



REPORT

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Comparative quality evaluation of spectacles (10 appendices)

SP Technical Research Institute of Sweden has performed comparative quality testing of ten pairs of spectacles obtained from five optician chains in Denmark: Nyt Syn, Louis Nielsen, Thiele, Synoptik and Profil Optik.

Scope and summary

The tested spectacles were purchased by two Danish individuals who were engaged by Shoptimizer AS, a company specialized in so called mystery shopping. Each shopper purchased five pairs of spectacles at different optician chains according to instructions provided by SP. The main goal was that they each should buy as similar spectacles as possible at the different opticians, both regarding frames and lenses, in order to get as comparable products as possible. One shopper should purchase spectacles with scratch-resistant and anti-reflective coatings (group 1), and the other should buy as inexpensive standard lenses as possible without any coating (group 2). Overall the final purchases were in quite good agreement with the original intent, although in group 2 the first spectacles from Profil Optik came with a AR-coating. The reason for this is unknown but prior to any testing a new pair of spectacles were purchased, this time without coating.

The main optical testing included lens power (sphere, cylinder, axis, evenness) and centre distances and positions, as this should be of most importance for most spectacle wearers. No significant deviations were noted for any of the spectacles and they can therefore be considered equivalent in that respect. Also some basic mechanical testing was carried out in order to ensure sufficient quality of the lens mountings and frames. No quality deviations in that respect were noted.

Other testing included evaluations of properties related to lens coatings, including scratch/wear-resistance, reflectance and cleanability. All spectacles supposed to have AR-coatings had adequate ones, with improved performances in the mentioned test compared to uncoated lenses. Within group 1 generally only small differences could be noted in the tests, but with the spectacles from Nyt Syn performing slightly better than the others in two of the three most decisive tests. Apart from that, the measured differences were very small and in most cases negligible. In group 2 the only significant difference was noted in the scratch/wear-resistance test, where the spectacles from Specsavers performed clearly the best, indicating a hard-coating.

In conclusion, all spectacles can be regarded as comparable from a consumer's viewpoint. Some small differences between the lens coatings were detected but these will generally have a very limited impact for the spectacle wearer. Clearly more significant are the differences between coated and uncoated spectacles.

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1. Client

Louis Nielsen A/S, Denmark

2. Spectacle purchase

The mystery shoppers carrying out the purchases were provided by the company Shoptimizer AS according to specifications given by SP. The observers, two Danish females, 20-35 years old, purchased spectacles from the following optician chains Denmark: Nyt Syn, Louis Nielsen, Thiele, Synoptik and Profil Optik. The purchases were carried out in March-April 2011. Each shopper took one vision test at the first store they visited, and were then instructed to use that prescription for the following purchases. With one exception this procedure was followed. At one store (Synoptik) shopper 2 had to take a new vision test as this was demanded by the optician and also free of charge.

The shoppers were given instructions about the type of lenses and frames they should strive to attain and they were also asked to fill in a short questionnaire regarding the purchase process. Note that all direct communications with the mystery shoppers went through Shoptimizer AS. Also, neither Shoptimizer AS nor the mystery shoppers were informed about the actual commissioner (Louis Nielsen). To SP's knowledge, none of the mystery shoppers had any prior expertise in spectacles but was in short given the following instructions prior to their shopping (see appendix 1 for a summary of the instructions). The specifications for the shoppers vision errors and type of lens and frame were chosen by Louis Nielsen.

Shopper 1 (near-sighted, sphere -2,00 D to -4,00 D, max cylinder -1,00 D):

Branded plastic frames.

Single vision plastic lenses, refractive index 1,6 (thinner), antireflective coating (AR-coating) including scratch resistant coating (hard coating).

Shopper 2 (sphere -2,00 D to +1,00 D, max cylinder -1,00 D):

Simple metal frame in the lowest price segment

Cheapest single vision plastic lens, refractive index 1,5, no AR-coating

In this report the tested spectacles are identified with 1 or 2 for the mystery shopper and A, B, C, D and E for the optician chain used for purchase (A = Nyt Syn, B = Louis Nielsen, C = Thiele, D = Synoptik and E = Profil Optik)

For unknown reasons the first spectacles purchased at Profil Optik by shopper 2 came with a AR-coating. This was not mentioned or indicated in any documentation but a decision was taken to purchase a new pair prior to any testing. After that all spectacles seemed to agree quite well with the specifications, and could be regarded as comparable within each group. However, measurements are indicating that spectacles 2B (Louis Nielsen) has a hard coating, which was not specifically order by the shopper or something that she was informed of. See appendix 2 for pictures and more information about the spectacles.

2.1 Prescriptions

The following prescriptions were used when purchasing the tested spectacles:

Shopper/eye	Sphere (D)	Cylinder (D)	Axis (°)	PD (mm)
1 / Right	-3,00			68
1 / Left	-3,25	-0,25	150	
2 / Right	-0,50			62
2 / Left	-1,00			
2D / Right	-0,75	-0,50	20	61
2D / Left	-1,00	-0,25	180	



2.2 Spectacle prices

In the table below the price for each tested pair of spectacles is presented, together with how the price is distributed among the ingoing costs, if specified.

Spectacles	Optician chain	Frame brand	Price (DKK)		
			Total	Frame	Lenses ¹
1A	Nyt Syn	Tom Ford	5295	2395	2900
1B	Louis Nielsen	Redgreen	2695	1695 ¹	1000
1C	Thiele	Burberry	4252 ²	1642	2610
1D	Synoptik	Prada	5090	2590	2500
1E	Profil Optik	MaxMara	3935	1895	2040
2A	Nyt Syn	People	1396	698	698
2B	Louis Nielsen	Specsavers	195		
2C	Thiele	Basic eye	355 ²		
2D	Synoptik		398	98	300
2E	Profil Optik	PER Nordlys	498		

¹ Price for frame with standard lenses

² Discount 10 %

2.3 Comparability between the purchased spectacles

Frames: The frames within both groups are somewhat different in terms of colour and size but are otherwise quite similar in function and material. For the basic mechanical tests performed on frame and glazing in this report, the differences should have no significant impact on the results.

Lenses: The lenses within each group are specified as having similar indexes (1,6 for group 1 and 1,5 for group 2) and should therefore be quite comparable within each group, although small differences in the lens materials may still exist. Also, even though the spectacles in group 2 was ordered without AR-coating, spectacles 2B most likely have a hard coating which obviously will influence the results in the scratch/wear-resistance test. In group 2 the spectacles from Synoptik was purchased with a slightly different (stronger) prescription but as the actual vision test is not included in this comparison this should not influence the outcome of the comparison in any significant way.

3. Date of test

April-May, 2011

4. Test methods

Tests have been performed in order to compare the quality of the purchased spectacles from a consumer's viewpoint. The emphasis has been on optical testing as these properties should be of most importance for most spectacle buyers, but also some basic mechanical tests have been performed in order to ensure that some minimum requirements are fulfilled with respect to strength and tenacity. Some of the measured and reported properties have been judged to be of mainly aesthetic or cosmetic nature, and have therefore not been included in the quality comparison. This includes weight, some dimensions and the colour of lens reflections.

Optical tests include spherical and cylinder power and axis, unevenness in power over the lens surface, transmittance, reflectance and the distance and position of optical centres (OC). Mechanical tests include glazing and bridge deformation, scratch/wear-resistance of lenses and a vibration test in order to detect loose or poorly mounted parts.

Other tests/measures include spectacle weight and some lens dimensions. Also, the hydrophobic and/or oleophobic properties (i.e. dirt rejecting properties and cleanability) that are often claimed for lens coatings have been checked using different methods.



The spectacles were carefully inspected at arrival at SP (prior to any testing).

Comment on standards: There are a large number of ISO- and ANSI-standards covering various aspects of consumer spectacles and suggesting test methods and tolerances for frame and lens properties. In this evaluation we have in most cases not directly related the results to any tolerances or specifications set by these standards, as this test mainly is performed in a comparative way. Relevant ISO-standards could be found on the website www.iso.ch under TC 172/SC 7 – “Ophthalmic optics and instruments”.

4.1 Weight and dimensions

Using a high resolution balance, each pair of spectacles was weighed. Lens dimensions and edge thickness were measured using a digital vernier calliper. The OC thickness was measured using a thickness gauge with spherical measuring tips.

4.2 Lens power and evenness, optical centres

The power (sphere and cylinder) was measured for all lenses using Rotlex FFV (Free Form Verifier), an instrument which utilizes wavefront analysis using Moiré Deflectometry. The results were verified with lensmeter TOPCON Model LM-3B.3BC, which was also used to determine the cylinder axes for the mounted spectacles lenses.

Using the Rotlex FFV, deviations in sphere and cylinder power were evaluated within a circle with radius 10 mm around the OC for each lens. As the optical path of the Rotlex FFV is slightly different compared to the human eye (when the spectacles are worn), these measurements do not fully evaluate unavoidable lens aberrations as discussed below but rather imperfections in the lens grinding and local deviations.

In order to accurately determine the distance between OC and their relative position in the frame, a laser beam was sent through the lenses and registered 1 m away on a fine graded paper. The spectacles were mounted horizontally on a graded slide and adjusted so that the deflection of the laser was zero.

Comment on aberrations: All corrective lenses exhibits different kind of errors (aberrations). The size of these errors depends mainly on the curvature, power and material of the lens. Also, these aberrations tend to increase near the lens edge. By varying lens parameters, aberrations can be minimized or kept at reasonably low levels. In this report no attempt have been made to measure or analyze these rather complex aberrations but it is assumed that the lens manufacturers have chosen proper front and back radii on the different lenses in order to keep these errors at reasonably low levels. Also, as most spectacle wearers tend to stay reasonably close to the OC with their eyes, for low power spectacles these aberrations are usually of little consequence to the wearer.

4.3 Transmittance

The spectral transmittance $\tau_F(\lambda)$ was measured in the range 350 nm to 780 nm in steps of 5 nm using a spectrophotometer Lambda 900 with a large integrating sphere for detection. Using the CIE spectral visibility function $V(\lambda)$ and appropriate standard illuminant the luminous transmittance τ_v was calculated as:

$$\tau_v = \frac{\int_{380nm}^{780nm} \tau_F(\lambda) \cdot V(\lambda) \cdot \Phi_X(\lambda) \cdot d\lambda}{\int_{380nm}^{780nm} V(\lambda) \cdot \Phi_X(\lambda) \cdot d\lambda},$$

where $\Phi_X(\lambda)$ is the spectral radiant flux of a CIE standard illuminant.

4.4 Reflectance

The total spectral reflectance $\rho_F(\lambda)$ was measured at an inclination angle of about 15° in the range 380 nm to 780 nm in steps of 10 nm using a monochromator Zeiss MM12. A large area silicon detector was used for detection. The luminous reflectance ρ_v was then calculated in a similar way as the luminous transmittance (4.3).

Pictures were taken of the reflections using a fluorescent tube as a light source. The spectacles were all placed the same way under the lamp and thereafter a digital camera, mounted on a stand with fixed aperture and shutter, were used for taking pictures.

4.5 Refractive index

In order to validate/check the ordered refractive lens indexes, the inner and outer radius at OC (along a possible cylinder axis) was measured with a lens clock. For strong aspheric lenses this method can give rather significant errors in the measured radii and in case of doubt an alternative method may need to be used. Calculating the lens power by use of the equation below, the refractive index was adjusted in order for the total lens power to match the measured one (according to 4.2). Note that the lens thickness has been neglected in the formula below, due to its very small influence.

$$P = (1-n)/r_i + (n-1)/r_o, \quad \text{where}$$

n = refractive index

r_i and r_o = inner and outer radius (m)

4.6 Scratch/wear-resistance

This test was based on paragraph 15 in EN 168 – “Personal eye protection – Non optical test methods”.

The lenses were demounted from the frames for all spectacles. Each lens was then placed on a disc rotating at approximately 80 rpm, at an angle of 45° . Then 800 ml of natural quartz sand with grain size 0,4/0,8 mm was poured through a long pipe, evenly distributing the sand over the lens surface.

Each lens was measured before and after this test using a haze-meter consisting of a light source and an integrating sphere which can be moved into two different positions. In position 1 the sphere measures the diffusely transmitted light (by use of a light trap) and in position 2 it measures the total transmitted light. By comparing the results before and after the falling sand test, the amount of diffusion (haze) caused by the sand could be calculated. In order to monitor the stability of the haze-meter a clean reference lens was always measured together with the tested lenses.

4.7 Glazing and bridge deformation

This test has been conducted according to paragraph 6.9 in EN 1836:2005 – “Personal eye protection – Sunglasses and sunglare filters for general use”. A similar test is described in ISO 12870:2004 – “Ophthalmic optics – Spectacle frames – Requirements and test methods”.

The spectacles were firmly clamped around the boxed centre on the left lens. Then a pressure peg (\varnothing 10 mm) was lowered on to the right lens' centre and further down until the pressure was 5 N, or the distance moved was 10 % of the distance between the boxed centres. This position was held for about 60 s before the pressure peg was lifted up. The distance travelled and the possible permanent distortion was recorded using a digital dial indicator. According to EN 1836:2005 this distortion should be less than ± 2 % of the distance between boxed centres in order for the results to be considered valid.



4.8 Vibration test

This test was based on paragraph 10.2 in BS 6102:Part 3:1986 – “Specification for photometric and physical requirements of lighting equipment” (British Standard).

The spectacles were placed and secured on a metal plate attached to an apparatus used for vibrating the plate against a steel block. Each pair of spectacles was vibrated for 10 minutes at 12 Hz. Afterwards the spectacles were inspected in order to detect any damage (loose screws, lenses etc.) that may have occurred.

4.9 Hydrophobic/oleophobic properties and cleanability

First the spectacles were thoroughly cleaned and rinsed under water, and the overall hydrophobic behaviour was visually judged. Also, one small water droplet (40 μ l) were put on each lens and the angle between the droplet and the lens were studied, as this angle is a general measure of how hydrophobic a surface is.

In order to quantify how hard greasy dirt sticks to the spectacles the following tests were performed:

First one lens on each spectacle was systematically covered with several fingerprints in a controlled way. After a certain time, a piece of tape was applied to the fingerprint covered lens surface. The tape was then smoothly removed by using a force gauge while the measured force was sampled. The removal of the tape (i.e. movement of force gauge) and the sampling was controlled via a computer. This procedure was repeated several times for both the left and right lenses, and for in- and outsides. Also, two different kinds of tape were used. The measured force has been shown to correlate well with both the hydrophobic property and with the overall cleanability of a lens.

4.10 Equipment list

Lensmeter TOPCON Model LM-3B
Rotlex FFV, s/n FFV5170
Spectrophotometer Lambda 900, SP inv.no. SP 503052
Monochromator Zeiss MM12, SP inv.no. 602754
Haze-meter UX10, SP inv.no. 502610
Force gauge SALTER, SP inv.no. 500560
Vernier calliper, SP inv.no. 501501
Lens clock Hilco, s/n 143414
Thickness gauge Mitutoyo, type 7313
Precision balance Mettler-Toledo, SP inv.no 602347
Dial indicator Kroeplin EM25, SP inv.no. 601219
Current amplifier Keithley 427, SP inv.no.500066
Multimeter Keithley, SP inv.no. 503458
Digital camera OLYMPUS C-5050, 5 Megapixel

5. Results

Upon arrival at SP all spectacles were in undamaged condition. No imperfections were found other than possibly the need for slight frame adjustments in some cases. Overall, no quality difference was found after a first visual inspection.

5.1 Weight and dimensions

In the table below some measures are summarized for information. For lens width and height, and for (lens) edge thickness the maximum values are reported. The lens thickness was measured at the optical centre, where all lenses have their minimum thickness. The reported effective (optical) lens areas are rough estimates for information purpose only. All units are in mm if not otherwise stated.



Measure	Spectacles no.				
	1A	1B	1C	1D	1E
Lens width	54,5	51,7	49,4	49,5	51,4
Lens height	34,6	25,8	28,5	31	30,7
Lens thickness left	1,19	1,20	1,53	1,17	1,18
Lens thickness right	1,28	1,25	1,50	1,22	1,17
Edge thickness left	3,7	3,3	3,6	3,1	3,3
Edge thickness right	3,4	3,1	3,5	3,0	3,0
Optical area (mm ²)	1500	1110	1040	1190	1230
Right lens weight (g)	4,4	2,9	3,11	3,3	3,3
Total weight (g)	35,1	28,9	26,4	31,3	34,0

Measure	Spectacles no.				
	2A	2B	2C	2D	2E
Lens width	53,4	51,2	48,0	52,0	49,4
Lens height	31,2	25,5	24,9	30,7	32,0
Lens thickness left	1,93	1,95	1,68	2,17	2,10
Lens thickness right	2,03	1,90	1,92	1,95	1,95
Edge thickness left	3,1	3,0	2,5	3,2	3,1
Edge thickness right	2,8	2,5	2,4	3,1	2,5
Optical area (mm ²)	1410	1080	850	1260	1230
Left lens weight (g)	4,4	3,2	2,6	4,1	3,9
Total weight (g)	24,6	20,4	18,4	23,6	22,1

The estimated measuring uncertainty is $\pm 0,5$ mm for lens height and width, $\pm 0,2$ mm for edge thickness, $\pm 0,05$ mm for centre thickness and $\pm 0,1$ g for the weight.

From a quality perspective the spectacle weight and size/shape is not reviewed, as this is mostly a personal opinion what is chosen. Lens thickness can be considered a quality feature, and in that respect none of the spectacles really stands out, especially not considering the lens sizes and how the mounted spectacles appear.

5.2 Lens power, uniformity and optical centres (OC)

5.2.1 Lens power

All measured sphere powers and cylinder powers were within $\pm 0,06$ D from the prescribed values. Any deviations are well within tolerances (ANSI Z80.1-2010) and thus clearly negligible for a spectacle wearer. The cylinder axes were within $\pm 3^\circ$ from the prescribed value for group 1. For spectacles 2D (which were ordered using a different prescription compared to the other spectacles in that group) the deviation in cylinder was 8° for the left lens but this is still well within tolerance and given the weak cylinder power, most certainly negligible for the spectacle wearer. In conclusion, all spectacles have satisfactory and comparable powers at OC.

5.2.2 Uniformity in lens power

Based on free form measurements within a circle with radius 10 mm centred around OC, power and cylinder deviations compared to OC was determined for all lenses. In all but one case the power deviations was within $\pm 0,06$ D for group 1, and within $\pm 0,05$ D for group 2. The left lens for spectacles 1C did show a bit larger deviation ($-0,12$ D) but given the total power of more than -3 D and the normal resolution of a prescription ($0,25$ D) this must be considered negligible. The cylinder deviations was within $\pm 0,08$ D for all lenses. Overall, no quality difference could be noted.

5.2.3 Optical centres (OC)

Below the distance between OC:s are reported for each pair of spectacles, together with how well the OC:s are centred within the frame.

Spectacles no.	Distance OC (mm)	Deviation from prescription (mm)	Centring in frame, offset (mm)
1A	68,3 ±0,5	+0,3	0,2
1B	68,2 ±0,5	+0,2	0,4
1C	68,0 ±0,5	0,0	0,2
1D	68,1 ±0,5	+0,1	0,0
1E	67,8 ±0,5	-0,2	0,3
2A	61,5 ±1,0	-0,5	0,5
2B	60,5 ±1,0	-1,5	0,3
2C	60,0 ±1,0	-2,0	0,3
2D	60,5 ±1,0	-0,5 ¹	0,3
2E	60,0 ±1,0	-2,0	0,4

¹ Prescribed PD-value 61 mm

An incorrect distance between the optical centres will cause a prismatic effect for the wearer. This prismatic refractive power is a combination of the error in OC distance and the overall power of the lenses. For all spectacles the total maximum prismatic effect caused by imperfect lens mounting is less than 0,2 D (using the so called Prentice's rule, see appendix 3), which is clearly negligible as the ANSI-tolerances is several times higher than this.

Also, for all spectacles the vertical positioning of OC:s are close to or slightly above the frame centres and within 1 mm for each pair of spectacles, which is without complaint. This is also the case for the horizontal centring (offset) shown above.

Overall, the positions and distances between the OC:s are satisfactory for all spectacles.

5.3 Transmittance

Below the luminous (or visual) transmittance values for CIE illuminant D65 (representing medium daylight conditions, colour temperature 6500 K) and CIE illuminant A (representing indoor conditions with incandescent light sources, colour temperature 2856 K) are presented. The measurements were made on the right lens of each spectacle. Diagrams of the spectral transmittance are presented in appendix 5.

Spectacle no.	Transmittance D65 %	Transmittance A %
1A	97,0	97,2
1B	97,5	97,8
1C	97,1	97,4
1D	96,9	97,2
1E	97,2	97,5
2A	92,5	92,5
2B	93,1	93,2
2C	92,6	92,6
2D	92,5	92,6
2E	92,2	92,2

The estimated measuring uncertainty is ±0,8 % in absolute transmittance and ±0,5 % in relative transmittance within each group of spectacles.

Within each group the difference in visual transmittance is less than 1 % for all spectacles. Also, when reviewing the spectral transmittance in appendix 5, all curves are relatively flat over the most important part of the visual spectrum (about 450 nm to 650 nm), which means that the perceived colours will remain unchanged when wearing the spectacles. The uncoated spectacles have significantly lower transmittance, but with slightly less spectral variation.

Overall, based on the amount and colour of the transmitted light, all spectacles are considered to be equivalent within each group. Also, all spectacles are adequately blocking most of the potentially harmful UV-radiation below 380 nm.

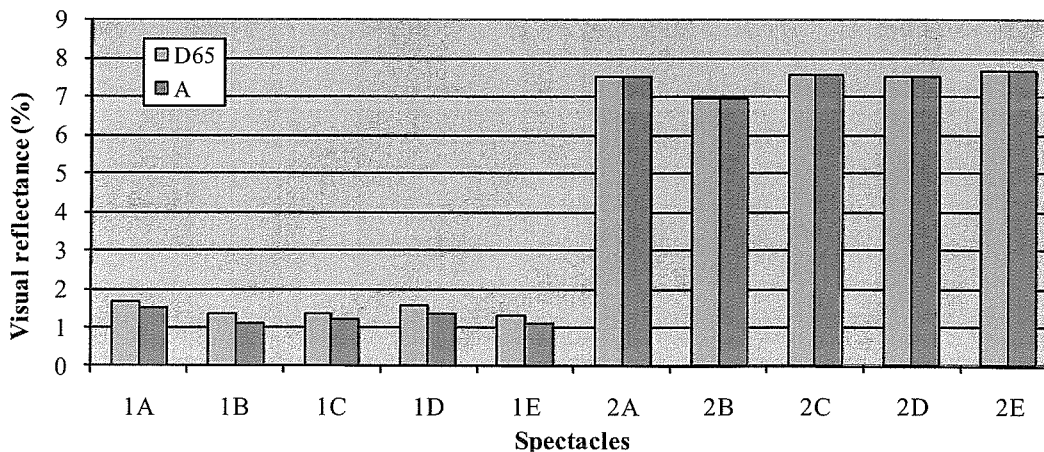
5.4 Reflectance

Below the luminous (or visual) reflectance values for CIE illuminants D65 and A are presented. Diagrams of the mean spectral reflectance are presented in appendix 6.

Spectacle no.	Reflectance D65 (%)		Reflectance A (%)	
	Left	Right	Left	Right
1A	1,5	1,8	1,4	1,6
1B	1,4	1,3	1,2	1,0
1C	1,4	1,4	1,2	1,2
1D	1,5	1,7	1,2	1,5
1E	1,4	1,3	1,1	1,0
2A	7,6	7,5	7,6	7,5
2B	6,9	7,1	6,9	7,0
2C	7,6	7,6	7,6	7,6
2D	7,5	7,6	7,5	7,6
2E	7,7	7,7	7,7	7,6

The estimated measuring uncertainty is $\pm 0,1\%$ in absolute reflectance.

Clearly the AR-coatings are reducing the reflectance significantly compared to the uncoated lenses. The results are quite similar within group 1 with mean reflectances within 0,5 % for all spectacles. Although spectacles 1B, C and E is performing slightly better than 1A and D, the differences is so small that they must be considered negligible for the spectacle wearer. Also in group 2 the differences is clearly negligible, although the slightly rippled spectral reflectance curve for spectacles 2B indicates that the lens have a coating of some kind (which is later confirmed by the scratch/wear-resistance test).



Apart from the absolute reflectance values, the uniformity between the lenses each pair of spectacles may also be considered a quality factor. Based on the values above and on the pictures presented in appendix 7, no significant variations in absolute reflectance or in reflected colour can be seen.

Of some importance for spectacle buyers could be how the reflections appear in terms of colour. This is shown in appendix 7, where all pictures have been taken under the same conditions. Slight colour changes may still have been introduced, but the difference between the spectacles is clearly visible. Obviously these pictures do not imitate real life conditions where only occasional weak reflections normally can be spotted, at least on the AR-coated lenses. No quality assessment is made based on the colours of the reflections as this property is judged to be of cosmetic nature.

5.5 Refractive index

Using the measured lens radii together with the measured powers, it was confirmed that all refractive indexes are in reasonably good agreement with the ordered (or assumed) indexes, that is around 1,6 for group 1 and around 1,5 for group 2. The measured front side radii and corresponding powers are presented in appendix 8.

5.6 Scratch/wear-resistance

Below the increase in diffusely transmitted light due to the falling sand test is reported. The test was performed using both the right and left lenses of each spectacle.

Spectacle no.	Mean increase in diffuse transmittance %	Spectacle no.	Mean increase in diffuse transmittance %
1A	1,1	2A	2,0
1B	2,1	2B	1,2
1C	1,5	2C	2,2
1D	1,4	2D	2,8
1E	1,8	2E	2,8
Test lens (CR-39)	2,8		

The measuring uncertainty is estimated to $\pm 10\%$ of the reported values.

When comparing the two groups to each other, one should be aware that the most common low index lens material (CR-39) is generally considered quite abrasion resistant even without a hard coating, especially when compared to most higher index lens materials¹. When comparing the measured increase in diffuse transmittance with visual inspections of the lenses under a lamp, the visual judgements agree very well with the measured values.

All lenses are more or less damaged after the test, but the difference between the least diffuse spectacles (1A and 2B) and the most diffuse (2D, 2E and test lens) is clearly seen. All spectacles in group 1 seem to have appropriate hard-coatings as expected, but spectacles 1A and to a lesser extent 1C and D stand out in a positive way. Also in group 2 there are some differences and especially spectacles 2B is significantly less diffuse than the other spectacles in that group, clearly indicating a hard-coating. Whether the somewhat better performance of spectacles 2A and C compared to 2D and E is because of a hard coating or just due to general material properties is not known.

In conclusion, given the severeness of the test, the most significant differences are found in group 2 and is believed to be related to a likely hard-coating on spectacles 2B performing clearly the best. That said, there are still some quite significant differences found also within group 1, with spectacles 1A performing the best closely followed by 1C and D.

¹ Schottner et al. (2003). Scratch and Abrasion Resistant Coatings on Plastic Lenses – State of the Art, Current Developments and Perspectives. Journal of Sol-Gel Science and Technology 27, 71-79

5.7 Glazing and bridge deformation

Spectacle no.	Applied force N	Deflection mm	Remaining deflection, mm
1A	5,0	6,1	0,4
1B	3,9	7,0	0,4
1C	4,5	7,0	0,5
1D	3,9	7,0	0,4
1E	4,2	7,0	0,4
2A	3,3	7,0	0,3
2B	3,1	7,0	0,3
2C	3,9	7,0	0,4
2D	4,1	7,0	0,3
2E	4,1	7,0	0,,

The estimated measuring uncertainties are $\pm 0,2$ N for the applied force, and $\pm 0,2$ mm for the deflections. A distance of 70 mm between the boxed centres was used throughout this test.

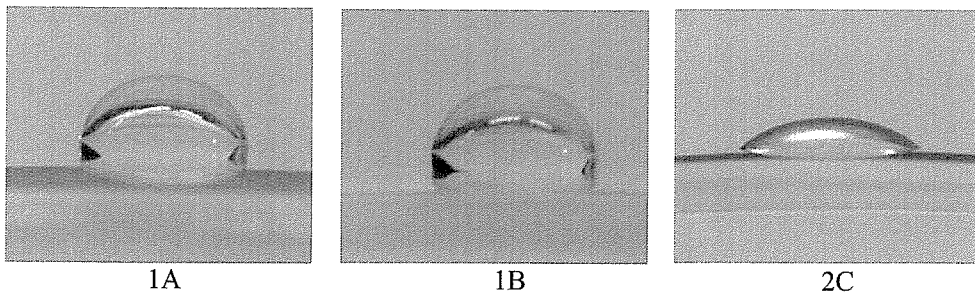
None of the spectacles fail the test according to the specifications set in the standards, that is the remaining deflections are sufficiently small and no lenses were loosened from the frames. Note that the small remaining deflections cannot be considered permanent as they seem to gradually decrease with time. No quality difference could be noted.

5.8 Vibration test

No damage was detected on the spectacles after 10 minutes of hard vibrations.

5.9 Hydrophobic/oleophobic properties and cleanability

All spectacles in group 1 exhibit similar water rejecting properties as only few and quite small water droplets could be seen on the lenses after cleaning and rinsing. In group 2 none of the spectacles have this property and all spectacles are performing quite similar. This can be seen on the pictures below, taken with a 40 μ l water droplet on top of cleaned lenses. The difference is quite clear between 1A and 2D, but very small between 1A and 1B.



Overall, when manually cleaning the spectacles with a soft piece of cloth it is not possible to detect any significant difference in cleanability between any of the spectacles in group 1. However compared to the spectacles in group 2, the AR-coated spectacles in group 1 clearly have more slippery lens surfaces which are judged as being somewhat easier to clean

The results from the tape removal measurement shown below, agree well with the above observations and although only small differences were noted among the most hydrophobic lenses in group 1, the results are at least in some parts significant.



Spectacle no.	Mean tape force N	Spectacle no.	Mean tape force N
1A	0,36	2A	2,1
1B	0,59	2B	1,8
1C	0,58	2C	1,8
1D	0,60	2D	2,0
1E	0,64	2E	1,9

The measuring uncertainty is estimated to $\pm 15\%$ of the reported mean values above.

Although several measurements have been made and with good repeatability, the results presented above is still influenced by many different parameters (lens curvature, application of fingerprints, pressure applied to tape and many others) so any small variations should be neglected.

Within both groups the differences are quite small but it is clear that the AR-coated spectacles in group 1 require significantly less force for the tape to be removed compared to the uncoated spectacles, showing that the fingerprint and tape combination is sticking much better to these lenses. The only slightly significant difference within the groups is that spectacles 1A is performing somewhat better than the other spectacles in that group. Within group 2 all spectacles must be considered equal in this respect.

From the above results it can be concluded that there are some measurable differences regarding cleanability and dirt rejecting properties of the lenses. However, the most significant conclusion is that all of the AR-coated lenses perform significantly better than the non AR-coated ones. Among the coated spectacles the differences were generally very small, but with spectacles 1A having a slightly more efficient dirt-rejecting surface than the others.

5.10 Others

5.10.1 Lens safety bevel (glazing)

In appendix 9 pictures of the left lenses' safety bevels or grooves are shown. All safety bevels and grooves seem to be adequate without any defects.

5.10.2 Frames and pads

All frames and hinges seem to function properly. For relevant frames, the pads seem to be adequately secured, and also either allows enough movement in order for the pads to adjust to the wearer's nose, or have very soft pads. Overall, no significant quality difference could be detected after a general frame check.

5.10 Result summary

5.1 Weight and dimensions – All spectacles have comparable quality.

5.2 Lens power, uniformity and OC –All spectacles have satisfactory and comparable quality.

5.3 Transmittance – Within each group all spectacles have comparable quality.

5.4 Reflectance – Within each group all spectacles have comparable quality.

5.5 Refractive index – All spectacles agree with the specified/ordered indexes.

5.6 Scratch/wear-resistance – In group 1 all spectacles have adequate hard-coatings but spectacles 1A performs slightly better than the others, closely followed by 1C and D. In group 2 spectacles 2B perform better than the others, which most certainly is thanks to a hard coating.



5.7 Glazing and bridge deformation – All spectacles have comparable quality.

5.8 Vibration test – All spectacles have comparable quality.

5.9 Hydrophobic/oleophobic properties and cleanability – In group 1 all spectacles have near comparable quality with a very small advantage for spectacles 1A. In group 2 all spectacles have near comparable quality .

5.10 Others – All spectacles have comparable quality.

Remark

The results are only valid for the tested objects.

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Appendices

Instructions to mystery shoppers

Information of purchase and spectacles

Terminology and concepts

Lens powers and evenness

Spectral transmittance

Spectral reflectance

Lens reflections from fluorescent tube

Lens front side curvature and calculated refractive power

Lens safety bevels

Tested quality properties and their impact on the wearer