Effect of Retinal Defocus on Rapid Serial Visual Presentation (RSVP) Digit Recognition

- **Jing Jing Xu, M.D.[1]**
- **Kenneth J. Ciuffreda, O.D., Ph.D.[1,2]**
- **Hao Chen, O.D.[1]**
- **Lu Fan, O.D. M.D.[1]**

1. Wenzhou Medical College
82 Xue Yuan Road
Wenzhou, Zheijiang 325000, China
2. SUNY/ State College of Optometry
Department of Vision Sciences
33 West 42nd Street
New York, NY 10036

Abstract

Nearly all objects in one's visual field are defocused to some extent, and its potentially deleterious effect on visual task performance is variable. The purpose of the present study was to assess the effect of retinal defocus on rapid serial visual presentation (RSVP) single digit recognition. Subjects were 17 myopic and two emmetropic, visually-normal, young adults. Single digit, random Arabic numbers (1-9; 40 total at each level) were presented on a computer screen using an RSVP paradigm under binocular viewing conditions. Full refractive corrections at 4m and 40cm were in place. Target contrast was 50% with 20/50 font size. Defocus lenses were introduced in descending order: +2.5, 2.0, 1.5, 1.0, 0.5D, and plano. Maximum digit recognition per minute was determined under each lens condition using a modified staircase technique. There was a rapid, linear decrease in digit recognition rate with increase in retinal defocus. The effect was greater at distance than at near.

Digit recognition speed was highly susceptible to retinal defocus, perhaps due to the dynamic nature of the stimulus. The results have implications related to everyday tasks in a complex and constantly changing dynamic visual environment, such as during driving and sports.

Xu JJ, Ciuffreda KJ, Chen H, Fan Lu. Effect of retinal defocus on rapid serial visual presentation (RSVP) digit recognition. J Behav Optom 2009;20:67-69.

Key Words

accommodation, depth-of-focus, digit recognition, rapid serial visual presentation, RSVP, refractive error, retinal focus

INTRODUCTION

Retinal defocus of varying magnitudes is present for virtually all objects in one's visual field, including the most sensitive central foveal region.[1,2] Despite this ubiquitous presence of retinal defocus in one's visual world, it may have an adverse effect on human visual performance if it exceeds an individual's "functional blur threshold."[3] For example, under a variety of conditions, such as reading[4] and sports[5] activities, there appears to be considerable tolerance. Up to approximately 2D of retinal defocus can be present without significant adverse consequences in task performance. In contrast, both conventional visual acuity and contrast sensitivity are subject to relatively rapid performance degradation with smaller amounts of retinal defocus (e.g., 1D).[6] Furthermore, under more stringent and restrictive dynamic viewing conditions, such as reading television captions with limited viewing durations, these smaller amounts of retinal defocus (e.g., +1D) have also been found to be deleterious.[7]

Another such limiting and restricted viewing condition is rapid-serial visual presentation (RSVP).[8] Here the temporal component of the target rapidly changes within a fixed spatial location. The importance of retinal defocus effects becomes especially critical because the RSVP paradigm has been advocated for use in reading text in low vision patients having oculomotor dysfunctions.[9] However, in such patients, the refractive error may be difficult to correct accurately due to the presence of abnormal fixational eye movements and/or visual field defects.[10] These could result in increased and undesirable retinal defocus. If the retinal defocus exceeds the depth-of-focus (DOF), one will experience the perception of blur.[11]

Thus, the purpose of the present study was to investigate the effect of spherical retinal defocus at both distance and near on RSVP in visually-normal, young adult subjects under binocular viewing conditions.

METHODS

Subjects

Nineteen visually-normal, young adult subjects (ages 18-30 years of age) participated in the study. There were 8 males and 11 females. The subjects were either clinical faculty or students at the Wenzhou Medical College. All were free of ocular pathology. They were comprised of 17 myopes (refractive range -0.50 to -5.62D, with a mean of -2.95D spherical equivalent) with astigmatism of less than or equal to 1.0D, and 2 emmetropes (refractive range +0.50 to -0.25D). The study protocol was approved by the Wenzhou College Medical Institutional Review Board, and written informed consent was obtained from each subject prior to their participation.

Apparatus

The stimuli were displayed on the center of a laptop computer screen placed at distances of either 4m or 40cm. Stimuli consisted of 40 single-digit, 20/50 random numbers (0-9) having a contrast of 50%. Numbers were used rather than letters or words to minimize the cognitive demand, as well as to simplify the report of blur. Screen luminance was 45 cd/m.[2]

Procedures

Subjects were placed within a chinrest/headrest assembly which was aligned with the center of the computer screen. A trial frame with full distance refractive correction was placed on the subject. Testing was performed under binocular viewing conditions at far, and then repeated at near. All testing was performed on the same day to minimize intra-subject variability. Defocusing convex lenses were then added binocularly in descending order: +2.5, 2.0, 1.5, 1.0, 0.5D, and plano. This sequence was used to maximize and maintain blur adaptation in order to be relatively constant throughout all testing.

For the far test condition (4m), cycloplegia was not used, so that viewing was naturalistic. Pupil size was approximately 4-5mm and was not controlled during the far testing.

For the near test condition (40cm), cycloplegia was used to control accommodative fluctuations that are prominent at this distance.[12] Plus lenses were added binocularly to obtain optical conjugacy with the computer screen. One drop of 1% cyclopentolate was administered, followed by two drops, 5 and 10 minutes apart. Testing proceeded 30 minutes later to allow full cycloplegia to take place and be maintained during the one hour of near testing.[13] Pupil size was approximately 7-8mm and was not controlled during the near testing.

For each distance and defocus amount, the 40 random numbers were presented.

The sequence was as follows: After a five minute practice session at an initial "equivalent reading rate" of 200 "words" per minute (wpm), testing commenced. Subjects were instructed to call out the test numbers as rapidly as possible. A staircase procedure was used. If the error rate did not exceed 5% (2 out of 40), the presentation rate was increased by the equivalent of 20 wpm. This continued until it exceeded 5%, at which time it was decreased by the equivalent of 10 wpm. Finally, when the error rate once again was less than 5%, the presentation rate was decreased by the equivalent of 5 wpm, which was the final designated "equivalent reading speed." This paradigm was then repeated in descending order of lens power.

Results

Figure 1 presents the distance findings. There was a rapid and linear reduction in maximum equivalent reading rate with retinal defocus. It was 190 wpm under the plano condition and reduced to 15 wpm equivalent under the 1.5D condition, and zero beyond. The largest fall-off in processing rate was between 0.5 and 1.0D of defocus. A one-way ANOVA was performed, and the effect of retinal defocus was found to be significant [F(3,50)=50.776, p=<0.0001]. The Fisher Least Significant Difference (LSD) post-hoc test indicated that all non-zero comparisons (plano to 1.5D) were significantly different from one another (p=<0.05).

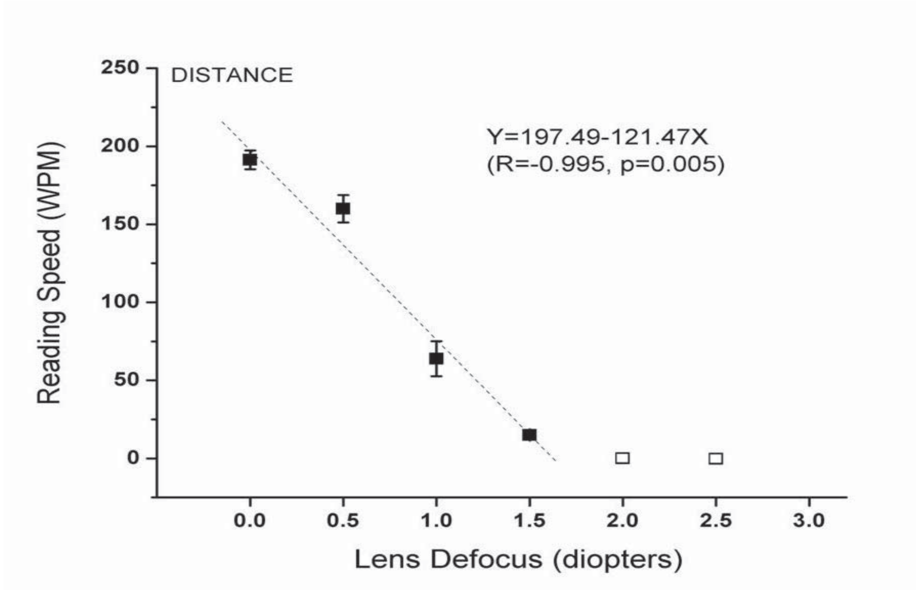

Figure 1: Equivalent reading rate as a function of lens defocus at distance. Plotted is the mean +/- 1 sem. The open symbols have a zero value and were not included in neither the statistical nor linear regression analysis.

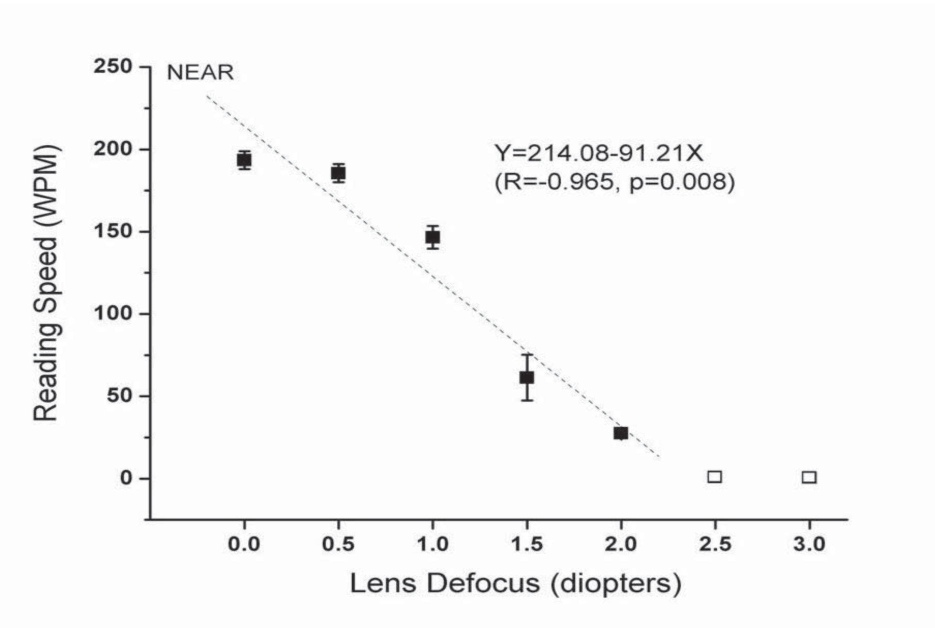

Figure 2: Equivalent reading rate as a function of lens defocus at near. Plotted is the mean +/- 1 sem. The open symbols have a zero value and were not included in neither the statistical nor linear regression analysis.

Figure 2 presents the near findings. There was a rapid and linear reduction in equivalent reading rate with retinal defocus. It was 193 wpm under the plano condition and reduced to 3 wpm under the 2.0D condition, and zero beyond. The largest fall-off in processing time was between 1.0 and 1.5D of retinal defocus. A one-way ANOVA was performed, and the effect of retinal defocus was found to be significant [F(4,69)=46.208, p=<0.0001]. The Fisher Least Significant Difference post-hoc test indicated that all non-zero comparisons (plano to 2D) were significant (p=<0.05) except for the following: plano and +0.50D, and +1.50D and 2.00D.

DISCUSSION

The present study demonstrated that RSVP digit recognition was sensitive to retinal defocus, especially at distance. Visual performance decreased most steeply at distance between 0.5 and 1.0D, whereas at near it occurred between 1.0 and 1.5D. The results are in general agreement with measures of threshold visual tasks (e.g., visual acuity and contrast sensitivity).[6,14-17] They are also in general agreement with reading television captions, which represents a non-threshold recognition task with a time restriction.[7] The captions are presented over a limited time period, and thereby the execution of regressive eye movements to reread and confirm context and meaning is more difficult to perform. In contrast, for conventional reading[4] and many sports-related activities (e.g., golf putting),[5] vision and visuomotor performance does not decrease noticeably until at least 2D of retinal defocus is imposed. Conventional reading and sport activities do not require a fine degree of visual resolution in the majority of cases.[18] Thus, the combination of a high visual resolution demand and/or a dynamic timing limitation appears to result in the most deleterious effect of retinal defocus. Similarly, defocus-related robustness has been found for overall driving ability, but not for sign detection and recognition during driving.[19]

There was consistently increased sensitivity to retinal defocus at distance versus near viewing. There are three possible reasons for this difference. First and foremost, there is the use of hyperfocal refraction.[1] Clinically, the dictum states that one should provide "maximum plus for maximum visual acuity." This results in a myopic refractive bias of +0.25 to +0.75D,[1,20] such that the distal edge of the DOF is approximately coincident with the target at optical infinity. This produces an effective "lead" of accommodation. Thus, with a relatively small increase in plus lens power to produce additional retinal defocus, and myopic shift, the DOF would be quickly exceeded. This would give rise to the perception of blur and correlated retinal-image degradation. In contrast, with use of minimum powered plus lenses to produce clarity of vision at near, there is a "lag" of accommodation present (~0.25 to 0.75D), with the proximal edge of the DOF now being approximately coincident with the near target.[1] Thus, considerably more defocus lens power must be added at near before the distal edge of the DOF is exceeded. This could account for all or most of the distance versus near difference in retinal defocus effect on RSVP digit recognition. Second, the pupil was dilated at near only. This would allow for the presence of increased ocular aberrations,[21] and probably result in a slight decrease both in the effective DOF and overall visual performance.[22] If pupil size had been equated, the actual effect on visual performance at near would probably be less under naturalistic viewing conditions than found in the present study. Lastly, the accommodative system typically exhibits a modest degree of oscillations at far (<0.1D),[12] but they were eliminated at near due to the use of cycloplegia. Accommodative oscillations may be helpful in detecting blur when an object is present near one edge of the DOF.[1] Thus, again under naturalistic viewing conditions, the presence of oscillations at near would likely result in a slight reduction in the tolerance for retinal defocus.

There were additional motivations for conducting the present experiment. First, it had been conceptualized to use the RSVP paradigm for the training of fixational eye movements in patients manifesting oculomotor abnormalities (e.g., amblyopia and brain injury),[8,18] as well as in visually-normal individuals for selected athletic events (e.g., rifle marksmanship).[23] Second, in both situations, refractive error correction has been found to be inaccurate in many cases,[18] thereby leading to increased and unwanted retinal defocus.

Thus, it was relevant to assess the effect of imposed retinal defocus on task performance in the present study. The RSVP digit recognition task was quite sensitive to retinal defocus, similar to that found for visual acuity, contrast sensitivity, and television caption reading. Hence, optimal refractive correction would be critical in all of the above tasks, and probably others, to maximize visual and visuomotor performance.

Acknowledgements

This study was supported by research grants from the Chinese National Key Technologies Research and Development Program, Beijing, China (2007BAII8B09) and the Zhejiang Provincial Program for the Cultivation of High-Level Innovative Health Talents grant to Dr. Lu Fan.

References

1. Ciuffreda KJ. Accommodation, the pupil, and presbyopia. In: Benjamin WJ, ed. Borish's Clinical Refraction. St. Louis, MO: Butterworth-Heinemann, 2006:93-144.
2. Wang B, Ciuffreda KJ, Irish T. Effect of blur adaptation on blur sensitivity in myopes. Vis Res 2006;46:3634-41.
3. Ciuffreda KJ, Selenow A, Wang B, Vasudevan B, et al. "Bothersome blur": A functional unit of blur perception. Vis Res 2006;46:895-901.
4. Levy-Schoen A, O'Regan JK. The effect of improper accommodation on the visual field and on eye movments in reading: In: Stark L, Obrecht G, eds. Presbyopia. New York, NY: Professional Press Books, 1987:178-84.
5. Bulson RC, Ciuffreda KJ, Hung. The effect of retinal defocus on golf putting. Ophthal Physiol Opt 2008;28:334-44.
6. Chung STL, Jarvis SH, Chung SH. The effect of dioptric blur on reading performance. Vis Res 2007;47:1584-94.
7. Thorn F, Thorn S. Television captions for hearing-impaired people: A study of key factors that affect reading performance. Hum Factors 1996;38:452-63.
8. Mitchell DC. The locus of the experimental effects in the rapid serial visual presentation (RSVP) task. Percept Psychophys 1979;25:143-49.
9. Cheong AM, Legge GE, Lawrence MG, Cheung SH, et al. Relationship between slow visual processing and reading speed in people with macular degeneration. Vis Res 2007;47:2943-55.
10. DeCarlo DK, Woo S, Woo GC. Patients with low vision. In: Benjamin WJ, ed. Borish's Clinical Refraction. St. Louis, MO: Butterworth-Heinemann, 2006:1591-161
11. Wang B, Ciuffreda KJ, Irish T. Equiblur zones at the fovea and near retinal periphery. Vis Res 2006;43:3690-98.
12. Miege C, Denieul P. Mean response and oscillations of accommodation for various vergences in accommodation feedback control. Ophthal Physiol Opt 1988;8:165-71.
13. Jose JG, Polse KA, Holden EK. Optometric Pharmacology. Orlando, FL: Grune and Stratton, 1984.
14. Bedell HE, Patel S, Chung ST. Comparison of letter and vernier acuities on dioptric and diffuse blur. Optom Vis Sci 1999;76:115-20.
15. Herse P, Bedell HE. Contrast sensitivity for letter and grating targets under various stimulus conditions. Optom Vis Sci 1989;66:774-81.
16. Ho A, Bilton SM. Low contrast charts effectively differentiate between types of blur. Am J Optom Physiol Opt 1986;63:202-08.
17. Thorn F, Schwartz F. Effects of dioptric blur on Snellen and grating acuity. Optom Vis Sci 1990;67:3-7.
18. Ciuffreda KJ, Wang B. Vision training and sports. In: Hung GK, Pallis JM, eds. Biomedical Engineering Principles in Sports. New York, NY: Springer-Verlag, 2004:407-34.
19. Higgins KE, Wood J, Tait A. Vision and driving: Selective effect of optical blur on different driving tasks. Hum Factors 1998;41:224-32.
20. Rosenfield M, Ciuffreda KJ, Rosen J. Accommodative response during distance optometric testing. J Am Optom Assoc 1992;63:614-18.
21. Vasudevan B, Ciuffreda KJ, Wang B. Nearwork-induced changes in topography, aberrations, and thickness of the human cornea after interrupted reading. Cornea 2007;26:917-23.
22. Ciuffreda KJ, Wang B, Vasudevan B. Depth-of-focus: Control system implications. Comput Biol Med 2007;37:919-23.
23. DiRusso F, Pitzalis S, Spinelli D. Fixation stability and saccadic latency in elite shooters. Vis Res 2003;43:1837-45.

Corresponding author:
Kenneth J. Ciuffreda, O.D., Ph.D.
State University of New York, State College of Optometry, New York, NY
kciuffreda@sunyopt.edu
Date accepted for publication:
May 20, 2009