5-2002

**Effect of monovision contact lenses on reading eye movements, reading speed and comprehension**

Sandy Johal  
*Pacific University*

Nazima Sangha  
*Pacific University*

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Effect of monovision contact lenses on reading eye movements, reading speed and comprehension

Abstract
Purpose. To extend our knowledge about how monovision contact lenses may affect reading eye movements, reading speed and reading comprehension.

Methods. A sample of 21 presbyopes was selected based on stringent inclusion criteria. Six trials of the Ober2 Visagraph were performed on each subject within hours of initiating monovision Rx. In three of the trials, the subject wore a distance vision contact lens correction with near reading spectacles; in the other three trials, the subject was tested wearing a monovision contact lens correction.

Results. Reading eye movements, reading speed and reading comprehension were measured by the Ober2 Visagraph. The Ober2 results indicated no difference in reading efficiency between the two conditions. Monovision and distance vision correction with near spectacles showed no significant differences in reading eye movements, reading speed or reading comprehension.

Conclusion. Monovision contact lens correction is a convenient modality for presbyopic correction and does not negatively influence reading efficiency as measured by the Ober2 when first worn. Further studies are needed to determine the effect of long-term monovision contact lens wear on reading.

Degree Type
Thesis

Degree Name
Master of Science in Vision Science

Committee Chair
Bradley Coffey

Keywords
monovision, Visagraph, reading speed, comprehension, saccades, fixations

Subject Categories
Optometry

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EFFECT OF MONOVISION CONTACT LENSES ON READING EYE MOVEMENTS, READING SPEED AND COMPREHENSION

By

SANDY JOHAL
NAZIMA SANGHA

A thesis submitted to the faculty of the
College of Optometry
Pacific University
Forest Grove, Oregon
For the degree of
Doctor of Optometry
May 2002

Advisors:
Bradley Coffey, O.D., F.A.A.O
Patrick Caroline, C.O.T., F.A.A.O
Peter Bergenske, O.D., F.A.A.O
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- Johnson and Johnson Vistakon for their support.
- Linda Powers for providing us with a list of possible subjects.
- Brian Wilber for providing us with a list of lion's club members that were interested in participating in the study.
- Our friends and family who helped and supported us along the way.
BIOGRAPHY OF AUTHORS

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Sandy Johal has a bachelors degree in cell biology and genetics from the University of British Columbia in Vancouver, BC. She will graduate with Honors in May 2003 from Pacific University College of Optometry. She plans to settle in the Pacific Northwest specializing in pediatric vision, acquired brain injury and primary care.

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Nazima Sangha obtained a bachelors degree in Microbiology at the University of British Columbia in Vancouver, BC. She will graduate with Honors in May 2003 from Pacific University College of Optometry. She plans to settle in the Pacific Northwest and is interested in specializing in low vision and/or vision therapy as well as primary care.
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S. Johal, N.N. Sangha, B. Coffey, OD, FAAO, P.J. Caroline, COT, FAAO, and P. Bergenske, OD, FAAO

Pacific University College of Optometry

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Key Words: monovision, Visagraph, reading speed, comprehension, saccades, fixations, regressions
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INTRODUCTION

In 1993, monovision accounted for approximately 80% of all contact lens presbyopic correction and was the most popular contact lens modality used to correct presbyopia (1). Monovision offers certain advantages over spectacle correction. These include aesthetics, clear distance and near vision with one modality, continued use of contact lenses after presbyopia, lack of fogging in temperature or humidity extremes and lack of visual difficulties frequently experienced with glasses while walking and using stairways (2). The original suggestion of this correction modality was attributed to Westsmith and involves correction of one eye for distance vision while the fellow eye is corrected for near vision (3,4). The underlying mechanism of monovision is still controversial. Some researchers reason that successful correction depends on the binocular system to centrally suppress blur from the defocused eye (5,6,7,8). However, another study shows that information from the blurred eye’s image is summed with information from the in-focus image of the fellow eye (2). Thus, under monovision viewing conditions the blurred eye may make a substantial contribution to the binocular perceived image. Although monovision correction has been in use for more than 30 years and several studies have investigated its effects on visual functions including stereopsis and contrast sensitivity, there have been no studies investigating monovision and its effect on reading.

Several studies show diminished stereopsis and stereoacuity in the presence of monocular blur (9,10,11,12,13). However, since near reading tasks are two dimensional and only require second-degree fusion (flat fusion), stereopsis is probably of little concern in reading. Monovision causes a reduction in contrast sensitivity for all spatial frequencies but only slightly for high contrast targets (14). Since reading is a high contrast task, it may have a slight effect on reading efficiency (15).

Under normal binocular reading conditions, the sensory input from both eyes is integrated to produce a clear stable image, which in turn is used to guide saccadic eye movements. During initial monovision wear, the clear and blurred images interact in the binocular cells of the visual cortex and lead to a less clear final image (16). We speculate the resulting final image may in turn compromise reading eye movements that are
dependent on visual input from both eyes. Poor eye movements during reading can manifest as reduced comprehension and reading speed, two of the variables measured in this study.

Reading efficiency and competence can be measured using the Ober2 Visagraph. The Visagraph monitors and records eye movements while reading a paragraph appropriate for the subject’s reading level. Following this reading, a short quiz measures reading comprehension. This reading efficiency measurement combined with standardized reading procedures provide a detailed evaluation of an individual's reading competence (17). The Visagraph has been successfully used in several studies (18,19,20, 21).

This study has been designed as a continuation of a previous work investigating the effect of monovision lenses on certain reading skills (22). The previous study was performed on a small population sample and the results could not be extrapolated to the general population. We use a larger sample of patients to investigate the effect of monovision contact lenses on reading eye movements, reading speed and comprehension using the Ober 2 Visagraph.

METHODS

Subjects

Twenty-one participants, 18 females and 3 males, met the following inclusion criteria:

1. At least 40 years of age (average age was 53.19).
2. Amplitude of accommodation less than 2.0D as measured via positive relative accommodation (PRA).
3. No known visual field abnormalities.
4. No known ocular or systemic allergies which might interfere with contact lens wear.
5. No known systemic disease or need for medication which might interfere with contact lens wear, e.g. antihistamines.
6. No known infectious disease (e.g. hepatitis, tuberculosis), immunosuppressive disease (e.g. HIV), or diabetes.
7. Spherical prescription in the range +0.50 to -12.00 D, and no more than 1.50 D of refractive astigmatism.
8. Distance visual acuity of 20/30 or better for each eye with spherical lenses. No ocular medications
9. No ocular medications
10. Normal corneal health with no contraindications of wearing soft contact lenses.
11. Normal binocular vision as indicated by the presence of constant heterophoria and at least 180 sec arc near stereoacuity (avg stereoacuity = 40.7 sec arc).

Each subject provided informed consent to the study protocol. An incentive for participation of $50 and a one-year supply of monovision contact lenses (Vistakon Acuvue 2) was provided to each subject for participation.

Protocol

The Ober 2 Visagraph was used to record and analyze reading eye movements. This instrument uses infrared sensors held in place by a pair of goggles that are worn by the subject during a reading task. These sensors work by comparing the relative intensities of reflected infrared light from near the limbus of the subject’s eye. The sclera reflects more infrared light than the cornea. For example, if the eye is turned temporally there will be a rise in the intensity of the reflected light from the nasal limbus accompanied by a decrease from the temporal limbus. The Ober 2 software processes this information.

The subjects were asked to read a short biographical paragraph. The paragraph was chosen randomly but after being chosen the patient was questioned on whether they were familiar with the topic. In order to eliminate bias, if the subject was familiar with the topic it was discarded and another topic was randomly chosen. After each reading passage there were ten standardized true/false questions to assess reading comprehension. The resulting computerized report includes: fixation/100 words, regression/100 words, average span of recognition (words), average duration of fixation (sec), rate of reading with comprehension (wpm), grade level efficiency, directional attack difficulty, rate adjusted for re-reading (words/min), comprehension questions correct (%), and other descriptive data.

Figure 1 outlines the flow of the protocol once the subject met the inclusion and exclusion criteria.
The study involved one independent variable, monovision versus single vision distance control, and several measured dependent variables. The measured dependent variables are summarized in Table 1.
Table 1. Summary of Dependent Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixation/ 100 words</td>
<td>The total number of times the eyes pause or remain relatively stationary during the reading of 100 words. During these pauses, perception of words and parts of words takes place.</td>
</tr>
<tr>
<td>Regression/ 100 words</td>
<td>Reflects the total number of reverse direction (right to left) fixations made during the reading of 100 words. Regressions are not to be confused with rereading.</td>
</tr>
<tr>
<td>Average span of recognition</td>
<td>The average number of words or parts of word perceived during a fixation or eye pause. This calculation is derived from the total number of fixations required to read 100 words. (words)</td>
</tr>
<tr>
<td>Av. Duration of Fixation</td>
<td>The average length of time (sec) the eyes paused or fixated, during which words or parts of words were perceived.</td>
</tr>
<tr>
<td>Rate of Reading with Comprehension</td>
<td>The reading length in words per minute for the countable part of the text.</td>
</tr>
<tr>
<td>Grade Level Efficiency</td>
<td>A numerical calculation based on analysis of subject’s fixations, regressions and rate as the key components of reading efficiency. This calculation is then translated into the equivalent grade level using norm values for easier evaluation.</td>
</tr>
<tr>
<td>Level of Text Read</td>
<td>The difficulty of the reading passage in grade level equivalence.</td>
</tr>
<tr>
<td>Directional Attack Difficulty</td>
<td>The percentage of regressions to total fixations. A low value is good and indicates that the subject has a tendency to follow text from left to right.</td>
</tr>
<tr>
<td>Rate adj. For Rereading</td>
<td>The reading rate if the time spent for rereading was removed. If no rereading occurred, it is equal to Rate of Reading with Comprehension.</td>
</tr>
<tr>
<td>Comprehension Questions Correct</td>
<td>This percentage of correct answers. 70% or more is acceptable.</td>
</tr>
</tbody>
</table>

Study Lenses

Vistakon Acuvue 2 lenses were used as the study lenses. The base curve of the lenses used were 8.3 and 8.7 and the diameter was 14.0.

Statistical Analysis

The study was a counter-balanced design in which subjects were fitted with Vistakon Acuvue 2 lenses. By design the study used repeated measures in two conditions: distance control contact lenses with near spectacle lenses and monovision. The measurement variables include reading eye movements, reading speed and comprehension using the Ober-2 Visagraph. These variables were scaled parametrically and analyzed using repeated measures two-tailed t-tests and post hoc chi square analysis.
RESULTS

Twenty-one presbyopic subjects were fit with contact lenses under two conditions to enable them to read at near. One condition was a monovision contact lens fit and the other was a distance contact lens fit with reading spectacles. The power of the near reading add was determined by using the 40cm binocular cross cylinder value relative to the best distance Rx or mid-point of the PRA and NRA. Each subject was assessed for reading performance by using the Ober2 Visagraph. Three trials were conducted for each condition. The first trial was discarded and the results from the latter two trials were analyzed.

The data were first analyzed to determine if differences existed within the two trials in each condition. The analysis revealed differences only within the monovision trials for fixations/100 words (p<0.03), indicating slightly better performance and less variability by the subjects on the first monovision trial. The number of fixations per 100 words for MV1 was 112.7 ± 26.3 compared to 128.7 ± 44.1 for MV2. These data are summarized in Table 2.
Table 2. Descriptive Data and Probabilities (t-test) for the Repeated Trials in Each of the Two Conditions Investigated

<table>
<thead>
<tr>
<th>Variable</th>
<th>Distance Vision Trial 1 Vs. Distance Vision Trial 2 (p-values)</th>
<th>Monovision Trial 1 Vs. Monovision Trial 2 (p-values)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DV1 Mean</td>
<td>DV2 Mean</td>
</tr>
<tr>
<td>fixations/100 words</td>
<td>126.4 ±44.4</td>
<td>123.1 ±32.7</td>
</tr>
<tr>
<td>Regressions/100 words</td>
<td>21.9 ±16.1</td>
<td>19.3 ±11.8</td>
</tr>
<tr>
<td>average span of recognition</td>
<td>0.86 ±0.21</td>
<td>0.86 ±0.21</td>
</tr>
<tr>
<td>average duration of fixation (sec)</td>
<td>0.27 ±0.03</td>
<td>0.27 ±0.03</td>
</tr>
<tr>
<td>Rate with comprehension</td>
<td>193.3 ±53.8</td>
<td>192.6 ±54.6</td>
</tr>
<tr>
<td>grade level efficiency</td>
<td>7.8 ±4.0</td>
<td>7.6 ±4.1</td>
</tr>
<tr>
<td>directional attack difficulty</td>
<td>0.17 ±0.07</td>
<td>0.14 ±0.06</td>
</tr>
<tr>
<td>Rate adjusted for rereading comprehension questions correct</td>
<td>0.88 ±0.14</td>
<td>0.88 ±0.11</td>
</tr>
</tbody>
</table>

Distance vision averages (DVA) of DV1 and DV2 are compared to the monovision averages (MVA) of MV1 and MV2 in Table 3. These comparisons should identify differences in reading performance between the two conditions. The two conditions do not differ except in regard to average duration of fixation. The DVA condition shows an average duration of fixation of 0.27 +/- 0.03 sec while MVA shows a slightly longer duration of fixation of 0.28 +/- 0.03 sec. This difference indicates that subjects wearing monovision spent, on average, an additional 0.01 sec during each fixation compared to the distance vision / near spectacle control.
Table 3. Descriptive data and probabilities (t-test) for the averaged data in the two conditions investigated

<table>
<thead>
<tr>
<th>Variable</th>
<th>Distance Vision Average Vs. Monovision Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DVA Mean</td>
</tr>
<tr>
<td>fixations/100 words</td>
<td>124.7 ±35.9</td>
</tr>
<tr>
<td>regressions/100 words</td>
<td>20.6 ±12.9</td>
</tr>
<tr>
<td>average span of recognition</td>
<td>0.86 ±0.21</td>
</tr>
<tr>
<td>average duration of fixation (sec)</td>
<td>0.27 ±0.03</td>
</tr>
<tr>
<td>Rate with comprehension</td>
<td>193.0 ±51.9</td>
</tr>
<tr>
<td>grade level efficiency</td>
<td>7.7 ±3.8</td>
</tr>
<tr>
<td>directional attack difficulty</td>
<td>0.15 ±0.05</td>
</tr>
<tr>
<td>Rate adjusted for rereading</td>
<td>223.8 ±56.7</td>
</tr>
<tr>
<td>comprehension questions correct</td>
<td>0.88 ±0.09</td>
</tr>
</tbody>
</table>

Due to the high variability between trials that is common with Ober2 measurements, the results were submitted to post hoc analysis using the chi square test. This analysis was performed to determine whether significantly more subjects performed better or worse in one condition regardless of the magnitude of the difference by condition. The chi square results were consistent with the t-test analyses and revealed no systematic difference in the reading eye movement performance between conditions.

**DISCUSSION**

Monovision contact lens correction, a common refractive correction for presbyopes, is the technique of correcting one eye for distance and the other for near. Despite the increased interest in monovision correction, there is no published research known to the authors that investigates the effects of monovision on eye movements used in reading. Reading is a two-dimensional, high contrast activity that requires coordinated, accurate eye movements to perform efficiently and is affected by the clarity of an image. The presbyopic population in the United States is increasing and is actively involved in many occupational and leisure activities that require reading. This study was conducted to investigate the effects of monovision contact lens correction on reading eye
movements, reading speed and reading comprehension as compared to distance contact lens correction with a near spectacle add.

The comparison of distance vision trial 1 (DV1) with trial 2 (DV2) results showed no significant differences (Table 2), indicating reliability and consistency of the measurement procedure. When comparing monovision contact lens correction to binocular correction, the results showed that reading characteristics measured by the Ober2 Visagraph are in general not affected. Of the several variables measured in this study, only the average duration of fixation was significantly worse with monovision correction. This difference was 0.01 sec (3.7%) and is probably not clinically significant. The greater fixation duration could be due to the extra time required to clear an image during a fixation or the time required to adequately suppress the blurry image from one eye. No differences were found in other variables related to reading speed, accuracy of reading eye movements, nor reading comprehension.

There are several reasons why monovision contact lens wear did not affect reading eye movements in this study. Input from the blurry eye (the distance corrected eye when looking at near) could be suppressed so that reading eye movements are primarily directed by the clear eye (the eye corrected for near when looking at near). Alternatively, the blur to one eye may not be enough to disrupt the binocular vision (second degree fusion) required for reading.

It takes most patients at least two weeks to adapt to monovision lens correction and it is recommended that doctors tell their patients it will take 4-6 weeks to adapt (14). In the current study, it would have been ideal if subjects were fit with one lens modality (distance vision or monovision) and allowed a minimum of two weeks to adapt before being tested, and then re-adapted for the other lens modality and measured. In this study, subjects were given ten minutes to adapt to their contact lenses prior to testing. This brief protocol was selected to encourage participation of subjects and to minimize fatigue effects during data collection. A longer adaptation time would have allowed for a more realistic measure of any effect on reading eye movements, however, it was not feasible at this time. The short time between MV1 and MV2 was like a short adaptation time and may account in part for the poorer performance shown for fixations/100 words and the insignificant trend toward poorer performance on nearly all of the other variables.
measured. It may be found that given enough time to adapt, monovision correction may in fact affect reading ability to some degree.

CONCLUSION

Monovision contact lens correction is an increasingly popular refractive correction for presbyopes, yet there is little research on the effects of monovision on reading. Fathali-Dashti et al. (21) reported on the effects of monovision contact lenses on reading speed and comprehension but were unsuccessful at making any conclusions because of a small patient sample. We aimed to replicate their study and investigate the effects of monovision correction on reading eye movements, reading speed and reading comprehension using the Ober2 Visagraph on a larger patient sample. Distance vision contact lenses with a near spectacle lens was used as a control to compare monovision results. For all reading eye movement variables measured, there was no difference between monovision correction and distance vision correction.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support of Johnson & Johnson Vistakon in the completion of this research.
REFERENCES


APPENDIX A

INFORMED CONSENT FOR PARTICIPATION IN A RESEARCH PROJECT

Pacific University College of Optometry

A. Title of Project: Effect of Monovision Contact Lenses on Reading Speed and Comprehension

B. Investigators: Bradley Coffey, OD, FAAO
Professor of Optometry
Pacific University College of Optometry

Patrick J. Caroline, COT, FAAO
Assistant Professor of Optometry
Pacific University College of Optometry

Sandy Johal and Nazima Sangha
Pacific University College of Optometry

C. Location: Pacific University College of Optometry, Forest Grove, OR

D. Date: November 2001 to March 2002

E. Description of Project: In this study, we will investigate the effect of monovision contact lenses on reading speed and comprehension. Initially, common clinical distance and near tests will be performed to determine if subjects meet the study criteria. If the criteria are met, we will then fit subjects with Vistakon Acuvue 2 contact lenses. Eye movements will be measured while reading a paragraph under two conditions: 1. monovision contact lenses and 2. distance vision contact lenses with near vision spectacle lenses.

F. Description of Risks: All procedures performed in this study will be current, accepted clinical procedures. Small amounts of redness may occur with contact lens wear, and there is an extremely small risk of ocular infection. If care is not taken when placing the goggles on, there is a small risk that the goggles may by chance strike your eye.

G. Description of Benefits: Results of this project will be used for evaluating the use of monovision contact lens correction while driving. Past experience has demonstrated the difficulty in recruiting subjects for monovision contact lens studies. For this study, we have made preliminary arrangements to recruit members of the Forest Grove, Oregon Lions Club as subjects. An incentive for participation of $50 will be provided each
subject. These cash incentives would be transferred to the Lions Club to assist them in their support of providing vision care services to the community.

H. Alternatives advantageous to Subjects- There are no additional alternative procedures or courses of treatment.

I. Confidentially: Records of this project will be maintained in a confidential manner and no name-identifiable information will be released.

J. Compensation and Medical Care: If you are injured in this experiment and it is not the fault of Pacific University, the experimenters, or any organization associated with the experiment, you should not expect to receive compensation or medical care from Pacific University, the experimenters, or any organization associated with the experiment.

K. Offer to Answer Inquiries: The experimenters will be happy to answer any questions you may have at any time during the course of this study. If you are not satisfied with the answers you receive, please call Dr. Karl Citek at (503) 359-2126. During your participation in the project you are not a Pacific University clinic patient or client and all questions should be directed to the researchers and/or the faculty advisor who will be solely responsible for any treatment (except in an emergency). You will not be receiving complete eye, vision, or health care as a result of participation in this project; therefore, you will need to maintain your regular program of eye, vision, and health care.

L. Freedom to Withdraw: You are free to withdraw your consent and to discontinue participation in this project at any time without prejudice or consequences to you. I have read and understand the above. I am 18 years of age or over or this form is signed by me and my parent or guardian.

Printed name of subject ________________________________

Subject's signature ________________________________

Printed name and signature of parent or guardian if subject is under 18 years of age ________________________________

Address ________________________________

City/State ________________________________

Zip ________________________________

Phone ________________________________

Date ________________________________
APPENDIX B

Examination Form

Name: ___________________________  Date: ___________________________

DOB: ___________________  Age: ___________________  Intern: ___________________

☐ Consent Form

Case History (Does the Patient Have Any Conditions That May Effect Contact Lens Wear?)

Eye Allergies: ___________________________

Allergies: ___________________________

Ocular Meds: ___________________________

Systemic Meds: ___________________________

Diabetes: ___________________________

Immunosuppressive Dz: ___________________________

Infectious Dz: ___________________________

Other Med Condn: ___________________________

Entrance Skills

Habitual Rx:  OD

OS

<table>
<thead>
<tr>
<th>VA</th>
<th>Habitual Dx</th>
<th>Habitual Near</th>
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<td>OD</td>
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</table>

Eye Preference

| PD   |
| CVF  |
| DxCT |
| NCT  |
| Stereo (at least 180") |
SLIT LAMP EXAM

Does the subject have any of the following conditions (Check if any)

- [ ] significant corneal edema
- [ ] corneal vascularization
- [ ] corneal staining
- [ ] bulbar hyperemia
- [ ] tarsal hyperemia
- [ ] Any active ocular infection
- [ ] Other abnormality of the cornea that may cause unsafe contact lens wear

<table>
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<th>OS</th>
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# Refraction

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**MSBVA with JCC (cyl < 1.50D)**

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**BSBVA**

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**Spherical Equivalent** (within +0.50 to +8.00 and -0.50 to -12.00 and VA 20/30 or better)

<table>
<thead>
<tr>
<th>OD</th>
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<tbody>
<tr>
<td>OS</td>
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**Near Subjective**

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**PRA** (net must be < 2.0D)

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#14b

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IS THE SUBJECT ABLE AND WILLING TO ADHERE TO THE INSTRUCTIONS SET FORTH IN THIS CLINICAL PROTOCOL?  YES  NO

**Visagraph**

- **MONOVISION TRIAL FIRST**
- **SINGLE VISION NEAR TRIAL FIRST**

**Distance Contact Lenses With Near Spectacles**

1. **Contact Lenses Used**
   - Power: OD  OS
   - Base Curve: OD  OS

2. **Assess CL Fit**
   - OD
   - OS

3. **Spectacle Power Used**
   - OD  OS

4. **Do a Trial Run of Reading Passage and Comprehension Test**

5. **2 Runs of Reading Passages and Comprehension Testing**

**Monovision Contact Lenses**

1. **Contact Lenses Used**
   - Power: OD  OS
   - Base Curve: OD  OS

2. **Assess CL Fit**
   - OD
   - OS

3. **2 Runs of Reading Passages and Comprehension Testing**