5-2002

The effects of monovision on distance stereopsis and driving performance

Taya M. Patzman
Pacific University

Brett J. Borstad
Pacific University

Jennifer A. Hupke
Pacific University

The effects of monovision on distance stereopsis and driving performance

Abstract

The effects of monovision on stereopsis and driving performance were evaluated on thirty-eight subjects (ages 22 to 55 years). Monovision performance was compared to the performance with distance contact lenses. Each subject had good ocular health, no apparent strabismus, and less than 1.00D of uncorrected astigmatism. Visual acuity and stereo acuity at 6m and 40cm, acuity suppression at 6m, and driving performance were measured for each condition. The results of the study indicated that mono vision reduced several aspects of visual performance. A significant difference (t=11.82, p=0.0001, df-=35) was present for distance visual acuity between the eye corrected for near compared to the eye corrected for distance. Near stereo acuity (t=3.16, p=0.0033, df=34) and distance stereo acuity (t=7.43, p=0.0001, df=20) were both significantly decreased with the monovision modality. The monovision lens showed a significant increase (t=-3.42, p=0.0016, df=35) in the amount of driving error. The statistical results were skewed because only those subject that were affected the least by monovision were analyzed. The subjects whose grossest level of stereo acuity and acuity suppression fell outside the measurable limits of the BVAT were excluded from the statistical analysis.

Degree Type

Thesis

Degree Name

Master of Science in Vision Science

Committee Chair

Bradley Coffey

Subject Categories

Optometry

The Effects of Monovision on Distance Stereopsis and Driving Performance

By

Taya M. Patzman

Brett J. Borstad

Jennifer A. Hupke

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

Advisor:
Bradley Coffey, O.D., F.A.A.O.

The Effects of Monovision on Distance Stereopsis and Driving Performance

Advisor:
Bradley Coffey, O.D., F.A.A.O. Bradley Coffey

Taya M. Patzman Taya M. Patzman

Brett J. Borstad Brett Borstad

Jennifer A. Hupke Jennifer A. Hupke

Acknowledgements

We would like to thank Dr. Coffey for all of his help and guidance on this project. We have a high regard for his knowledge and expertise in optometry. We appreciate all of his time and effort that he put towards the project to make it a success.

Biographies

Taya M. Patzman

A native of Bismarck, ND, is currently completing her Doctorate of Optometry at Pacific University in Forest Grove, OR. She attended the University of North Dakota before entering optometry school. She graduated from Pacific University with a Bachelor of Science degree in December of 1999. After graduating from Pacific in May of 2002, she plans to return to North Dakota to practice optometry.

Brett J. Borstad

A native of Bismarck, ND, is currently completing his Doctorate of Optometry at Pacific University in Forest Grove, OR. He graduated with a Bachelor of Science degree from the University of North Dakota in May of 1998. After graduating from Pacific University in May of 2002, he plans to practice full scope optometry in the state of Colorado with his fiancée, Leilani Phillips O.D., and play in the mountains whenever possible.

Jennifer A. Hupke

A native of Langford, SD, is currently completing her Doctorate of Optometry at Pacific University in Forest Grove, OR. She graduated from the University of South Dakota with a Bachelor of Science degree in May of 1998. After graduating from Pacific University in May of 2002, she plans to practice optometry in the Midwest.

Table of Contents

Abstract

The effects of monovision on stereopsis and driving performance were evaluated on thirty-eight subjects (ages 22 to 55 years). Monovision performance was compared to the performance with distance contact lenses. Each subject had good ocular health, no apparent strabismus, and less than 1.00D of uncorrected astigmatism. Visual acuity and stereo acuity at 6m and 40cm, acuity suppression at 6m, and driving performance were measured for each condition.

The results of the study indicated that monovision reduced several aspects of visual performance. A significant difference ($t=11.82$, $p=0.0001$, $df=35$) was present for distance visual acuity between the eye corrected for near compared to the eye corrected for distance. Near stereo acuity ($t=3.16$, $p=0.0033$, $df=34$) and distance stereo acuity ($t=7.43$, $p=0.0001$, $df=20$) were both significantly decreased with the monovision modality. The monovision lens showed a significant increase ($t=-3.42$, $p=0.0016$, $df=35$) in the amount of driving error. The statistical results were skewed because only those subject that were affected the least by monovision were analyzed. The subjects whose grossest level of stereo acuity and acuity suppression fell outside the measurable limits of the BVAT were excluded from the statistical analysis.

Introduction

The monovision approach for presbyopia was first proposed in 1958 by Westsmith[1,2]. Since its inception, it has been a controversial prescribing modality[3]. Monovision is defined as correcting one eye for distance vision and the other eye for near vision. Due to the anisometropia produced intentionally by the monovision correction, it departs from the conventional and widely accepted goal of providing a fully balanced binocular correction[4]. Some clinicians feel that a balanced binocular correction must be a goal in every ophthalmic prescription and that the intentional anisometropia created by monovision is ethically unacceptable[3]. In monovision, because the image of one eye is only blurred and not occluded, binocularity is greatly compromised but not lost completely[5].

Although monovision is not binocularly desirable, it is the most common method of compensating presbyopia for contact lens wearers[6]. Along with the advantage of ease of fitting, monovision appears to be more visually acceptable than current bifocal contact lenses for most patients[4]. Many practitioners agree that monovision has a greater success rate than bifocal contact lenses for patients who desire to continue contact lens wear[4]. Monovision contact lens wear has a reported success rate of 50% to 75%[7]. Back et al. reported that it was the most successful system with a success rate of 67% compared to concentric center-near lenses, or a combination of center-near/center-distance concentric lenses[8]. Careful patient selection is an important factor in a successful monovision fit. Structured, detail-oriented persons are not as successful as patients who are adaptable and optimistic[7]. Patients who have great near point demands and require high near point resolution or stereopsis are also not good candidates for monovision. Neither are patients with occupational requirements in mesopic or scotopic lighting conditions[3].

Back et al. reported that the relative success of monovision was due to the superior quality of vision associated with single vision lenses versus bifocal contact lenses, especially at distance. However, 34% of their subjects preferred the bifocal option over monovision[8]. In that study, of the patients who were able to wear a contact lens, 79.6% were satisfied with the visual compromise that monovision produced. There were no subjects in the study who failed in monovision and had a successful outcome when refitted with bifocal contact lenses. However, patients who were unsuccessful with bifocal contact lenses were sometimes successful with monovision[8]. Erickson et al. found unsuccessful monovision patients generally showed greater reductions in visual acuity and stereo acuity than successful monovision patients. These results suggest that monovision success is related to the level of deficits induced in these visual functions[9].

Monovision imposes some disadvantages. A blurred image is seen at distance and at near in one of the eyes with monovision. Binocular suppression, necessary to perceive a clear image, may cause problems with stereopsis, difficulty with glare, and decreased binocular contrast sensitivity[10]. Adverse symptoms reported during the first week of monovision wear were hazy vision, occasional loss of balance, and a small visual field constriction for the near eye[1].

Harris and Classe explored the legal implications of monovision. They indicated that practitioners prescribing monovision would be clinically and legally responsible for its effects. Monovision patients should be informed of the adaptation period when there is the greatest risk. Patients should be warned of any side effects that may require extra caution to prevent harm to themselves or someone else. Failure to warn the patient of any adverse effects may make the practitioner subject to legal action. Therefore, before the contact lenses are dispensed to the patient, the patient should be required to sign an informed consent stating the risks and explaining the alternative options[1,3].

It is recommended that monovision patients be provided with a distance contact lens for the near corrected eye or a pair of spectacles when keen vision is needed in the distance or when driving under mesopic or scotopic conditions where blur suppression is more difficult[3]. The same holds true for near vision. An extra near lens may be needed when there are demands for critical near work[1]. Compliance is often difficult with monovision patients because they perceive themselves to be seeing clearly at all distances without visual compromise. Many patients forget to carry their compensatory prescription or neglect to wear it[3].

Some patients may inherently possess the visual skills needed for monovision success such as the ability to adapt, which is critical in blur suppression and task performance, and which unsuccessful monovision wearers lack[11,12]. The abrupt onset of anisometropia in monovision presents significant challenges to the presbyopic visual system. The initial adaptation period may be more difficult for some monovision patients. According to Erickson et al. it is unlikely that binocular visual acuity or stereo acuity improve with monovision adaptation[9].

Questions have been raised concerning the loss of binocularity with the use of this modality. There are conflicting reports on the effect of monovision on stereopsis. Several reports suggest that good visual acuity is not required for stereopsis, while others report that relatively low amounts of monocular blur may reduce or eliminate stereopsis[13]. Koetting found that 94% of patients fit with monovision lenses exhibited stereopsis within established norms for their age group[1]. Conversely, Peters reported that 80% of his subjects lost stereopsis with 1.00D monocular blur[13].

McMonnies and Beier's data on the effects of monocular blur on stereoacuity indicated that a clinically acceptable level of 40 seconds arc of stereo acuity can be maintained with 1.00 D blur on the Randot test and 0.5 D on the Titmus test. Most of the subjects were able to maintain moderate levels of stereopsis with 2.00 D monocular blur and 20% of the subjects maintained gross stereopsis with even 4.00 D monocular blur[2].

Stereo acuity is reduced as a result of reducing contrast, lowering spatial frequency, and inducing anisometropia. Numerous studies have shown that stereo acuity is substantially reduced under anisometropic and aniseikonic viewing conditions[4]. Monocular blur caused a more rapid decrease in stereoacuity than induced aniseikonia[13]. Clinicians often view these deficits in stereopsis as the major disadvantage of the monovision technique[14].

The amount of near add worn by the patient and the amount of visual acuity decrease in the distance eye had a direct correlation with the amount of stereopsis lost[15]. Levy and Glick reported a stereo acuity level of 50 seconds arc on the Titmus test for subjects with a two-line interocular difference in Snellen visual acuity[13]. Patients with successful monovision have a much smaller reduction in stereoacuity than patients who are unsuccessful[7]. Schor, Landsman, and Erickson and also Westendorf and Overton have shown that information from the suppressed eye continues to be processed and thus contributes to stereopsis.

The primary advantage of binocular vision is to provide stereopsis and enhance depth perception. Tasks with many disparity cues, such as driving, showed the greatest binocular advantage with use of binocular cues to enhance performance[16]. Perspective overlay, motion parallax, and size are monocular cues that contribute to depth perception. Most of our daily activities are rich in both monocular and binocular cues to depth perception[7,16].

There have been many studies investigating the role of stereopsis in task performance. Sheedy has been the premier investigator. He and his colleagues showed that binocular vision time performance was consistently better than the monovision time performance at all testing periods. There were also more performance errors under the monovision conditions than the binocular conditions for near occupational tasks such as pointers and straws and letter editing. The improvement under binocular conditions for the various tasks are as follows: pointers and straws improved 29.5%, needle threading 20.4%, file cards 8.9%, grooved pegboard 4%, and reading speed 3.7%. They also found that the resolution tasks suffered the most with the monovision correction[5].

Monovision remains a relatively successful clinical option although binocular deficiencies are created. The effect that these binocular deficiencies have on functional visual performance is questioned. Studies indicate that binocular cues enhance the performance of common tasks, such as pointers and straws, card filing, and letter editing[5].

There are several theories of fitting monovision. One common practice is to fit the preferred eye as the distance eye. Sanchez states that the distance lens should be on the left eye since the left eye plays the more important role in driving[17]. If the distance lens is worn on the right eye, there is the possibility that the driver's nose will create an obstacle to the far left where there is the most automobile traffic[17]. Sanchez recommends that the distance lens always be fitted to the patient's left eye since drivers encounter oncoming traffic in the left half of the visual field when passing[17,4].

Monovision has been shown to affect one's ability to drive especially at night. Studies have reported that up to 80% of monovision patients report problems with night driving[18]. Appropriate warnings should be given to patients who drive. Patients who wear monovision should first be instructed to ride as a passenger before they get behind the wheel. Monovision may affect older drivers in whom visual processing and reaction times are increased compared to younger drivers. The most common reported problems with older drivers is night driving, along with driving in poor weather conditions and in heavy traffic[19]. When driving at night, headlights from oncoming cars appear to the near eye large and out-of-focus, contrary to the image perceived by the distance eye as small and clear. Monovision patients often have difficulty suppressing the larger, out-of-focus image of the near eye[7].

Blur suppression is crucial in the success of monovision. The ability to see clearly at distance and near is due to interocular suppression of anisometropic blur[11]. If it were not for the binocular blur suppression, monovision could result in a mixed signal of blurred and clear vision at both distance and near resulting in unacceptable vision[11].

Successful monovision wearers' ability to suppress interocular blur is approximately 100 times greater than for unsuccessful monovision wearers. Schor, Landsman, and Erickson quantified this by reducing the contrast of a bright test spot, viewed binocularly while wearing various plus lenses monocularly, until the out-of-focus image was suppressed[11]. Blur suppression is critical for night driving. Under photopic conditions, interocular blur suppression is effective. However, when driving a car at night under mesopic and scotopic luminance conditions anisometropic blur is not suppressed binocularly[11]. Interocular blur is the most difficult to suppress under scotopic conditions with small, bright targets similar to headlights on a car[12]. According to some researchers, one of the concerns with monovision is the judgment of speed while driving. Wood et al. reported that subjects seemed worse at estimating their own speed while wearing monovision compared to their habitual correction, however the differences were not significant. They also found no significant differences in driving performance abilities with monovision compared to their habitual correction. The driving performance ability was assessed on an open road course measuring sign recognition, mirror checks, lane deviation, driving time, parking angle, and speed estimation[18]. Our study explored the effects of monovision on distance stereopsis and it's effect on driving performance error.

Subjects and Methods

Subjects for this study were recruited from the population at Pacific University College of Optometry with an age range of 22 to 55 years. Those subjects 45 years or above were considered presbyopes. To be included in the study subjects were required to have less than 1.00 D of uncorrected astigmatism, no recent ocular pathology, and no strabismus.

A cover test at 6m and 40cm was performed to rule out strabismus. The unilateral cover test was performed three times on each eye, then the alternating cover test for five cycles, and finally a unilateral cover test was preformed three times on each eye. An isolated 20/40 letter at 6m was used for the distance target and a bead with an accommodative target at 40cm was used for the near target. Detection of any amount of strabismus disqualified the subject from the study.

Subjects were asked if they had any recent history of ocular pathology such as infections, inflammation, or trauma. Subjects who reported positive recent ocular pathologies were excluded from the study.

The hand-over-hand method was used to determine ocular preference at 6m. The subject was instructed to extend their arms downward in front of them, thumbs crossed with the fingers of one hand overlapping those of the other hand. The subject was then instructed to raise his or her arms and sight a distant object through the hole formed between their thumbs and fingers of the two hands. The eye that was visible through the hole was the preferred eye. Four trials were run, first with the right hand over the left, then alternating with the left over the right, then right over the left, and finally the left over the right. The results were recorded and the eye that was preferred the most during testing was determined to be the preferred eye for the remainder of the study.

The subjects were asked to wear their habitual contact lens correction to the study. The contact lens parameters were determined by the patient's previous ocular examinations. Contact lenses were dispensed to the patients not currently wearing lenses. The non-presbyopic subjects were provided monovision lenses with a random amount of add power from +1.00D to +2.50D. Presbyopic patients were dispensed a lens with a near power matching their current spectacle bifocal add. This lens was placed on the non-preferred eye, as determined by previous testing. A random selection of which modality was worn first was used to decrease the effect of a learning curve.

Visual acuities for OD, OS, and OU were measured through the monovision correction modality and the best distance correction modality. A non-self-illuminating log mar chart was used at 6m and a reduced log mar chart was used at 40cm. The best visual acuity was determined when the subject was unable to correctly identify more than half of the letters on a line.

Near stereopsis was measured using a modified Titmus circles test at 40cm. A typoscope was made out of a black piece of construction paper. The examiner positioned the card so that only one set of circles was visible at a time. At that time the examiner would instruct the subject, "Which one of these circles appears closer to you?" The stereo acuity demand was presented in a random order to prevent an "adaptation" effect that would falsely improve their stereo acuity level.

Distance stereopsis was measured using the Mentor BVAT at 6 meters. The patient was seated and the BVAT accessory goggles were positioned over their eyes. The subject was given the following instructions: "I am going to show you a group of four circles. One of these circles may appear closer to you when compared to the other circles. I would like you to tell me as quickly as possible which of these circles is the closest one of the four." The patient was presented the stereopsis targets starting with 400 seconds arc. The test was continued until the subject was no longer able to correctly identify two targets at the same level of stereopsis.

Acuity suppression was measured using the Mentor BVAT at 6 meters. The patient was seated and the BVAT accessory goggles were positioned over their eyes. The subject was given the following instructions: "I am going to present to you a variable number of letters. I would like you to tell me how many letters you see. I also would like you to tell me if any of the letters appear to flicker or disappear." The acuity level at which the patient first reported some of the letters to be missing or flickering was recorded as the level at which the patient first started to suppress.

Driving performance was assessed on a blacktop, outdoor parking lot that was illuminated with random streetlights. Since testing took place outside with variable lighting conditions the examiner graded the ambient light level subjectively as either bright or dim. "Bright" was given to testing periods that occurred during the day. "Dim" was given to testing periods that occurred at dusk or at night. Two pairs of cones were designated as a start line and a stop line. Each pair of cones was positioned four meters apart. A thin, matte black colored rope was stretched along the blacktop between the two stop cones. This served as a point of reference from which the examiner measured the error. The distance between the start line and the stop line was twenty meters.

The subjects were required to drive their own car for this portion of the study. Therefore familiarization with the vehicle was not a factor. The car was positioned so that the front of the car was aligned with the start cones. After proper positioning, the subjects were given instructions on how to perform the test. The subjects were informed that they were to drive forward until they believed the front of their car was parallel with the plane of the stop cones. They were instructed to maintain a comfortable, consistent speed for the three trials. After their vehicle came to a complete stop, the subject was instructed to keep the vehicle stationary until measurements were made.

After coming to a complete stop, the examiner measured the amount of error from the front of the car to the stop plane. A positive value indicated that the front of the vehicle crossed the stop plane and a negative value indicated that the front of the vehicle failed to reach the stop plane. A meter stick was used to measure the error to the nearest _ cm. No feedback was given to the subjects to help them with further attempts. The three individual trials were timed. The time started with the onset of movement by the vehicle and stopped when the vehicle came to a complete stop. The subjects performed the task three times wearing the best distance correction modality and three times wearing the monovision correction modality. The near testing was performed between the two driving tasks.

Results

Subject Data

A total of thirty-eight subjects were tested in this study. Two of those subjects were excluded from analysis due to inconsistencies in their findings. The average age of the subjects in this study was 28 years with a range of 22 to 55 years. There were eight subjects 43 years or older involved in the study that we consider presbyopes. Thirteen subjects were emmetropes and twenty-five subjects were myopes.

Preferred Eye

Nineteen subjects demonstrated right eye preference and eleven subjects had left eye preference. Eight subjects showed no ocular preference. Of those subjects who showed no preference, five were assigned to have their right eye as the monovision eye and three were assigned to have their left eye as the monovision eye.

Visual Acuities

All of the comparisons between lens conditions were done using repeated measures t-tests. A significant difference ($t=11.82$, $p=0.0001$, $df=35$) was present for distance visual acuity between the eye corrected for near compared to the eye corrected for distance. The monovision modality also caused a significant difference ($t=2.69$, $p=0.0109$, $df=35$) in binocular visual acuity when compared to the distance binocular visual acuity. The data for distance visual acuity are shown in Table 1.

Table 1. Distance VA with different viewing conditions and lens modalities				
Modality	Mean (Snellen)	SD	Minimum (Snellen)	Maximum (Snellen)
Monocular with distance modality	20/22	6.9	20/11	20/42
Binocular with distance modality	20/18	4.7	20/10	20/33
Near eye with monovision modality	20/90	3.6	20/35	20/134
Distance eye with monovision modality	20/22	6.6	20/13	20/41
Binocular with monovision modality	20/21	6.6	20/11	20/42

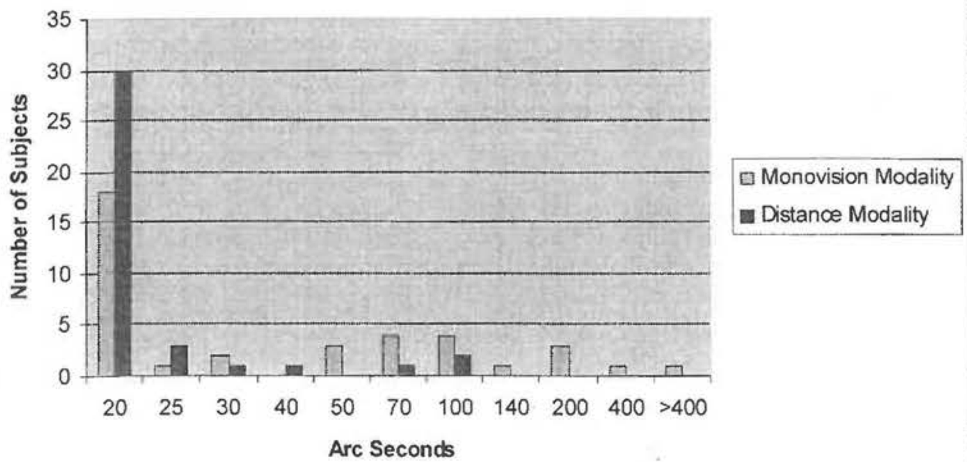
There does not appear to be a difference between the monovision lens modality and the distance lens modality when comparing near visual acuity findings. The data for near visual acuity are shown in Table 2.

Table 2. Near VA with different viewing conditions and lens modalities				
Near VA (Modality/Eye)	Mean	SD	Minimum	Maximum
Monocular with distance modality	20/22	13.7	20/16	20/73
Binocular with distance modality	20/20	8.7	20/16	20/51
Near eye with Monovision Modality	20/20	8.3	20/16	20/63
Distance eye with monovision modality	20/23	14.5	20/16	20/78
Binocular with Monovision Modality	20/19	6.6	20/16	20/51

Stereo Acuity

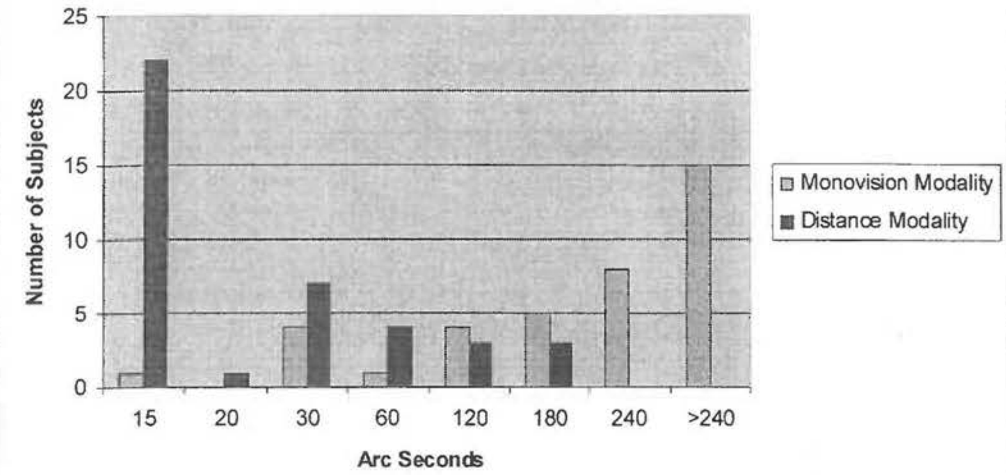
Stereo acuity changes were determined by comparing stereo acuity with the monovision modality to stereo acuity with the distance lens modality. All of the comparisons between lens conditions were done using repeated measures t-tests. Near stereo acuity ($t=3.16$, $p=0.0033$, $df=34$) and distance stereo acuity ($t=7.43$, $p=0.0001$, $df=20$) were both significantly decreased with the monovision lens modality. On average, 130 seconds arc were lost on distance stereopsis and 41 seconds arc were lost on near stereopsis with the monovision modality. Figure 1 shows the distance stereo acuity data. Figure 2 shows the near stereo acuity data.

FIGURE 1
Near Stereo Acuity



It must be noted that only those subjects who were able to achieve a gross level of stereopsis were used for calculations. Fifteen subjects were excluded in the distance stereo acuity analysis and one subject was excluded from the near stereo acuity analysis because they were unable to achieve the grossest level of stereo acuity that the BVAT was able to measure.

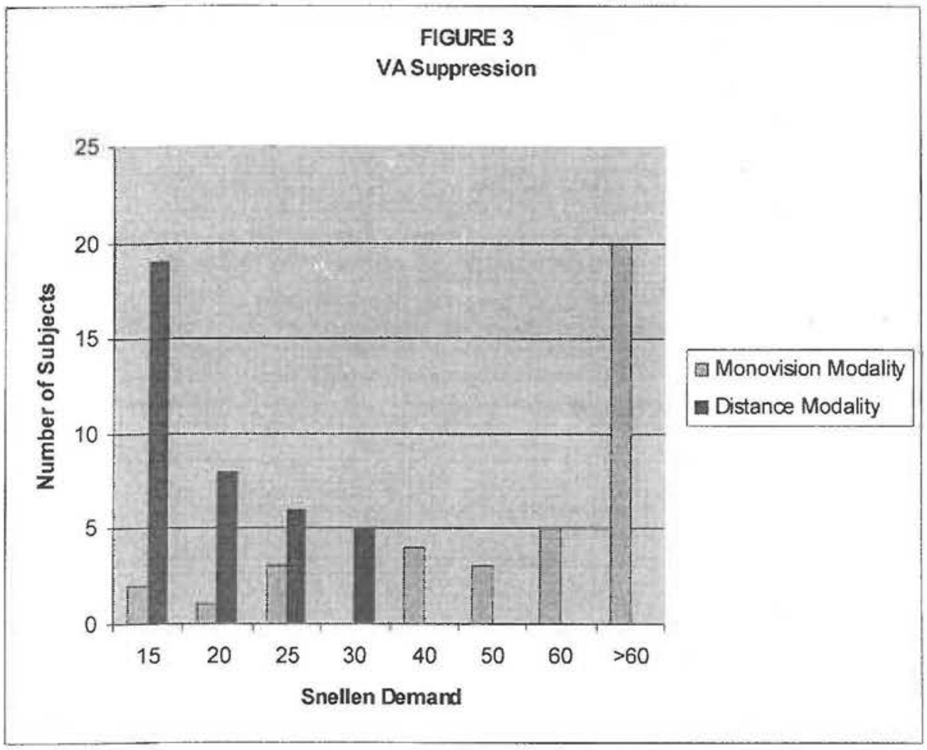
FIGURE 2
Distance Stereo Acuity



The amount of time required to achieve stereopsis at distance was eliminated from analysis due to a protocol problem that caused the information to be invalid.

Acuity Suppression at Distance

Comparisons between lens conditions were done using repeated measures t-tests. There was a significant decrease ($t=6.9$, $p=0.0001$, $df=16$) with the monovision lens modality in the level at which acuity suppression occurred. On average two lines of acuity were lost before suppression occurred with the monovision modality. Again when analyzing this portion of the data nineteen subjects were excluded from statistical analysis because they suppressed at the grossest level that the BVAT was able to measure, 20/60. A mean decrease in acuity suppression from approximately the 20/20 line with the distance modality lens to the 20/40 line with the monovision modality was measured. Those who had decreased stereo acuity at distance were more likely to have a grosser level at which they started to suppress. Data for acuity suppression are shown in Figure 3.



Driving Performance

Comparisons between lens conditions were done using repeated measures t-tests. Driving error was determined by measuring the error from the stop line. The mean error with the monovision lens modality was compared to the error with the distance lens modality. The monovision lens showed a significant increase (t=-3.42, p=0.0016, df=35) in the amount of driving error. However, when looking at the error range, the distance lens modality showed a larger standard deviation (30.3 cm) than monovision lens modality (12.6 cm).

The amount of time elapsed between start and stop between the two modalities was not significantly different (t=1.5, p=0.257, df=35).

The comparisons between the three trials on the driving variables were done using repeated measures one-way analysis of variance (ANOVA). There was a significant difference ($F=5.04$, $p=0.009$, $df=105$) between the first driving attempt with the monovision lens compared to the second and third attempt. On the first trial the subjects significantly undershot the stop plane by –34.9 cm in comparison to the second and third trials –26.9 cm and –26.9 cm respectively. A learning curve is evident due to the reduction of driving error on the second and third attempts. The distance lens modality does not show a significant ($F=2.26$, $p=0.11$, $df=105$) difference between the three trials.

As a group ($n=24$) the monovision modality showed a greater amount of driving error in the dim lighting condition. Subjects tested with the bright lighting condition did not exhibit this effect ($n=12$).

Discussion

Visual Acuities

As expected the monovision lens caused a decrease in the monocular distance visual acuity of the eye that was wearing the near lens. The monovision modality also caused a slight decrease in the binocular distance visual acuity. This slight decrease is expected due to the ability of the monovision subject to suppress blur. The measurements of visual acuity were performed under photopic conditions, which are the least stressful for the visual system to perform under.

It would be expected that a larger amount of add power in the monovision lens would affect visual acuity to a greater amount. However this was not the case in this study. Due to large variability in the data no apparent pattern was observed. In addition, poor fitting contact lenses may have affected the visual acuity of some of the subjects resulting in poorer visual acuities then expected.

Near visual acuity was unaffected as a whole for the subjects in this study. Only a few true presbyopes were subjects in this study. The majority of the subjects were young adults with no accommodative problems. In a study where all of the subjects are presbyopes the monovision modality would be expected to be associated with an improvement in near visual acuity. Due to the small number of true presbyopes involved in the study, separate analysis of their data was not conducted. Some subjects showed a remarkable decrease in near acuity with the monovision lens. This was likely due to a poor fitting contact lens.

The protocol of this study did not allow the subjects to adapt to the monovision lens. Therefore these results are a sample of how the visual system reacts immediately after putting on a monovision lens. The literature states that there is an adaptation process that takes place after wearing monovision lenses which was not addressed in this study.

Stereo Acuity

Distance stereo acuity was devastated with the monovision modality. With the distance modality a majority of the subjects were able to discern a stereo acuity of 15 seconds arc. The poorest stereo acuity recorded for this modality was 180 seconds arc. With the monovision lens modality fifteen subjects (42%) were unable to see the 240 seconds arc demand target. Because these subjects' true stereo acuity was less than the minimum measurable with the BVAT, they were excluded from statistical analysis. The statistics therefore only examine those subjects whose stereo acuity was affected the least by the monovision modality. This skews the statistics to show that the monovision modality performs better than it actually does.

Near stereo acuity was also affected by the monovision modality, but not to the extent as the distance stereo acuity. With the distance lens modality thirty subjects (83%) were able to discern 20 seconds arc (the finest level tested). The best stereo acuity at near with the distance lens modality was 100 seconds arc. With the monovision modality eighteen subjects (51%) were still able to perceive the 20 seconds arc demand line. Only one subject was unable to see the grossest level (400 seconds arc) tested. The monovision lens caused a mean decrease in stereo acuity of 41 seconds arc.

Again it must be noted that a majority of subjects in this study were not presbyopes. It is hard to predict what the decrease would have been for subjects that were truly dependent on the add power of the monovision lens. Due to the limited number of true presbyopes involved in this study, statistical analysis was not preformed on their results alone.

One would expect that a larger add power would cause a greater decrease in stereo acuity. Our results do not show a clear pattern of decreased stereo acuity with a higher add power. Even without the correlation of higher add powers causing a larger decrease in stereo acuity, it is obvious that the monovision lens compromises binocular function. How the binocular system adapts to this change was not assessed by this study. We know that the system is incredibly flexible and perhaps this is how patients are able to function.

Acuity Suppression

Acuity suppression was tested to determine the level at which central suppression occurs. The literature states that those subjects who are better at suppression are more likely to adapt to monovision. With the distance lens modality, the lowest level at which suppression occurred was the 20/30 demand line with a majority of subjects being able to see at least the 20/20 demand line without suppressing. With the monovision modality, the level of acuity suppression for nineteen subjects (53%) was unable to be measured because they suppressed at the lowest level (20/60).

All of the subjects that were unable to see the whole 20/60 demand line due to suppression were eliminated from analysis because their true level of performance was not quantifiable. The statistical results were again skewed because only those subjects that were affected the least were analyzed. If all of the subjects' true level of performance could have been evaluated, the actual effect of the monovision lens condition on acuity suppression would have shown a much greater decrease. For the subjects analyzed, acuity suppression occurred with letters two visual acuity lines larger than with the distance lenses.

Driving Performance

Analysis of the driving performance showed that the monovision modality causes a greater mean amount of error than the distance lens modality. The standard deviations for the mean driving error with monovision modality and the distance lens modality are similar to each other (25.4 cm and 24.4 cm respectively). This indicates that the range of errors were about the same for the two modalities.

Examination of the mean maximum amount of error and the mean minimum amount of error shows both to be greater with the monovision lens modality. The average error for the best driving performance with monovision was worse than that with the distance lenses. Also, the average error for the worst driving performance with the monovision lenses was worse than that with the distance lenses.

It is interesting to note that comparison of the mean range of error shows the distance lens modality to have a greater mean range (26.7 cm) than the monovision lens modality (21.6 cm). However, statistical analysis shows this not to be significant. Likely the cause for this increase was the large variability found within the trials of the distance lens modality.

Comparison of the three trials amongst each other in the monovision modality showed that the first trial was significantly worse than the other two trials. This phenomenon was not demonstrated with the distance lens modality in which all trials were similar to each other. The likely cause of the difference with the first trial was due to visual uncertainty caused by the monovision lens. The visual system was allowed to reset itself after determining its perceived amount of error from the first trial thus allowing more accurate attempts at the second and third trials.

Comparison of the time between the two modalities shows there to be no significant difference. We expected the monovision lens modality to require a longer amount of time to complete the task due to visual uncertainty. There also was no significant difference between the time of the first trial and the following trials with either the monovision modality or the distance lens modality.

Another variable to compare was the lighting conditions. In the dim condition the error in driving performance with the monovision was still observed. However, this error disappears with those subjects tested in a bright condition. Only twelve subjects were tested in the bright condition compared to twenty-four subjects in the dim condition. It was likely that this large amount of error was due to the decreased ability to suppress in dim conditions. It is often reported by monovision patients that they experience the most difficulties driving at night with their monovision lenses.

Summary

Monovision inherently compromises visual function compared to distance contact lenses. Monovision patients can expect a decrease in distance visual acuity, near and far stereo acuity, acuity suppression, and an increase in driving error.

Distant stereo acuity was reduced significantly and to a greater extent than is evident in the data. Fifteen subjects were unable to distinguish the 240 seconds arc demand target. Because these subjects' true stereo acuity was less than the minimum measurable with the BVAT, they were excluded from statistical analysis. Therefore, the statistics only examine those subjects whose stereo acuity was least affected by the monovision modality. This skews the statistics to show that the monovision modality performs much better than it actually does.

The same holds true for acuity suppression. All of the subjects that were unable to see the whole 20/60 demand line due to suppression were eliminated from analysis because their true level of performance was unable to be tested. The statistical results were again skewed because only those subjects that were affected the least were analyzed. If all of the subjects' true level of performance could have been evaluated, the actual effect of the monovision lens condition on acuity suppression would have shown a much greater decrease.

The power of the monovision add did not seem to predict any of the measured variables. The correlations were low partly to the large variability in the visual acuity data in the monovision condition.

Analysis of the driving performance showed that the monovision modality caused a greater mean amount of error than the distance lens modality. Comparison of the three trials showed that the first trial was significantly worse than the other two trials. The likely cause of the difference with the first trial was due to visual uncertainty caused by the monovision lens. Finally lighting conditions played a role in driving performance error. In dim conditions the error was increased due to the subjects' decreased ability to suppress in these conditions.

In summary, monovision caused a decrease in several aspects of visual function including distance visual acuity, near and far stereo acuity, acuity suppression, and an increase in driving error.

Subject Data

Subject #	Age	Ref Cond. M, E, H	Mono Eye	Mono Power	Test Order	VA R Mono Far	VA L Mono Far	VA OU Mono Far	VA R Mono Nr	VA L Mono Nr	VA OU Mono Nr
1	25	E	R	1.00	2	42/-2	13/-2	13/-2	16	16	16
2	25	E	L	1.25	1	16/-2	42	14/-3	16/-2	16/-1	16/-1
3	25	E	L	2.25	2	21/+1	107	16	16	25	16
4	25	M	L	1.00	1	16	83/+1	16/-2	16/-1	25/-1	16
5	29	M	L	1.50	1	16	33/-2	16	16	16	16
6	29	E	R	2.00	2	67	21/-1	21/-2	16	16	16
7	24	M	R	2.00	1	53/-3	27/+1	21/-1	63	50	50/-1
8	24	M	L	1.50	2	21/+1	133	16	16	16/-1	16/-1
9	22	E	R	1.25	1	53/-2	11/-2	11	16	16	16
10	22	M	R	1.50	1	83/+2	16/+1	16	16/-2	16	16/-2
11	27	E	L	1.25	2	21/-1	53	21/-1	16/-2	16	16/-1
12	23	M	L	1.25	1	16/-2	107/+1	16/+1	20/+2	20	16
13	24	M	R	1.25	1	107	21/-2	21/-1	16	16	16
14	23	M	L	2.00	1	27	107	27	20	16	20
15	25	E	L	1.50	2	16	53/-1	21/-1	16	16/-2	16/-1
16	24	M	R	2.00	2	133/-1	33/-1	33/+1	16	16/-1	16/-1
17	22	E	L	1.25	2	33	67/+1	16	25/+2	16/-1	16/-2
18	27	E	R	1.00	1	42/-1	21	16	16	20/-1	16/-1
19	23	M	L	1.50	2	16/-1	133/+1	16	16/-2	16/-1	16
20	25	M	L	1.75	1	21/+2	133	16/-1	16	16	16
21	24	E	R	1.25	2	53/+2	13/-2	13/-2	16	16	16
22	26	M	R	2.50	1	133	27/+1	27/-1	20/-1	16	16
23	23	M	L	2.50	2	13	133	13	16	16	16
24	24	M	L	2.00	2	21	133	21	16/-1	16	16/-1
25	25	M	L	2.00	1	42/+1	133	42	25	16	16
26	32	E	L	1.75	2	21	67/-1	21/-1	16/-2	16	16/-2
27	46	M	L	1.50	2	27	83/-2	21	80/+2	16	16
28	55	M	L	1.00	1	21	53/+1	21	50/-1	25	32/+2
29	48	M	R	1.75	2	67	33	33	25/-1	40/-1	32
30	48	M	L	1.25	1	27	67	21	25	25	20
31	47	M	R	2.25	2	27/+1	21	21/+1	20/+2	25/+1	20/+1
32	23	F	L	1.75	2	21/+2	133/+2	21/+2	16	20/+2	16
33	24	M	L	2.50	2	21	133/+2	21	16/-1	16	16/-2
34	23	F	R	2.50	1	53/+1	16/-1	16/-1	16	16	16
35	24	F	L	2.50	2	27/-2	133	33	16	25	16
36	48	M	R	1.25	1	67	42	67/+2	16	20/+2	16
37	45	M	L	1.25	1	33/+2	133	21/-1	25	16/-1	16/-1
38	53	F	L	1.75	1	27/+2	107/-2	27/-2	63/+2	25	20/+2

Subject Data

Subject #	VA R Dist Far	VA L Dist Far	VA OU Dist Far	VA R Dist Nr	VA L Dist Nr	VA OU Dist Nr	Eye Pref	Eye Pref%	Stereo Nr Mono	Stereo Far Mono	VA Supp Mono
1	16/+2	13/-2	13/+1	16	16	16	OS	100%	20	60	60
2	16/+1	16/+1	16/+2	16/-1	16/-1	16/-1	OD	100%	20	240	40
3	16	21	16	16/-1	16	16	OD	100%	70	180	>60
4	16	21/-1	16	16	21	16	OD	75%	50	180	40
5	16/+1	16	16/+1	16	16/-1	16	None	50%	50	30	15
6	21/-1	21/-2	21/+1	16	16	16	OS	100%	20	180	>60
7	27	27/-1	21/-1	16/-2	50/-2	16/-1	None	50%	20	120	>60
8	21/+1	21/-1	16/-1	16	16/-1	16/-1	OD	100%	20	120	>60
9	13/+1	13/+2	13/+3	16	16	16	OS	100%	20	240	60
10	16/-1	21/+2	16/-1	16	16/-1	16	None	50%	100	>240	50
11	27	27	16/-1	16/-1	16	16	OD	100%	20	30	25
12	16/-2	21/-1	16/-2	16/-2	16	16	OD	100%	200	>240	>60
13	21	21	21/+1	16/-1	20	16	None	50%	100	>240	>60
14	27	33	21	20	25	16/-1	None	50%	100	240	>60
15	21	21/-2	16/-2	16/-1	16/-1	16	OD	75%	20	240	60
16	21/-1	21/-1	21	16	16/-1	16	None	50%	50	>240	>60
17	33/-3	33/-2	33	20/+2	16	16/-1	OD	100%	20	>240	40
18	21	21	16/-1	20/-2	20	16	OS	75%	20	30	25
19	21/+2	27	16/-1	16	16	16	OD	100%	200	>240	>60
20	13/-1	13	11/-1	16	16	16	OD	100%	25	>240	>60
21	13/-1	16/+1	13/-1	16	16	16	OS	75%	20	30	15
22	27/-1	21/-1	21/-1	16	16/-1	16	OS	100%	>400	120	>60
23	16	16/+2	13/-1	16	16	16	OD	100%	70	120	>60
24	21	27	16	16/-2	16	20/+2	OD	75%	20	>240	60
25	42	16	16/+1	25/-1	16	16	OD	100%	20	240	50
26	21/-1	16/-1	16	20	16	16/-2	None	50%	20	240	50
27	27/+1	21	21	80/-2	50	50	OD	75%	100	>240	20
28	21/-1	21/-1	21/+2	50/-2	32/+1	32	OS	75%	20	180	60
29	42	33	33	32	32	32	OS	75%	30	>240	>60
30	27	21	16	25	32	32/+2	OD	100%	70	>240	>60
31	27/+1	27/+2	27/+3	40/-1	25	20/-2	OS	100%	200	15	25
32	21/-2	27/-2	21/+1	20	16/-2	16	OD	100%	400	>240	>60
33	21	16	16	16	16	16	OD	100%	20	>240	>60
34	21/+2	16/-1	16	16	16	16	OS	100%	200	>240	>60
35	33/+1	21	16	16	16	16	OD	75%	20	240	>60
36	21	53/+2	21	40/-1	16/-1	16	OD	100%	70	240	>60
37	42/+2	27/-2	16/-2	20/-2	63	16/-2	OD	100%	30	180	40
38	21/-2	16/+1	21/+1	63/-1	63/+1	50/-1	OS	75%	140	>240	>60

Subject Data

Subject #	Stereo Nr Dist	Stereo Far Dist	Stereo Far Dist Time Seconds	VA Supp Dist	Drive Mono Err1 cm	Drive Mono Err2 cm	Drive Mono Err3 cm	Drive Mono ErrMn cm	Drive Mono Time1 Seconds
1	20	30	1.77	15	-38.50	-45.50	-34.00	-39.33	6.84
2	20	15	4.24	15	-34.50	-27.00	-15.50	-25.67	15.53
3	20	30	2.83	30	-29.50	-17.00	-9.00	-18.50	4.42
4	20	15	7.41	15	-36.00	-7.00	-13.50	-18.83	9.60
5	20	15	1.93	15	-47.00	-15.50	-8.00	-23.50	9.93
6	20	20	5.68	15	-36.50	-26.00	-32.00	-31.50	11.12
7	25	15	3.17	15	-3.00	-10.00	-10.50	-7.83	12.49
8	20	15	3.66	20	-17.00	-7.50	-1.00	-8.50	7.52
9	20	15	2.56	15	-7.00	6.00	-2.50	-1.17	7.16
10	25	60	9.86	15	-58.50	-21.00	-35.50	-38.33	8.20
11	20	15	9.83	25	-9.00	11.00	-2.00	0.00	6.08
12	20	30	1.30	15	-36.50	-36.50	-10.00	-27.67	11.21
13	20	15	3.01	15	-15.50	-25.00	-22.50	-21.00	5.32
14	25	30	8.66	20	-95.50	-63.50	-62.00	-73.67	6.38
15	20	15	7.15	15	-76.00	-60.00	-45.50	-60.50	7.69
16	20	15	6.81	25	-41.00	-62.50	-59.50	-54.33	5.07
17	20	30	8.63	20	-60.50	-75.00	-99.50	-78.33	5.99
18	20	15	2.58	15	-93.00	-92.50	-73.00	-86.17	5.25
19	20	15	4.99	15	-66.50	-32.00	-37.50	-45.33	6.27
20	20	15	3.37	15	-13.00	-17.50	-29.50	-20.00	5.12
21	20	15	2.83	15	-12.00	-20.00	-14.50	-15.50	6.14
22	20	15	2.96	25	-52.50	-39.00	-59.00	-50.17	5.23
23	20	15	3.84	20	-17.50	-62.00	-81.00	-53.50	4.77
24	20	60	6.43	25	-38.00	-36.00	-35.00	-36.33	4.65
25	20	60	4.32	25	-32.00	-20.00	-23.00	-25.00	7.47
26	20	15	4.32	15	-19.50	-14.50	-5.00	-13.00	6.89
27	100	30	9.83	15	-25.00	-6.50	-6.00	-12.50	5.48
28	20	15	8.81	30	15.00	11.00	11.00	12.33	9.45
29	20	120	13.34	30	-13.00	-13.50	-11.50	-12.67	6.04
30	70	60	5.44	20	-39.00	-18.50	-13.00	-23.50	6.12
31	20	15	3.33	25	-17.50	-3.50	2.00	-6.33	7.13
32	40	30	9.62	30	-93.00	-54.50	-70.50	-72.67	11.10
33	20	15	4.17	20	-60.50	-64.50	-43.00	-56.00	5.71
34	20	15	8.49	20	-26.00	-39.00	-21.00	-28.67	9.59
35	20	15	3.63	15	-27.50	-8.00	-2.00	-12.50	7.90
36	100	180	7.23	30	6.00	0.00	-11.00	-1.67	6.45
37	20	120	4.40	15	-18.00	0.00	-3.00	-7.00	7.40
38	30	120	10.19	20	-37.00	-30.50	-20.50	-29.33	8.40

Subject Data

Subject #	Drive Mono Time2 Seconds	Drive Mono Time3 Seconds	Drive Mono TimeMn Seconds	Drive Dist Err1 cm	Drive Dist Err2 cm	Drive Dist Err3 cm	Drive Dist ErrMn cm	Drive Dist Time1 Seconds
1	6.41	7.13	5.35	-25.50	-14.00	-24.00	-21.17	9.41
2	7.20	6.62	7.84	0.00	-10.50	-16.50	-9.00	7.20
3	4.27	5.08	4.19	2.00	-5.00	5.50	0.83	4.76
4	6.82	6.17	6.65	-29.50	15.00	30.00	5.17	5.93
5	6.67	9.09	7.67	-4.50	-6.50	-13.50	-8.17	8.27
6	11.43	10.69	9.81	-32.50	-27.50	-31.00	-30.33	10.52
7	9.81	9.63	9.73	-20.50	-29.50	-21.50	-23.83	10.90
8	8.57	8.73	8.21	37.00	8.50	25.00	23.50	9.03
9	7.76	5.94	7.47	7.00	1.00	-2.00	2.00	5.53
10	8.90	8.26	8.84	18.50	18.00	-3.50	11.00	5.43
11	6.28	6.09	7.36	-20.00	-7.50	-3.50	-10.33	8.53
12	9.94	8.73	10.47	-16.00	-13.50	0.00	-9.83	8.02
13	6.02	5.74	7.52	5.00	-2.00	7.00	3.33	6.23
14	6.29	7.01	8.42	-57.00	-44.50	-50.00	-50.50	5.60
15	7.09	6.85	9.16	-13.50	20.50	-12.00	-1.67	8.67
16	5.72	5.71	8.13	-41.00	-67.00	-71.00	-59.67	6.43
17	6.16	6.24	8.85	-50.00	-48.50	-71.50	-56.67	6.71
18	5.32	5.67	8.56	-48.00	100.00	-78.00	-8.67	5.09
19	5.20	5.77	9.06	-12.50	-53.50	-34.50	-33.50	6.35
20	6.40	6.24	9.44	-39.00	-31.00	-22.00	-30.67	5.43
21	5.86	6.81	9.95	-38.50	12.00	-10.00	-12.17	5.78
22	5.49	5.56	9.57	-50.00	-46.00	-36.50	-44.17	5.44
23	4.68	4.45	9.23	-31.50	-38.00	-53.00	-40.83	4.59
24	4.31	4.82	9.45	-73.00	-12.00	-43.50	-42.83	3.88
25	7.87	8.47	12.20	-26.00	23.50	15.50	4.33	7.01
26	7.16	7.33	11.85	-13.50	-3.00	-23.00	-13.17	6.43
27	6.66	6.30	11.36	-55.50	-18.00	-7.50	-27.00	6.33
28	9.12	8.40	13.74	11.00	14.50	1.00	8.83	7.51
29	6.38	6.67	12.02	8.50	-3.00	15.00	6.83	7.21
30	7.23	6.50	12.46	1.00	-3.00	-1.00	-1.00	6.60
31	6.70	7.02	12.96	-10.00	-3.50	-4.50	-6.00	7.49
32	10.94	11.53	16.39	-73.00	-85.00	-75.50	-77.83	11.29
33	5.73	5.67	12.53	-57.50	-60.00	-71.00	-62.83	6.04
34	7.47	8.40	14.87	-7.50	-18.50	-20.50	-15.50	6.47
35	7.87	8.22	14.75	-9.00	-13.00	-11.00	-11.00	10.26
36	7.33	7.44	14.31	4.00	22.00	25.00	17.00	5.49
37	7.19	6.53	14.53	-36.50	-16.00	-14.50	-22.33	7.52
38	8.30	8.50	15.80	-35.00	-31.00	-29.00	-31.67	8.00

Subject Data

Subject #	Drive Dist Time2 Seconds	Drive Dist Time3 Seconds	Drive Dist TimeMn Seconds	Light level
1	8.13	7.32	6.47	Dim
2	7.79	6.71	5.93	Dim
3	4.49	5.40	4.41	Dim
4	7.26	7.31	6.13	Dim
5	7.29	7.08	6.91	Dim
6	12.08	11.38	10.00	Dim
7	8.01	7.69	8.40	Dim
8	9.44	7.92	8.60	Dim
9	5.17	5.53	6.31	Dim
10	3.03	6.43	6.22	Dim
11	8.28	7.41	8.81	Dim
12	9.08	8.07	9.29	Dim
13	6.24	6.41	7.97	Dim
14	5.36	5.63	7.65	Dim
15	8.84	9.38	10.47	Dim
16	5.66	5.95	8.51	Dim
17	7.09	6.17	9.24	Dim
18	5.93	5.75	8.69	Dim
19	5.38	5.39	9.03	Dim
20	6.64	6.19	9.57	Dim
21	12.37	6.83	11.50	Dim
22	5.14	5.44	9.51	Dim
23	4.70	4.59	9.22	Dim
24	3.63	4.25	8.94	Bright
25	7.24	6.78	11.51	Bright
26	6.06	6.23	11.18	Bright
27	5.92	6.18	11.36	Bright
28	8.11	8.17	12.95	Bright
29	7.33	5.95	12.37	Bright
30	5.91	6.30	12.20	Bright
31	8.38	6.98	13.46	Bright
32	11.29	9.52	16.03	Bright
33	5.59	4.99	12.41	Bright
34	6.44	6.42	13.33	Bright
35	9.62	9.27	16.04	Bright
36	6.07	5.56	13.28	Bright
37	7.68	7.08	14.82	Bright
38	8.53	7.99	15.63	Bright

References

1. Harris MG, Classe JG. Clinicolegal Considerations of Monovision. J Amer Optom Assoc 1988;59:491-495.

2. Beier C. A Review of the Literature Pertaining to Monovision Contact Lens Fitting of Presbyopic Patients: Clinical Considerations. International Contact Lens Clinic 1977; March/April: 49-56.

3. Josephson JE, Erickson P, Back A, Holden BA, Harris M, Tomlinson A, Carrfre BE, Finnemore V, Silbert J. Monovision. J Am Optom Assoc 1990;61:820-826.

4. Erickson P, Schor C. Visual Function with Presbyopic Contact Lens Correction. Optom & Vis Sci 1990;67:22-28.

5. Sheedy JE, Harris MG, Busby L, Chan E, Koga I. Monovision Contact Lens Wear and Occupational Task Performance. Am J Optom Physiol Opt 1988;65:14-8.

6. Kirschen D, Hung C, Nakano T. Comparison of Suppression, Stereoacuity, and Interocular Differences in Visual Acuity in Monovision and Acuvue Bifocal Contact Lenses. Optom & Vis Sci 1999; 76:832-837.

7. Hom M. Monovision and LASIK. J Am Optom Assoc 1999;70:117-121.

8. Back A, Holden B, Hine N. Correction of Presbyopia with Contact Lenses: Comparative Success Rates with Three Systems. Optom & Vis Sci 1989;66:518-525.

9. Erickson P, McGill E. Role of Visual Acuity, Stereoacuity, and Ocular Dominance in Monovision Patient Success. Optom & Vis Sci 1992;69:761-764.

10. Sheedy JE, Harris MG, Gan CM. Does the Presbyopic Visual System Adapt to Contact Lenses? Optom Vis Sci 1993;70:482-486.

11. Schor C., Landsman L., Erickson P. Ocular Dominance and the Interocular Suppression of Blur in Monovision. Am J Optom Physiol Opt 1987;64:723-730.

12. Schor C, Carson M, Peterson G, et al: Effects of Interocular Blur Suppression Ability on Monovision Task Performance. J Am Optom Assoc 1989;60:188-192.

13. Lovasik JV, Szymkiw M. Effects of Aniseikonia, Anisometropia, Accommodation, Retinal Illuminance, and Pupil Size on Stereopsis. Invest Ophthalmol Vis Sci 1985;26:741-750.

14. McGill E, Erickson P. Stereopsis in Presbyopes Wearing Monovision and Simultaneous Vision Bifocal Contact Lenses. Am J Optom Physiol Opt 1988;65:619-626.

15. Gutkowski M, Cassin B. Stereoacuity and Monovision in the Contact Lens Management of Presbyopia. Binoc Vis Q 1991;6:31-36.

16. Sheedy JE, Bailey IL, Buri M, Bass E. Binocular vs. monocular Task Performance. Am J Optom Physiol Opt 1986;63:839-846.

17. Sanchez FJ. Monovision: which eye for near? Contact Lens Forum 1988;13:57.

18. Wood J, Wick K, Shuley V, Pearce B, Evans D. The Effect of Monovision Contact Lens Wear on Driving Performance. Clin Exp Optom 1998;81:100-103.

19. Wood JM, Troutbeck R. The effect of Restriction of the Binocular Visual Field on Driving Performance. Ophthal Physiol Opt 1992;12:291-298.