READING WITH DIFFUSIVE AND DIOPTRIC BLUR.

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Abstract

Purpose: Dioptric and diffusive blur have been used to simulate visual impairments, including cataract. The impact of blur on reading has not been well described. This study reports the impact of diffusive and dioptric blur on reading rates in older and younger subjects. **Methods:** Two groups of ten subjects aged 63 to 72 years and 21 to 35 years, with no known ocular or other condition that might affect reading, participated in the study. Monocular vision (visual acuity and letter contrast sensitivity) and monocular silent reading rate (short passages, with comprehension test) were measured with best optical correction, diffusive blur (Bangerter foil 0.3) and dioptric blur (+1.75DS). Text was read with acuity reserves of 0.1 logMAR (1.3x visual acuity) to 0.8 logMAR (6.3x). **Results:** There was no significant difference in visual acuity or letter contrast sensitivity between the two groups or between the types of blur (average visual acuity 20/14 with best-correction and 20/65 with blur). The older group read slightly, but not significantly, more slowly (p=0.20). The two blur conditions reduced reading rates about equally in the older group, but dioptric blur had a greater effect than diffusive blur in the younger group (p=0.02). Maximum reading rate with blurs was reached at an acuity reserve of about 0.4 logMAR, and at about 1.0 logMAR with best corrected. Maximum reading rates with blurs were slower than best-corrected (p<0.05), even though acuity reserve was equated. **Conclusions:** Diffusive and dioptric blur equated for impact on visual acuity and letter contrast sensitivity had the same effect on reading rates in the older group, but a different effect in the younger group. Hence, younger subjects reading with blur may not be a good simulation of the impact of blur on older subjects. The lower maximum reading rates with blurs, despite magnification, may be a consequence of the visual angle of the text. When acuity is sufficiently reduced, the magnification required to provide a large acuity reserve may itself be a factor limiting maximum reading rates of people with visual impairments.
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Introduction

- Many visual impairments reduce reading rates.
- Blur may simulate effects on reading of some visual impairments such as cataract and corneal dystrophy.
  Question: Do diffusive and dioptric blurs have the same effect?
- Though most visually impaired people are seniors, often young people are used to simulate the effects of visual impairment.
  Question: Does age matter?
- Magnification improves reading rates.
- Acuity reserve (AR; Whittaker and Lovie-Kitchin, 1993) is a description of effective magnification.
  Question: Does acuity reserve equate reading performance?

Methods

- 40 subjects - normal vision, native English speakers.

Reading Rate

- ~100 word passages.
- Five line 'pages' on a computer monitor.
- Same layout for all letter sizes.
- Silent reading with comprehension test.

Average subject age and best-corrected vision.

		Experiment 1	Experiment 2
Older Subjects	*Age (years)*	67±3	68±5
	*VA * (logMAR)*	-0.14±0.06 (20/15)	-0.08±0.09 (20/17)
	Letter CS1 ‡ (log contrast)	0.18±0.08 (1.5%)	0.25±0.14 (1.8%)
	Letter CS4 § (log contrast)	0.21±0.11 (1.6%)	0.28±0.17 (1.9%)
Younger Subjects	*Age*	27±5	24±5
	VA (logMAR)*	-0.18±0.06 (20/13)	-0.18±0.07 (20/13)
	Letter CS1 ‡ (log contrast)	0.15±0.10 (1.4%)	0.16±0.10 (1.5%)
	Letter CS4 § (log contrast)	0.20±0.09 (1.6%)	0.18±0.10 (1.5%)

* Single letter visual acuity with B-VAT.
‡ 20/250 B-VAT letters at 3ft (fundamental freq. ~1cpd)
§ 20/60 B-VAT letters at 3ft (fundamental freq. ~4cpd)

Experiment 1 – Effect of blur and age

Methods

- Compared best-corrected, diffusive blur and dioptric blur for acuity reserves of 0.1 to 0.8 logMAR (1.25 to 6.3 times VA).
- Diffusive blur was 0.3 Bangerter filter (VA: +0.50±0.04 logMAR (20/63)).
- Dioptric blur was +1.75DS (VA: +0.52±0.07 logMAR (20/66)).
- 10 "older" and 10 "younger" subjects (Table).
- Matched visual acuity and letter contrast sensitivity across blurs (p>0.12).

Results - Figures 1 & 2

Do diffusive and dioptric blurs have the same effect?
No, and the effect depends on age.

- Older subjects: effects of diffusive and dioptric blur were different (*interaction*, p=0.002) (in particular, different at 0.1 logAR; p=0.008).[1]
- Younger subjects: reading was slower with dioptric blur than diffusive blur (p=0.02), but the difference between blurs was the same over the AR range (*no interaction*, p=0.42).

Does age matter? **Yes.**

Does acuity reserve equate performance? **No.**

- Maximum reading rate with blur was slower than best-corrected (p < 0.05).
- Acuity reserve at maximum reading rate was smaller with dioptric blur (p=0.03) and diffusive blur (p=0.07) than best-corrected.
- Differences in the visual angle may account for the difference in maximum reading rate (Figure 2). This was examined in Experiment 2.

1 There was no difference when plotted against letter size (Figure 2) due to the spectacle magnification effect of the defocusing lens.

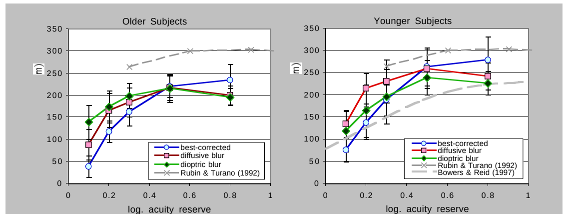

Figure 1. Average reading rates of older (left) and younger (right) groups when vision was best-corrected and blurred. Error bars are 95% confidence limits. Data from Rubin and Turano (1992, n=13, 21 to 85 years) and Bowers and Reid (1997, n=10, 18 to 35 years) are shown for comparison.

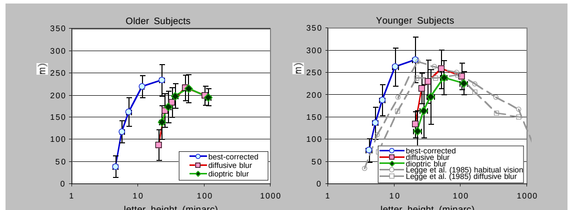

Figure 2. Average reading rates of older (left) and younger (right) groups when vision was best-corrected and blurred as a function of letter height. Error bars are 95% confidence limits. Data from Legge et al. (1985, n=4, between 20 and 30 years) are shown for comparison.

Experiment 2 – Effect of large text sizes and age

Methods

- Extended acuity reserve range to 0.1 to 1.55 logMAR (1.25 to 35 times VA) for best corrected only.
- Different 10 "older" and 10 "younger" subjects (Table).

Results – Figures 3 & 4

Does age matter? **Yes.**

- Reading rates of the older subjects clearly declined after reaching a maximum at about 0.7 logMAR acuity reserve (Figure 3 left).
- For the younger subjects there was no clear decline from maximum reading even at 1.55 logMAR acuity reserve (Figure 3 right).

Does letter size explain reduced maximum reading rates with blur?
Probably.

- The decrease in best-corrected reading rate at large letter sizes is consistent with the lower maximum reading rate with blur observed in Experiment 1 (Figure 4).

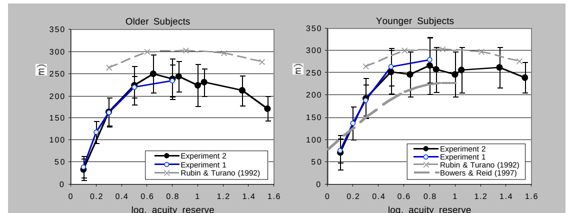

Figure 3. Average reading rates of older (left) and younger (right) groups when best-corrected. Error bars are 95% confidence limits. Data from Rubin and Turano (1992) and Bowers and Reid (1997) are shown for comparison.

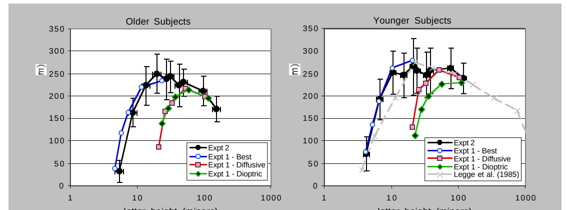

Figure 4. Average reading rates of older (left) and younger (right) groups when best-corrected as a function of letter height. The best-corrected data overlaps with the blur data at the larger letter sizes. Error bars are 95% confidence limits. Data from Legge et al. (1985) are shown for comparison.

Discussion

- Diffusive and dioptric blurs **did not** have the same effect.
- The effect of blur depended on age.
- At small acuity reserves, subjects read faster with blur (Figure 1). Is more information available in words that are near single-letter threshold for blur than best-corrected?
- Age affects reading rates with best-corrected at large letter sizes. This may be due to differences in visual span.
- Acuity Reserve **did not** equate reading performance.
- Letter size restricts the maximum reading rate with blur. This may help to explain the limited maximum reading rates with visual impairment.

References

Bowers AR, Reid VM. (1997) Eye movements and reading with simulated visual impairment. *Ophthal Physiol Opt.* 17: 392-402.
Legge GE, Pelli DG, Rubin GS, Schleske MM. (1985) Psychophysics of reading-I. Normal vision. *Vision Res.* 25: 239-252.
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Appendix

What is a good equation to fit this sort of data?

Simple Exponential Function

- Initially, reading rate (RR) data were fit with an exponential function of the acuity reserve, *AR*:

$$RR = RR_{\max}\left(1-\exp\left(-\frac{AR}{AR_0}\right)\right) \quad (1)$$

RR_{max} = maximum reading rate; AR_0 = acuity reserve constant., that describes the rise in RR. The *AR* that resulted in 95% RR_{max} (= $3AR_0$,) can be defined as the *required AR*.

- In experiment 1, *required AR* with blur was about 1.0 logMAR for best-corrected and about 0.4 logMAR for blur.
- The validity of the simple exponential fit is doubtful since the data may reach a peak and then decline (Figures 1 & 2).

"Broken-line" Exponential Function

- An alternative equation that combined two exponential equations. One described the initial rise in *RR* as *AR* increased from zero to *AR=M*, and another that described the fall in *AR* at large letter sizes (*AR>M*). *RR* at *M* is maximum reading rate:

$$RR = \begin{cases} R\left(1-\exp\left(\frac{C-AR}{AR_0}\right)\right), & \text{if } AR < M \\ R\left(1-\exp\left(\frac{C'-AR}{AR'_0}\right)\right), & \text{else} \end{cases} \quad (2)$$

where *M* is the AR at which the two curves join, AR_0 and AR_0', describe the rise and fall of RR, respectively; *C* to *C'* describe the absolute minimum and maximum in *AR*, respectively. C was set to zero, making that equation the same as equation 1. We used a least squared fitting procedure with six degrees of freedom (variables: M, R, C, AR_0, C' and AR_0').

Results.

- Broken-line exponential fits are shown in Figure 5.
- Maximum RR predicted: 241wpm at 22minarc for older subjects.
- Maximum RR predicted: 267wpm at 20minarc for younger subjects.

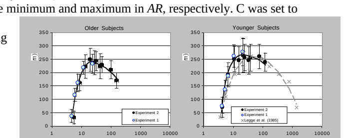

Figure 5. Broken-line exponential fits to our best-corrected reading rate data shown as solid lines. Fit to Legge et al. (1985) habitual vision data shown as the dashed line. Error bars are 95% confidence limits.