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An evaluation of the contrast sensitivity function with the Corning CPF-511 lens

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An evaluation of the contrast sensitivity function with the Corning CPF-511 lens

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AN EVALUATION OF
THE CONTRAST SENSITIVITY FUNCTION
WITH THE CORNING CPF-511 LENS

BY
TIMOTHY ORTIZ
JEFFERY SAYLER
TRAJAN SOARES
JON WILLEMS

A thesis submitted to the faculty of the
College of Optometry
Pacific University
Forest Grove, Oregon
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May, 1990

Advisors:
SCOTT OVERTON, O.D.
ALEXANDER PEPE, O.D.
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The Corning CPF-511 lens' influence on the contrast sensitivity functions of 34 low vision and 80 normal patients was evaluated using the Vistech 8000 near contrast sensitivity tester. Contrast sensitivity functions were measured with and without peripheral glare under three conditions: through the patient's habitual corrective lens, through a plano lens placed over the habitual correction, and through a Corning CPF-511 lens placed over the habitual correction. The lens induced statistically significant decreased contrast sensitivity at middle and high spatial frequencies in the normal population. Low vision patients demonstrated increased contrast sensitivity at lower spatial frequencies and decreased sensitivity at higher frequencies, however the majority of these trends were statistically insignificant. This study gives insight as to why CPF lenses increase subjective performance in low vision patients. Key Words: contrast sensitivity, low vision, Corning CPF lenses, Vistech contrast sensitivity testing, glare sensitivity.

INTRODUCTION

In 1982, the Corning Medical Optics Department began marketing a series of selective absorption photochromatic lenses known as Corning Photochromatic Filter (CPF) lenses. These lenses absorb ultraviolet light and the blue end of the visible spectrum. There are five lenses in the series; the CPF-511™, CPF-527™, CPF-450™, CPF-550™, and CPF-550XD™. The model number refers to the wavelength in nanometers to which the lenses attenuate. When in their darkened state, the lenses absorb 99 percent of the visible and ultraviolet light below the respective attenuation wavelength. (See Figure 1).

FIGURE 1: CPF-511 & GREY-COATED CPF-511 TRANSMISSION CURVES
Corning has proposed that CPF lenses may provide visual enhancement for patients with a variety of disorders such as cataracts, age-related macular degeneration, retinitis pigmentosa, glaucoma, diabetic retinopathy, optic atrophy, albinism, aphakia, and corneal dystrophies. Recently, two studies evaluated the CPF lens' effect on visual acuity in low vision patients. Neither study was able to demonstrate significantly increased visual acuity in low vision patients using CPF lenses. However, both studies reported enhanced subjective vision (reduced light-dark adaptation time, and improved visual acuity, contrast, & eye comfort) with the use of CPF lenses.

Unlike visual acuity, which measures spatial resolution of very fine targets with 100 percent contrast, the contrast sensitivity function (CSF) provides information about a patient's vision across a spectrum of spatial frequencies. Moreover, standard Snellen visual acuity testing corresponds only to higher spatial frequencies and does not relate to the patient's need to resolve a wide variety of spatial frequencies as they do in the real world. The CSF consists of contrast thresholds for sinusoidal grating targets of differing spatial frequencies and can be a valuable diagnostic tool for the clinician, as pathological and refractive states can lead to specific patterns of contrast sensitivity loss. Selective losses at the low or midrange spatial frequencies, or both, can be overlooked by Snellen acuity testing, lending to the importance of using contrast sensitivity testing for diagnostic purposes.

The purpose of this study is to see if increased contrast sensitivity at low to medium spatial frequencies is responsible for enhancing subjective vision in low vision patients using the CPF-511 lens. If in fact the CPF-511 lens does improve the human contrast sensitivity function, this study will justify the optometric prescription and the added patient expense of CPF lenses for low vision patients.

METHODS

Thirty-four low vision patients were selected from the Pacific University College of Optometry Low Vision Clinic to participate in this study. The patients ranged in age from 19 to 88 years, of whom 13 were females and 21 males. The criterion for a low vision patient in this study was a best corrected, monocular, distance Snellen visual acuity between 20/30 and 20/200. If both of a patient's eyes met this criterion, then both eyes were utilized in this study. If only one of the patient's eyes met the criterion, then only one eye was used in the low vision population study and the other eye was either (1) included in the normal population study if its acuity was better than 20/30; or (2) omitted from the study if its acuity was poorer than 20/200. Acuities were determined with a projected Snellen acuity chart at 20 feet. The low vision subjects' eyes had a variety of ocular disorders including: cataract (n=15), age-related macular degeneration (n=4), ocular albinism (n=2), optic atrophy (n=5), advanced glaucoma (n=3), aphakia secondary to congenital rubella (n=2), subluxated lens (n=1), and diabetic retinopathy (n=2).
The control group consisted of 80 normal subjects from the Pacific University College of Optometry Vision Clinic. The group ranged from 21-37 years, containing 35 females and 45 males. All had best corrected visual acuities of 20/25 or better, with no evidence of ocular pathology other than trace crystalline lens changes.

Both groups were given a vision screening to determine refractive status and an ocular health check to categorize the cause of low vision. Their habitual, distance acuity lens (if any) was worn throughout the test.

Contrast Sensitivity Functions were measured using the Vistech 8000 Contrast Sensitivity Tester®, a newer, in-instrument version of the Vistech Chart System. Contrast sensitivity previously measured with the new Vistech contrast testing system in persons aged 4-87 years, compared well with those previously reported for the Vistech contrast sensitivity wall charts. The instrument utilizes Arden plates containing sinusoidal wave patterns with spatial frequencies of 1.5, 3, 6, 12, and 18 cycles per degree which were tested in a random order. Within each spatial frequency, patients identified the orientation of the lines (up, left, or right) in a series of 7 plates containing successively decreasing levels of contrast. All subjects received the same instructional set. They were told that their ability to detect contrast was going to be tested under three different lens conditions and that they should try to determine the orientation of as many lines as possible within each frequency, even if it meant guessing. Care was taken to prevent subjects from knowing which lens should help or hinder their performance. Subject responses were recorded then plotted on the standardized Vistech CSF recording form (See Figure 2) according to the last correct response within each spatial frequency.

A contrast sensitivity function was constructed under three different lens conditions. Each lens was tested in a random order for each eye tested. The three lens conditions tested were: (1) their best corrected, distance acuity lens alone; (2) their best correction in combination with a plano (placebo) lens; (3) their best correction in combination with the CPF-511 lens. Both the plano and CPF-511 lens were placed in the Vistech 8000 lens holder while the patient's correction was worn in its habitual form (spectacles or contact lenses). The Vistech 8000 is a near-viewing instrument but was always tested in the infinity (distance) mode using of a pair of +4.00 diopter lenses in the viewer to eliminate the need to incorporate different near add powers due to varying accommodative abilities between patients. All patients were asked to report any noticeable changes in subjective vision between the three lenses while looking in the viewer and looking around the testing room.

It should be noted that we did not use the CPF-511 lens that is standardly prescribed. Because the CPF lens is a photochromatic lens, it is important to test its effects in its darkened state. The lens requires a peak wavelength of 320 nanometers (UVA) for dissociation of silver halide crystals within the lens matrix. Using a J-A Photomultiplier (model R213) calibrated against a Molecron PR200 Pyroelectric Radiometer to measure relative spectral output of the Vistech 8000 Contrast Sensitivity Tester, we found the instrument emits radiant power of about 450 to 700 nanometers, peaking at 580 nm (See Figure 3). Minute amounts emitted below 450 nm were recorded directly from the Vistech lamps, however these were lost on their way to the Vistech's apertures. Therefore we were forced to use a #3 grey-coated version of the CPF-511 lens that has a spectral transmission curve closely resembling that of a standard darkened CPF-511 lens (See Figure 1).

The Vistech 8000 also allows one to measure contrast sensitivity functions under non-glare, central glare, and peripheral glare conditions using a set of bright lights near the center or in the periphery of the visual field respectively. CSFs in this investigation were tested under non-glare and peripheral glare conditions. Peripheral glare CSFs were always tested after non-glare CSF were tested in order to minimize the effects of different rates of light-dark adaptation time between patients, although the lenses and spatial frequencies were still tested in a random order.
FIGURE 2: THE VISTECH CSF RECORDING FORM

VISTECH CONSULTANTS, INC.
Multivision Contrast Tester
MCT 8000 EVALUATION FORM

DAYTIME TESTING

DAY VISION

DAY VISION WITH PERIPHERAL GLARE

PHOTO STRESS RECOVERY TIME
___ seconds

RADIAL GLARE

Position One

Position Two

Letter Acuity
Near: Left ___ Right ___
Distance: Left ___ Right ___

Contrast Sensitivity Equivalent Acuity
Near: Left ___ Right ___
Distance: Left ___ Right ___

% Contrast Sensitivity Loss

CATARACT FUNCTIONAL DISABILITY TEST


Cataract Functional Disability Test

OBSERVER NAME ____________________________ DATE __________

COMMENTS ____________________________________________________________________________

Tested by: _____________________________________________

The normal range of contrast sensitivity is shown in the shaded region for each glaucoma group. The normal range is only measured if the MCT is properly calibrated as described in the instruction manual. It is provided as a test for the diagnosis of bilateral, monocular, or unilateral vision loss and should not be considered a control tool for the normal range. If the patient’s contrast sensitivity is outside the normal range, it may be due to a boarder neuropathological condition. The patient’s condition should be tested in conjunction with other diagnostic techniques.

FIGURE 3: RELATIVE SPECTRAL OUTPUT OF THE VISTECH LAMP

RELATIVE OUTPUT (Percent)

WAVELENGTH (nm)
RESULTS

The effects of the 3 lenses were compared using unpaired 2-tailed t-tests. (See Table 1 for mean scores, standard deviations, and probability values). (See Figures 4 & 5 for CSFs). The data had a reliability factor of 93 percent according to the t-test.

### TABLE 1: MEAN SCORES, STANDARD DEVIATIONS & PROABILITY VALUES IN CONTRAST SENSITIVITY UNITS

<table>
<thead>
<tr>
<th>POPULATION</th>
<th>SPATIAL FREQUENCY (CPD)</th>
<th>1.5</th>
<th>3</th>
<th>6</th>
<th>12</th>
<th>18</th>
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<td></td>
<td>P Value</td>
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<td>0.0001</td>
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<td>34.1±14.0</td>
<td>51.0±19.5</td>
<td>65.1±30.0</td>
<td>64.9±29.0</td>
<td>23.5±12.3</td>
</tr>
<tr>
<td>(no glare)</td>
<td>PL score</td>
<td>35.2±17.4</td>
<td>49.4±20.9</td>
<td>66.5±31.4</td>
<td>61.9±29.9</td>
<td>22.9±10.4</td>
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<tr>
<td></td>
<td>CPF score</td>
<td>36.0±18.8</td>
<td>51.4±24.0</td>
<td>57.7±25.3</td>
<td>44.5±30.4</td>
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<td>P Value</td>
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<td>0.7867</td>
<td>0.0005</td>
<td>0.0001</td>
<td>0.0001</td>
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<tr>
<td>(glare)</td>
<td>HAB score</td>
<td>38.7±15.4</td>
<td>61.7±34.5</td>
<td>72.4±31.9</td>
<td>66.2±31.8</td>
<td>25.0±10.7</td>
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<tr>
<td></td>
<td>PL score</td>
<td>38.5±15.5</td>
<td>60.4±30.3</td>
<td>74.6±35.3</td>
<td>62.6±31.9</td>
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<td></td>
<td>CPF score</td>
<td>36.9±16.2</td>
<td>59.2±27.3</td>
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<td>35.4±24.5</td>
<td>16.1±11.0</td>
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<td>0.5026</td>
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<tr>
<td>(no glare)</td>
<td>HAB score</td>
<td>23.3±12.2</td>
<td>33.3±22.1</td>
<td>23.4±19.3</td>
<td>8.6±10.2</td>
<td>3.4±3.4</td>
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<td></td>
<td>PL score</td>
<td>24.9±19.9</td>
<td>30.6±19.8</td>
<td>22.0±15.3</td>
<td>8.4±7.6</td>
<td>3.4±3.6</td>
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<td></td>
<td>CPF score</td>
<td>28.0±15.5</td>
<td>36.6±29.7</td>
<td>20.4±16.4</td>
<td>7.4±6.4</td>
<td>2.5±2.6</td>
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<tr>
<td>LOW VISION</td>
<td>P Value</td>
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<td>0.3548</td>
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<td>0.5652</td>
<td>0.4295</td>
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<td>(glare)</td>
<td>HAB score</td>
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<td>6.9±7.6</td>
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<td>PL score</td>
<td>19.8±18.3</td>
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<td>2.4±3.0</td>
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<td>CPF score</td>
<td>26.2±20.8</td>
<td>29.6±21.0</td>
<td>15.9±14.2</td>
<td>5.9±4.7</td>
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</table>

In the low vision population without glare, the CPF-511 lens demonstrated statistically insignificant increased contrast sensitivity at spatial frequencies of 1.5 and 3 cycles per degree (cpd), increasing mean contrast sensitivity scores from 23.3 to 28.0 (p=0.38) and 33.3 to 36.6 (p=0.17) respectively. Contrast spatial frequencies of 6, 12, and 18 cpd produced decreased sensitivity from 23.4 to 20.4, 8.6 to 7.4, and 3.4 to 2.5 with only the highest frequency's reduction of contrast sensitivity being significant (p=0.48, 0.50, and 0.04 respectively).

In the normal population, a slight increase in contrast at the lowest frequency (1.5 cpd) was shown with the CPF lens, increasing values from 34.1 to 38.0 (p=0.25). No change was seen at 3 cpd (51.0 without the lens: 51.4 with the lens; p=0.35). Statistically significant decreased contrast sensitivity was demonstrated at the three middle to high spatial frequencies: 65.1 to 30.0 (p=0.03) at 6 cpd, 64.9 to 44.5 (p=0.0001) at 12 cpd, and 23.5 to 15.6 (p=0.0001) at 11 cpd.
When peripheral glare was added to the testing conditions for the low vision patients, only the lowest frequency showed increased sensitivity (21.4 to 26.2, p=0.07). All other frequencies gave decreased sensitivity with the middle (6 cpd) being significant (at 3 cpd mean values decreased from 35.0 to 29.6, p=0.36; at 6 cpd from 19.6 to 15.9, p=0.02; at 12 cpd from 6.9 to 5.9, p=0.57; and at 18 cpd from 2.7 to 2.3, p=0.43).
In the normal population with peripheral glare, the CPF-511 lens demonstrated decreased contrast sensitivity at all spatial frequencies with the middle, mid-high, and highest frequency responses being significant. (38.7 to 36.4, \( p=0.44 \) at 1.5 cpd; 61.7 to 59.2, \( p=0.35 \) at 3 cpd; 72.4 to 60.3, \( p=0.0005 \) at 6 cpd; 66.2 to 35.4, \( p=0.0001 \) at 12 cpd; and 25.0 to 16.1, \( p=0.0001 \) at 18 cpd).

When the plano lens was added to the habitual correction, means scores changed from +1.4 to -3.0 (\( x=-0.54 \)) without glare and +2.2 to -3.6 (\( x=-0.62 \)) with peripheral glare. Low vision patients viewing through the plano lens showed changes from +1.6 to -2.7 (\( x=-0.67 \)) without glare and -0.2 to -7.7 (\( x=-2.04 \)) with glare. However, none of these values were significant.

No significant difference in performance was demonstrated when the low vision population was analyzed as retinal pathology (n=16) or media opacity/pathology (n=18) (See Table 2 and Figures 6 & 7).

<table>
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<tr>
<th>LOCATION OF PATHOLOGY</th>
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<th>6</th>
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<td>MEDIA (no glare)</td>
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<td>HAB score:</td>
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<td>11.7±12.6</td>
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<td>MEDIA (glare)</td>
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<td>PL score:</td>
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<td>RETINA (no glare)</td>
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<td></td>
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<td>0.274</td>
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FIGURE 6: CSF OF MEDIA VS. RETINAL PATHOLOGY (WITHOUT GLARE)

FIGURE 7: CSF OF MEDIA VS. RETINAL PATHOLOGY WITH GLARE
DISCUSSION

Early studies investigating the CPF lens' effect on visual acuity showed significant improvements. Lynch and Brilliant tested 16 retinitis pigmentosa patients and found a 3/4 of a line increase in Snellen visual acuity with the CPF 550 lens when compared to an equivalent neutral density filter. Tupper et al. reported a 40 percent improvement in visual acuity for cataract patients under non-glare conditions and a 70 percent increase under glare conditions. More recently, Barron and Weiss showed no increase in visual acuity in a population of low vision patients using the CPF-527 lenses. They attributed their results to the fact that, unlike previous studies, they used randomized versions of acuity charts to prevent any learning occurring from multiple presentations of the same acuity chart. Furthermore, they noted that the previous studies did not randomize the order of lens presentation.

Our results demonstrated no statistically significant increase in the objective measurement of contrast sensitivity when comparing the CPF-511 lens to a clear (plano) lens or without any other lens besides the best distance correction. However, as similar studies on the CPF lens' effect on visual acuity have previously reported, many of our low vision patients' subjective responses indicate an improvement in contrast sensitivity with the CPF-511 lens. Our patients reported subjective increases in contrast and comfort which could be due to a placebo effect of a lens placed before an eye. This is unlikely though, because of the minor differences seen when comparing the effects of the habitual correction with that of the correction and a plano lens; average Arden grating score changes with the plano lens were -0.9 for normals and -0.6 for low vision patients without glare and -0.5 and -2.3 with glare. This suggests that the recognizable improvement in contrast sensitivity is very subtle and, thus, the human contrast sensitivity is too sensitive for our present CSF testing techniques. The low spatial frequency improvement in low vision patients, although statistically insignificant, may offer some insight into the subjective improvement of contrast in these patients. Further investigation into the CPF lens's effect on retinal illuminance would benefit by comparing the CPF lens in its lightened state and comparing the lens against a neutral density filter transmitting the same amount of light as the CPF lens.

The findings of this investigation show that the Corning CPF-511 lens decreases contrast sensitivity to spatial frequencies of 6 to 18 cpd in normal and low vision patients which carries significant implications for the prescribing clinician. These trends only reached significance at spatial frequencies of 6, 12, and 18 cpd in normal patients, and 18 cpd in low vision patients. This decrease in contrast sensitivity is most likely a result of the CPF-511 lens' reduction of overall retinal illuminance. Because the darkened CPF-511 lens as tested reduces overall retinal illuminance to 12 percent (47 percent in its lightened state), important luminant information about detail (high spatial frequency contrast) must be absorbed by the lens. This particularly important since we tested the lens under normal room illumination (7 foot-candles) while the lens was designed for use in bright environments. This emphasizes the fact that CPF lenses must be used with good illumination. Therefore, the clinician must determine if the low vision patient has the potential to see high spatial frequency contrast. If so, it may be more beneficial to consider alternative means of low vision aids for that patient.
Age differences between our normal and low vision subjects must be taken into consideration. Studies have shown age-related loss in sensitivity to intermediate (5.0 and 9.8 cpd) and high (16.5 cpd) spatial frequencies. This is due to a number of factors including crystalline lens changes, pupillary miosis, and age-related degenerations, all of which ultimately reduce retinal illuminance. Therefore one would expect some decrease in contrast sensitivity between our normal and low vision subjects (regardless of the presence of pathology) since the low vision population had a mean age of 60.1 years while the normal population averaged 26.7 years. However we did not compare differences between groups; just within each group.

Because our results failed to demonstrate any significant increase in contrast sensitivity when the CPF-511 was used in peripheral glare conditions, our study does not support the theory that CPF lenses increase subjective vision by reducing the patient's glare sensitivity as previously hypothesized by Barrou and Waiss. The trends of decreased contrast sensitivity with glare may have been expected as 50 percent of the low vision population was diagnosed with either nuclear sclerosis or cortical cataracts; conditions highly susceptible to disability glare. However, the data shows no significant difference between groups when the low vision population's performance with the CPF-511 lens was analyzed as either retinal pathology or media opacity. However, trends revealed the CPF lens improve performance in patients with media opacities more than patients with retinal pathologies, especially at lower spatial frequencies in glare. This suggests CPF lenses may be better suited for certain low vision patients with specific types of pathology.

CONCLUSION

This study may have important implications for the efficacy of prescribing CPF lenses to low vision patients. The CPF-511 lens tends to increase contrast sensitivity at low spatial frequencies and decrease sensitivity at higher frequencies. Patients with very poor visual acuities may profit from the use of CPF lenses since the benefits of increased contrast sensitivity to low spatial frequencies may outweigh the lens' adverse effects on high spatial frequencies which are already diminished to some extent in low vision patients. The lenses are not suited for patients with normal or marginally reduced visual acuities since they reduce overall retinal illumination and absorb useful luminant information about high spatial frequency contrast. However, no conclusion about the effects of the lens can be made about the general low vision population; each individual patient must be analyzed separately to determine if the lens' benefits are enough to warrant their prescription. There is no conclusive evidence that the CPF-511 lens improves subjective vision by increasing contrast sensitivity. The biomechanics of increased subjective vision with CPF lenses remains to be seen as more sensitive measures of CSFs continue to develop and other modes of action investigated.
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REFERENCES

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