6.296$, $p=.005$, $\omega^2=.261$ at an acuity level of 20/40; L-S, $p=.007$; L-U, $p=.001$; F-S, $p=.003$; F-U, $p=.013$; Bonferroni correction at alpha level of .0167. In addition, blurred vision also significantly increased the total errors committed for the letter conditions: L-S, $F(2, 27)=5.179$, $p=.0125$, $\omega^2=.218$; L-U, $F(2, 27)=5.360$, $p=.0110$, $\omega^2=.225$, but not for the form conditions: F-S, $F(2, 27)=2.532$, $p=.098$, $\omega^2=.093$; F-U, $F(2, 27)=3.652$, $p=.039$, $\omega^2=.093$; $p > .150$. For all significant results, the effect size (ω^2) was relatively "large" (Cohen, 1977).

DISCUSSION

The present study is the first to assess the effect visual acuity loss on neuropsychological test performance by simulating blurred vision, a condition usually resulting from correctable visual impairment (CVI) such as refractive error or cataracts in the elderly. In general, our results demonstrate that blurred vision results in significantly lowered scores on most nonverbal tests assessed in the present study, particularly for those defined by small-sized/high-spatial-frequency items. Results from the present study demonstrate that minimal to moderate visual acuity loss (i.e., 20/40 or 20/60) significantly affects performance on tests commonly used during neuropsychological assessment and include, but are not limited to (a) the Picture Completion, Coding, Picture Arrangement, and Symbol Search subtests of the WAIS, (b) Conditions 1 through 3 of the D-KEFS Trial Making Test, and (c) all conditions of the MWCT. As expected, blurred vision (whether minimal or moderate) did not significantly affect performance on verbal tests (i.e., Similarities, Information, and Arithmetic WAIS subtests), nor on tasks defined by larger sized/lower spatial-frequency item characteristics (i.e., Matrix Reasoning WAIS subtests). Our results stress the importance of knowing a patient's visual acuity at the time of neuropsychological evaluation since even a "minimal" loss of visual acuity (20/40) significantly affects performance on a variety of commonly used nonverbal tests. Given that performance on such nonverbal tasks is in large part used to compile cognitive profiles upon which diagnosis is based, it can be argued that reduced acuity can at least indirectly result in profiles hypothetically interpretable as reflecting reduced cognitive ability, particularly for functioning targeted by a specific task significantly affected by lowered acuity.

Neuropsychological test characteristics most affected by blurred vision

In agreement with previous studies (Kempen et al., 1994; Skeel, et al., 2003), our results suggest that blurred vision predominantly affects performance on neuropsychological tasks requiring efficient (a) processing of small-sized/high-spatial-frequency items to be completed and/or (b) visual scanning. For example, even a minimal loss of acuity (20/40) significantly affected performance for the Coding and Symbol Search WAIS subtests and all conditions of the MWCT, as well as the Visual Scanning, Number Sequencing, and Letter Sequencing conditions of the D-KEFS. These results are consistent with those of Skeel et al. (2003), who demonstrated that persons with moderate (20/30–20/50) and severe (<20/70) impairment of near visual acuity performed significantly worse on both the Coding subset of the WAIS and the Trails B subtest of Trial Making Test. However, they unexpectedly found no effect of blur on d2 Test of Attention performance, a task that necessitates both efficient visual scanning capabilities and intact visual acuity given the small-sized/high-spatial-frequency items comprising the task. They argued that their negative result was due to the fact that scanning for relevant stimuli in this task is in an expected direction (i.e., from left to right), and, therefore, participants did not have to adjust their focus on consecutively scanned items in unexpected directions during task completion, as is the case for other visual scanning tasks where performance was found to be affected by blurred vision (i.e., Trails B). This argument is not consistent with our results for the following reason. Participants performed significantly worse when blurred for all conditions of the MWCT test, regardless of whether the target letter (i.e., A) or symbol (bisected circle) to be circled was embedded within structured (arranged in rows and columns) or nonstructured (arranged in pseudorandom fashion) distractors. When distractors were structured, all participants searched for the target in a systematic left-to-right manner, much as they did during d2 Test of Attention task completion or searching for a word within a written text. Therefore, visual scanning efficiency was not affected by expected scanning direction for the MWCT; reduced performance on this visual search task is entirely dependent on whether vision is blurred or not, particularly since the targets and distractors comprising these tasks are small and differ by high-spatial-frequency characteristics.

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Naturally occurring versus simulated blur

Previous studies investigating the effect of reduced visual acuity on neuropsychological test performance used participants that had existing visual impairment—that is, uncorrected refractive error or naturally occurring blurred vision. For example, the participants in the Kempen et al. (1994) study presented binocular Jaeger visual acuity of J5 (≈ Sellen equivalent 20/50) to worse than J14, with a median of J12 (≈20/130). Based on their uncorrected near visual acuity, Skeel et al. (2003) classified participants as belonging to perfect (20/20), mild impairment (20/25), moderate impairment (20/30–20/50), or severe impairment (<20/70) categories. Skeel et al. (2003) suggests that it is advantageous to assess the impact of decreased visual acuity of test performance in patients who already have existing visual impairment since patients can incorporate natural compensation strategies to accommodate sensory loss, suggesting that such an approach offers a more ecological valid result (Van Boxtel et al., 2001). However, it can also be argued that the compensatory strategies developed by these patients in their natural environment are probably not applicable to the neuropsychological setting, where they are asked to complete unnatural tasks such as cancellation, line tracing, and visual search tasks under strict time restraints and a novel environment, where their strategies may not necessarily apply. For this reason, we consider the accuracy with which we systematically manipulated the degree of blur to be more important in the context of the present study than the potential of compensatory strategies not being used by the participants. In addition, grouping participants as a function of their visual acuity (within a predetermined range) may result in less precise associations between level of acuity and task performance. We found that increasing blur from 20/40 to 20/60 significantly affected performance for certain tasks (i.e., Picture Completion and Picture Arrangement WAIS subtests) but not for others. Therefore, by manipulating visual acuity to target blur levels, one can establish a “minimal” or “cutoff” acuity above which certain tests should not be administered since they significantly affect task performance. Categorizing participants results in a range of acceptable acuities rather than an exact or precise cutoff acuity (see Skeel, Schutte, van Voorst, & Nagra, 2006). For this reason, we argue that simulating blur is advantageous over measuring the effects of naturally occurring blur in the context of the present and similar studies.

Effect of ocular pathology on neuropsychological task performance

In addition to CVI, ocular conditions such as glaucoma, age-related macular degeneration (ARMD), retinitis pigmentosa, and diabetic retinopathy also result in reduced visual acuity (and contrast sensitivity and visual fields deficits). As with the simulated blurred groups (i.e., 20/40 and 20/40) in the present study, we have recently demonstrated (Bertone, Wittich, Watanabe, Overbury, & Faubert, 2005) that the performance of patients with ARMD is significantly reduced on nonverbal neuropsychological tasks, particularly for tasks characterized by visual scanning strategies (Trail Making Test, D-KEFS) and small-sized/high-spatial-frequency items (i.e., Digit Symbol and Symbol Search WAIS subtests). Performances on larger sized/lower spatial-frequency defined tasks were less affected (i.e., Picture Completion subtest of the WAIS and the Hooper Visual Organization Test, VOT) by ARMD. However, when patients were reassessed within a 6-week period using the same battery of tests in magnified versions (tests size increasing by 150%), performance increased to near-normal levels for tasks defined by small-sized/high-spatial-frequency items, but not for larger-sized/lower spatial-frequency defined tasks (performance remained constant), particularly for ARMD patient with severe loss of acuity loss and central vision. These findings are important in that they demonstrate that loss of visual acuity, whether the result of CVI or ocular pathology, significantly affects performance on neuropsychological testing and compromises the validity of cognitive status diagnosis derived in part for nonverbal neuropsychological test results if the visual acuity of the patient is not known. By correcting for the loss of visual input (by stimulus magnification), task performance was improved for the ARMD group. Taken together, the results of Bertone et al. (2005) and those of the present study demonstrate that nonverbal neuropsychological task performance can be significantly affected by either degrading (i.e., blurring) or enhancing (i.e., magnifying) visuosensory input, irrespective of cognitive status.

Patient populations most affected by reduced visual acuity: The elderly

Patient populations likely to present nonoptimal visual acuity at the time of assessment include persons who have sustained traumatic brain injury (TBI; Skeel et al., 2003) and of course, persons with ocular pathology (Bertone et al., 2005;

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Kempen et al., 1994; Skeel et al., 2006). However, we argue that the patient population most relevant to the arguments presented in this study are elderly patients (Van Boxtel et al., 2001)—specifically, elderly patients being assessed for probable dementia.

The prevalence of CVI is increases with age and is often untreated. In fact, some epidemiological studies have demonstrated that approximately 1 out of 4 (or 25%) of participants over the age of 75 with "corrected vision" still had a visual capabilities considered to be impaired (Evans et al., 2002); the authors considered this figure to be a conservative estimate. Some studies have found even higher prevalence of CVI for the same age group (i.e., Jack, Smith, Neoh, Lye, & McGalliard, 1995; Reinstein et al., 1993). New refractive corrections would likely improve the visual acuity in many older adults (Tielsch et al., 1990) and, consequently, performance on nonverbal tasks. These statistics are of important concern for practitioners involved in the assessment of cognitive status for patients potentially suffering from dementia of the Alzheimer or Parkinson type, mild cognitive impairment, and other age-related degenerative pathologies affecting the elderly. In theory, one out of every four patients assessed probably has non-optimal visual acuity when assessed, even when wearing his or her corrective lenses. As we have demonstrated, even minimal visual impairment (i.e., 20/40) has significant effects on performance on certain tasks often used as part of batteries to either diagnose a probable dementing process or differentially diagnose between different types of dementia. For this reason, knowledge of the ocular status of elderly patients is necessary in order to carry out an efficient and precise cognitive assessment. Therefore, that failure to take into account the patient's visual capabilities may lead to an erroneous interpretation of a poor performance on a particular nonverbal task that targets a specific cognitive function. For example, it is plausible that poor performances on nonverbal memory tasks currently used in dementia test batteries (i.e., Faces, Family Pictures, and Visual Reproduction subtests of the Wechsler Memory Scale-III, the Rey–Osterrieth Complex Figure Test, etc.) may at least in part be accounted for nonoptimal visual correction. In addition to reduced acuity, decreased contrast sensitivity caused by age-related eye disease is another type of visual impairment that may be associated with reduced performance on certain visual memory tasks (Skeel et al., 2006).

Not only is the prevalence of CVI increased with age, it is also accelerated with age (Evans & Rowlands, 2004). As mentioned by Skeel et al. (2003), it is quite possible that the visual acuity of an elderly patient evaluated on a yearly basis changes to a larger degree than that of younger patients. One would therefore expect that elderly patients would be less likely evaluated with their optimal correction. Hypothetically, it is possible that in addition to presenting continuing cognitive decline, elderly patients may also present increased CVI making it difficult to dissociate ocular-related loss form cognitive-related loss with time. Another scenario is that the real cognitive status of such patients remains relatively unchanged but due to changing visual status, their cognitive profile, based in part on nonverbal test results, will reflect deteriorating cognitive status. Such a scenario is simulated by our intrasubject results where scores on the Digit Symbol Coding/Symbol Search WAIS subtests were significantly decreased as blur was increased for the same participant, tested within the same session. In this case, participants presented the same cognitive status but their task performance was entirely dependent on their visual acuity. It can be argued that the same pattern of results would be manifested for other nonverbal tasks, particularly for those defined by small-sized/high spatial-frequency items.

Clinical implications: The need to establish protocol

It is common practice, as well as common sense, to ask a patient to wear his or her corrective lenses before neuropsychological assessment. However, it is not known whether the intake interview of either private or public health practitioners includes the following fundamental questions regarding the patient's ocular status at the time of assessment: Is the patient's corrected visual acuity optimal? What is the patient's present corrected acuity? When was patient's last optometric assessment? Does the patient suffer from any ocular condition causing degraded visual capacities (i.e., cataracts, glaucoma, diabetic retinopathy, etc.)? Are the corrective lenses worn by the patient issued by a health professional or simply over-the-counter reading glasses? It is above and beyond the neuropsychological profession to be able to efficiently assess the ocular status of the patients being evaluated. However, it is possible to inform oneself through communications with other professionals responsible for the ocular health of the patient, and not by simply asking the patient about his or her own vision as precise self-assessment is sometimes not possible (Friedman et al., 1999; Klein et al., 1999; Skeel et al., 2003). We suggest that the knowledge of the patient's ocular status at the time of assessment is

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advantageous for a precise cognitive profiling and suggest that it should be part of standard protocol when possible. At the very least, we consider it is to be the neuropsychologist's responsibility to be informed of any visual difficulty the patient presents at the time of assessment. This can be done by either communicating with vision health professionals responsible for the patient's ocular health (i.e., ophthalmologist or optometrist) before cognitive assessment takes place or assessing the patient's near visual acuity using one of many near vision charts currently available. Finally, if significant visual dysfunction is suspected, the neuropsychologist should interpret reduced performance on certain visual tasks with caution.

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