

THE DIFFERENCE IN VISUAL PERFORMANCE BETWEEN MONOVISION
FIT CONTACT LENSES AND PROGRESSIVE ADD SPECTACLE LENSES.

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ABSTRACT

Background: The Federal Aviation Administration (FAA) currently doesn't allow for the use of monovision contact lenses for the correction of presbyopia. This research study intends to quantify the differences in visual performance between monovision fit contact lenses, which are disallowed, and progressive add spectacle lenses, which are allowed. *Methods:* We fit five presbyopic patients with monovision contact lenses. We also fit the same patients with Varilux Panamic© progressive add spectacle lenses (PAL). Each subject wore one mode of correction at a time. The subjects were then asked to complete four visual tasks using each mode of correction. The four tasks were distance acuities using the ETDRS logarithmic acuity chart, near acuity using the Lighthouse acuity card, Useful Field of View (UFOV) computer test, and the Waynes saccadic fixator. The two modes of correction were compared using their measured performance for each test. We then analyzed the data to determine if there was a significant statistical difference in visual performance between the two modes of correction. *Results:* Both distance and near acuities were better with monovision contacts when both eyes were open, however the difference was not statistically significant. There was no significant difference between the modes in the performance of the Waynes saccadic fixator or the UFOV. *Conclusion:* Based on this early pilot study and the literature searches we conducted, there is no scientific data to support the FAA's position to prohibit contact lens wear for presbyopia.

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Introduction

The Federal Aviation Administration (FAA) has the responsibility to regulate the physical fitness of civil airmen through a process of medical certification. A key component of the initial, as well as, ongoing recertification of medical fitness is the assessment of visual abilities. With the increase in the average age of civil airmen, the determination of acceptable modalities for correcting presbyopia is becoming an increasingly common and controversial issue. The current standard requires that airmen with first or second class medical certificate have corrected visual acuity of 20/20 in each eye at distance, 20/40 or better in each eye at 16 inches and airmen age 50 or older must also demonstrate 20/40 at 32 inches. Airmen with third class medical certificates must demonstrate 20/40 or better visual acuity at distance and 16 inches.¹

The FAA currently prohibits pilots from wearing monovision fitted contact lenses, or any contact lens modality, for the correction of presbyopia.¹ Additionally, the vision standard's artificial constraints of monocular visual acuity performance precludes the use of monovision fitted contact lenses even if the contact lens prohibition were lifted. Monovision fitted contact lens correction, with one eye fitted for distance correction and the other eye for near correction, provides excellent distance and near acuity under 'natural' binocular conditions but not under monocular testing conditions. Millions of people and thousands of pilots successfully wear this correction modality in virtually every other occupational and recreational activity. Multifocal spectacles, commonly in the

form of progressive addition lenses and reading only half-eyes, with their inherent ophthalmic and optical limitations under natural environmental conditions, are permitted because they provide good performance on the monocular visual acuity test. Clinically, it is accepted that spectacles with progressive addition lenses (PAL) and monovision fitted contact lenses (MCL) offer different benefits and limitations for correcting presbyopia. The PAL modality offers better stereo acuity and an infinite range of near to intermediate power, but has peripheral distortion and requires precise head positioning to obtain proper focus for near. The MCL modality offers better peripheral vision, equivalent near vision in up, down and lateral gaze and the freedom from spectacle interference with headphones, but decreased stereopsis.

We questioned whether or not there was scientific data to explain or support the FAA policy. A literature search was conducted and found no studies that showed a loss of visual task performance with properly prescribed and adapted MCL modality. There is a great deal of research in the area of PAL and MCL modalities as effective correction of presbyopia, however, there are few studies that have quantified and compared visual performance for these modes of correction. One study showed no significant difference in visual acuity between PAL and MCL modalities, but there was a reduction in stereopsis using MCL.² The decrease of stereopsis with MCL is obvious and well documented, however the effect of decreased stereopsis on visual task performance of piloting an airplane or operating a motor vehicle remains speculative.

The current FAA vision standard arbitrarily limits the correction options for presbyopia. Others have questioned the validity of the FAA near vision standard; a study conducted by the U.S. Air Force found that it is inappropriate to test pilots' near visual acuity at 16 inches. The reason is that most instrument panels have a viewing distance of 26-28 inches.³ This study questioned the validity of the FAA monocular visual acuity standard as an indicator of visual fitness to pilot an airplane and the resultant exclusion of monovision fitted contact lenses as a correction for presbyopia. Objective, quantifiable measures of visual performance (speed of recognizing central and peripheral visual information and eye-hand coordination) along with primary visual abilities of subjects are compared using two the modalities of presbyopic correction.

Methods

Subjects were screened and selected based on the following criteria:

- Refractive error between $-4.00D$ and $+2.00D$ and less than $1.00D$ of astigmatism
- Presbyopia of at least $2.00D$ addition
- Visual Acuity of at least 20/25 near and far
- No evidence of constant or intermittent strabismus
- No evidence of significant or progressive ocular disease upon biomicroscope assessment

Subjects who met all the inclusion criteria were fitted with monovision Ciba Dailies soft contact lenses (MCL) and with Varilux Panamic© progressive add spectacle lenses (PAL) according to the manufacturers fitting criteria. The spectacle PAL's also had Crizal™ antireflective coating. A total of five subjects were recruited.

Four tests of visual performance were administered. Two clinical tests were chosen to quantify visual acuity; the ETDRS logarithmic acuity chart for distance acuity and the Lighthouse acuity card for near acuity. Additionally, two tests of visual performance were used; the Useful Field of View (UFOV) computer test and the Waynes saccadic fixator. The order of correction mode and visual performance testing was randomized to control for learning effect for the various tests and mode of correction.

Visual Acuity

The ETDRS and Lighthouse acuity charts were chosen to allow reporting of acuities as the Log of the minimum angle of resolution. Using this method, acuities can be reported down to the letter instead of the conventional line.

Distance and near acuities were measured in maximum room illumination (60 foot candles) using overhead fluorescent fixtures and incandescent fixtures.

Acuities were recorded as the Log of the minimum angle of resolution (MAR).

Each 0.10 of acuity refers to one line of acuity with each value of 0.02

representing one letter on a given line. A value of 0.00 is assigned to the standard 20/20 equivalent. A negative number indicates acuity of better than 20/20.

Distance and near acuities were taken monocularly and binocularly using each mode of correction. Monocular acuities wearing monovision were only taken at the distance each eye was corrected for. All visual acuity measurements were reported in LogMAR units in a spreadsheet by subject number.

Useful Field of View - UFOV

The UFOV test was designed to quantify two visual performance skills determined to be important in operating motor vehicles, speed of visual recognition and visual spatial awareness. Drivers with deficits in these areas have been shown to make more errors in visual judgment which puts them at higher risk of causing a car crash.^{5,6} The test quantifies these skills by presenting increasingly complex visual spatial targets at progressively shorter periods of exposure. The UFOV was selected for this study because of the similarity of requisite visual skills necessary for driving and piloting and its ability to produce reliable, objective datum for intrasubject comparison. The UFOV has been shown to have good repeatability and validity, being able to identify drivers with impaired performance of visual recognition and visual spatial awareness.⁴

All three subtests of the UFOV test were administered at a distance of 24 inches in front of a 15-inch CRT monitor in dim room illumination according to standard testing procedures.

In the first task, a box, with either a car or a truck in it, is briefly flashed in the center of the screen followed by a screen of visual interference. The subject is then prompted to identify what was in the box, the car or the truck. The test gives several presentations, given at different exposure times, to bracket the subject's threshold.

The second task is the same as the first with the addition of simultaneously presenting a second object (car) in one of eight peripheral positions. The subject is then prompted to identify the image presented in the central box as well as identify the location of the second object (car) in the periphery.

The third task builds on the previous two. It is the same as the second task, with the addition of visual noise dispersed on the screen along with the peripheral car. The screen has the box in the center with a car in the periphery. All the other available screen space is filled with triangles. After the presentation, the subject is prompted to identify what was in the box and the location of the peripheral car. All three tasks are bracketed around the subject's threshold.

After the test is completed, the UFOV program gives a numeric score for each section. These raw scores represent the shortest exposure time that the subject could correctly identify the visual information presented, with lower scores indicating better performance. The scores for each vision correction modality (PAL and MCL) were recorded into a spreadsheet for statistical comparison.

Waynes Saccadic Fixator

The Waynes saccadic fixator is an instrument that is typically used for training eye-hand coordination. There are several different procedures that can be used and a built-in timing system is effective for objectively tracking a subject's visual performance over time. The instrument is comprised of 33 illuminated switches arranged in a 28 inch diameter circle. The switches are illuminated in a random order and the subject is to push each button as soon as it lights up. Each time a switch is correctly pressed, another one lights up. The score was set to be how many buttons are correctly pushed in one minute, higher values indicate better performance. While there are no performance standards for this activity, a change in eye-hand reaction time within a subject while wearing different correction modalities would indicate impaired visual performance.

This kind of visual spatial coordination is exactly the kind of task a pilot is required to do in the cockpit of commercial aircraft. Commercial aircraft are equipped with many instrument panels that contain warning lights. These panels are located in various peripheral locations throughout the cockpit. When a

warning light illuminates, the pilot must press the illuminated switch, thus acknowledging that there is a warning.

The test was performed in a sitting position, arms length from the unit, in normal room illumination. Each subject was allowed to perform the test twice with each mode of correction. The results of the two administrations for each modality were averaged and then the averaged scores were compared for potential differences due to correction modality.

Results

The results of each test were measured and are recorded in the following tables for each of the four tests. Statistical analysis was performed using the statistics program Medcalc. A paired t-test was used in order to determine whether the visual performance of the PAL modality differed from the MCL modality in a significant way. Included in the t-test analysis are mean difference, standard deviation, P-values and confidence intervals.

The definition of mean difference is self-explanatory, while the standard deviation measures the degree of dispersion of the data from the mean value. The larger the standard deviation, the farther away they are from the mean value. A P-value is the probability that a given result could happen by chance. The P-value for this study was set at 0.05, which is standard in research. A P-value smaller than this 0.05 level was determined to be significant (the null hypothesis was rejected),

while those with a higher value were not significant. Finally, the confidence interval gives a range of values which is likely to include the mean difference between the two conditions, in this case log MAR acuity, number of switches activated, or milliseconds. A larger range indicates the test did not have adequate precision to detect a statistical difference for this population.

Distance Visual Acuity

The raw data collected is shown below in table 1. The performance of each modality can be compared directly for each subject. Intuitively, one would think that the PAL modality would provide better acuity, this was shown to be incorrect.

Table 1 Distance Visual Acuity raw data

		PAL's (log Mar)	Contacts (log Mar)
Subject #1	OD	-0.16	-0.18
	OS	-0.16	X
	OU	-0.18	-0.26
Subject #2	OD	0.08	-0.25
	OS	0	X
	OU	0.06	-0.29
Subject #3	OD	-0.02	X
	OS	0.08	0.08
	OU	0.02	0.08
Subject #4	OD	-0.14	-0.08
	OS	-0.14	X
	OU	-0.15	-0.16
Subject #5	OD	0.02	-0.02
	OS	0.08	X
	OU	0	-0.08

The results of the paired t-test are shown in table 2. Although the values for MCL modality are better with both eyes in all but one subject, a p-value of .256 illustrates that this difference did not reach statistical significance.

Table 2 Distance acuity analysis

	Mean Difference	STD	P-Value	95% Confidence Interval
PAL-CL	-0.092	0.156	0.256	-.285 to .101

Near Visual Acuity

Table 3 contains the raw data obtained for the near visual acuity, and table 4 shows the results of the paired t-test. The data shows that the acuity with MCL is better than the PAL modality. However, this difference was not shown to be statistically significant as the p-value was greater than 0.05. These findings are consistent with previous studies.

Table 3 Near visual acuity raw data

		PAL's (log Mar)	Contacts (log Mar)
Subject #1	OD	-0.1	X
	OS	-0.06	-0.1
	OU	-0.06	-0.1
Subject #2	OD	0	X
	OS	0	-0.08
	OU	-0.1	-0.06
Subject #3	OD	0.02	-0.08
	OS	0.26	X
	OU	0.02	-0.04
Subject #4	OD	0.1	X
	OS	0	0.08
	OU	0	-0.18
Subject #5	OD	0.16	X
	OS	0.16	0.06
	OU	0	0.06

Table 4 Near acuity analysis

	Mean Difference	STD	P-Value	95% Confidence Interval
PAL-CL	-0.036	0.095	0.446	-.154 to .082

Wayne Saccadic Fixator (WSF)

Each subject was given the opportunity to practice on the Wayne saccadic fixator prior to the actual testing. This was done in hopes of lowering, if not eliminating, the learning curve. However, it is still evident that each of the subjects' second trial is better in performance than the first. This illustrates that there may be some persistent learning effect. The PAL modality proved superior, in performance, during the Wayne saccadic fixator phase of the test. This difference, however, was not statistically significant. The raw scores are listed below in table 5.

Table 5 WSF raw scores

		PAL's (seconds)	Contacts (seconds)
Subject #1	Trial 1	43	44
	Trial 2	47	47
Subject #2	Trial 1	41	40
	Trial 2	45	45
Subject #3	Trial 1	38	35
	Trial 2	38	40
Subject #4	Trial 1	42	33
	Trial 2	47	42
Subject #5	Trial 1	35	37
	Trial 2	37	41

The paired t-test results in table 6 are taken from the averages of the two trials for each subject. This was done in order to reduce the learning effect as well.

Table 6 WSF analysis of averages

	Mean Difference	STD	P-Value	95% Confidence Interval
PAL-CL	-0.9	3.698	0.615	-5.492 to 3.692

UFOV

There are three parts to the UFOV and the results to each are recorded in table 7.

The lower the raw score in any given part, the lower the calculated risk. There was no statistical analysis reported on part 1 because all subjects attained the best possible score for each modality, creating a ceiling effect. Part 2 and Part 3 were analyzed, however, and the results are displayed in table 8, 9 and 10.

Table 7 UFOV raw data and risk category

		PAL's (milliseconds)	Contacts (milliseconds)
Subject #1	Part 1	16	16
	Part 2	16	16
	Part 3	53	83
Subject #2	Part 1	16	16
	Part 2	70	16
	Part 3	193	253
Subject #3	Part 1	16	16
	Part 2	26	190
	Part 3	170	150
Subject #4	Part 1	16	16
	Part 2	16	16
	Part 3	76	86
Subject #5	Part 1	16	16
	Part 2	180	23
	Part 3	143	150

There were two subjects that did the same with both modalities. Two subjects did better with the MCL correction, while only one did better with PAL correction.

The analysis of part 2 below, however, shows that the difference between the two modalities is not significant.

Table 8 UFOV Part 2

	Mean Difference	STD	P-Value	95% Confidence Interval
PAL-CL	-9.4	116.21	0.865	-153.694 to 134.894

Correction with PALs seemed to out-perform the MCLs in part 3 of the UFOV. Only one subject did better with the MCL mode. Even though this seems like a significant difference between the two, table 9 shows otherwise.

Table 9 UFOV Part 3

	Mean Difference	STD	P-Value	95% Confidence Interval
PAL-CL	17.4	29.723	0.261	-19.513 to 54.313

When looking at the raw data in table 7, it is evident that there is one subject that did not perform very well in part 2, and another that did not perform well in part 3. Analysis of the combined scores of part 2 and 3 also showed a statistically insignificant difference between the two modes of correction. This analysis is displayed below in table 10.

Table 10 UFOV Average of Part 2 & 3

	Mean Difference	STD	P-Value	95% Confidence Interval
PAL-CL	4	52.412	0.873	-61.078 to 69.078

Discussion

Due to time and budget constraints of the study only five subjects were evaluated, although more would have been ideal. Even though the study used an intra-subject comparison there was no statistical difference between the two modes of correction for any of the variables studied. However, the fact that there is no empirical evidence or trend in the data indicating MCL correction has poorer performance than PAL is still important, especially considering the study design imposed a greater challenge to the MCL modality. Within the limited subject population, only two had worn contacts before and four of the subjects were

established PAL spectacle wearers. Since visual performance testing was conducted only a few minutes after initial fitting of MCLs one would expect visual performance to suffer, because of the lack of time to adapt to the correction modality. Furthermore, subjects were fitted with a high quality PAL design with anti-reflection coating, creating a high standard for the MCL modality to compare to.

It was anticipated that the PAL modality would provide better performance on the visual acuity tests and that MCL modality would offer better visual performance for the visual field and near vision in different positions of gaze requirements of the UFOV and Wayne Saccadic Fixator. In addition to having more subjects in the study, refinements in the study design such as increased time for adaptation to the different modes and an eye-hand task with a greater peripheral field demands may produce a better statistical outcome. Another possible component of the inconclusive results is the possibility of a persistent learning effect. In future studies a baseline for each person needs to be established before conducting the experiment.

In addition to the quantifiable visual performance aspects of this survey the subjects were asked two questions regarding the two modes of correction. The first was which modality did they like the best? Three of the subjects preferred the progressive add lenses, whereas two preferred the monovision contact lens correction. Of the four original progressive wearers, one experimented with

monovision through the course of the study. The second question was: did you find one test particularly harder with one or the other modality? The majority of the subjects found that the UFOV was more difficult with monovision contact lenses than with progressive add lenses, which was surprising because statistically there was no difference. Perhaps the decrease in stereo acuity was what they noticed.

Despite the FAA's concern that the use of monovision contact lenses by pilots is unsafe, we have empirically shown that the visual performance of monovision lenses is equal to that of progressive add lenses. So why does the FAA prohibit the use of contact lenses for the correction of presbyopia? The only thing that has been proven to be deficient with the use of monovision is stereo acuity.

It appears that the reduction in stereo acuity is considered too significant and is therefore a safety hazard. In fact, the National Transportation Safety Board (NTSB) has listed MCL correction as one factor contributing to at least one major aircraft crash.⁵ That being said, the FAA does not require a minimum level of stereo acuity for an airman medical certificate. The closest requirement is for the 1st class pilot license, which is the license an airline pilot is required to have. That requirement is that the pilots have sufficient fusion to maintain binocularity.¹ Markovits found PAL's to be superior to flat top bifocals in a pilots' ability to quickly identify and locate an object on the instrument panel.⁶ Another study found that single vision spectacle lenses were superior for doing peripheral tasks

compared to PAL's.⁷ In light of these studies, shouldn't the FAA ban the use of flat top bifocals?

Other questions that this study raises include: What is the minimum level of stereo acuity required to safely operate an aircraft or a motor vehicle? Why doesn't the FAA have a minimum stereopsis requirement? Are there other measures of visual performance that are more valid in predicting medical fitness than physical abilities such as visual acuity?

In conclusion, this study was merely a stepping stone to further investigation of the visual performance of monovision contact lenses. The results of this study demonstrate a potential mechanism for future studies to refine and expand upon. It is hoped that future investigations will produce evidence of differences in visual performance or put to rest the assumption that MCL correction poses a safety risk for pilots and that the FAA will be able to confidently allow the option of this correction modality for its pilots.

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