DISCOMFORT GLARE FROM DAYLIGHTING: INFLUENCE OF CULTURE ON DISCOMFORT GLARE PERCEPTION

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Abstract

In a context where lighting standards are developed based on glare indices, no study has ever investigated that these indices could be used analogously for subjects having different cultures and living in different climates. The wide variability existing between individuals' discomfort glare perceptions suggests, however, that some of the factors influencing discomfort glare perception are still unknown, and culture might be one of them. This paper aims to determine the existence of differences between the discomfort glare perceptions of Belgians and Chileans. A field study was conducted in Chile and Belgium, for which a total of 288 measures of the lighting environments and subjective glare assessments were collected. Statistical analyses of the Belgian and Chilean datasets showed that Chileans perceive discomfort glare differently than Belgians. It is therefore hypothesised that existing discomfort glare indices might not be suited for Chilean subjects accustomed to a different type of lighting environment.

Keywords: discomfort glare, daylight, culture, glare assessment, HDR imaging

1 Introduction and state of the art

Energy efficiency and well-being are both major challenges in construction nowadays. In order to profit from the benefits of daylight, whether they are related to energy, occupants' performance, or well-being (Boyce, 2003), office buildings tend to have wider windows. But a larger surface of glazing implies an increased risk of discomfort glare. If daylight becomes disturbing, occupants will most probably use shading devices and turn on artificial lighting. When daylighting conditions return to a comfortable situation, occupants often forget to open the shading devices (O'Brien, 2013), cancelling all the benefits of daylight.

To consider this growing issue of discomfort glare from daylight, recommendations to limit glare will be part of the new European daylight standard (prEN17037). These recommendations use the Daylight Glare Probability (DGP) (Wienold, 2006) as a reference index, prescribing a threshold value that the DGP should not exceed more than 5% of usage time. Concerning discomfort glare from artificial lighting, recommendations are mainly based on the Unified Glare Rating (UGR) index (CEN, 2011). Other indices have been developed as well to evaluate discomfort glare, such as the DGI (Chauvel, 1982) and the DGI_{mod} (Fisekis, 2003) for daylighting, the CGI (Einhorn, 1979) for artificial lighting, or the UGP (Hirning, 2014) for both artificial and daylighting.

However, the wide variability existing between individuals' discomfort glare perceptions cannot be properly explained by current indices (Van Den Wymelenberg, 2016). One reason could be that some of the factors influencing discomfort glare perception are still unknown. According to Van Den Wymelenberg (Van Den Wymelenberg, 2014), one of the current knowledge gaps in discomfort glare is the lack of information about the moderating effect of several factors, such as the observer's culture, age or the outside view. A recent literature review lists every factor having at least been the object of an experiment as a potential element influencing discomfort glare perception, including the culture (Pierson, 2017a).

The culture is defined in this study as the climatic and indoor conditions to which the subject has been accustomed during the major part of his life, his behaviour towards this environment and his expectations about it. The observer's culture might therefore influence his or her discomfort glare perception. To date, discomfort glare indices have been developed through experiments involving particular populations. No study has examined that these indices could be used analogously for subjects having different cultures, namely subjects experiencing different climates and having different sensitivities towards daylight. Several observations have been made in the last 20 years, though, suggesting that subjects from different cultures might have different sensitivities towards discomfort glare.

The first observation was made by Subova et al. while they were conducting a laboratory experiment on the subjective response to discomfort glare in Slovakia (Subova, 1991). From the results of the study, a difference in subjective discomfort glare levels was noticed between the Slovak subjects and the subjects of a similar study carried on in the USA. It was hypothesised that the difference "*might be caused by a greater sensitivity of the population in Middle Europe adapted to lower luminance conditions*". Iwata et al. made a similar assumption regarding the difference in tolerance towards discomfort glare between Japanese and American subjects (Iwata, 1992). Japanese subjects were reported in the study as being tolerant to higher levels of discomfort glare than American subjects. This observation should, however, be tempered since the procedures between Hopkinson and Iwata et al.'s studies were not exactly the same. Pulpitlova et al. carried out another study in Slovakia (Pulpitlova, 1993) based on Hopkinson's discomfort glare scale. The mean luminance values evaluated by the Slovakian subjects for each discomfort glare level were similar to those evaluated by American subjects in a study conducted in Seattle, USA (MacGowan, 1986), but differed from the ones evaluated by Japanese subjects in Iwata et al.'s study (Iwata, 1992). Lee et al. reinforced the assumption that Asians have a different tolerance towards discomfort glare compared to Caucasians (Lee, 2007). The DGI thresholds proposed by Hopkinson and the ones obtained from their study with Asian subjects were compared, and indicated a significant difference. At high glare source luminance, Caucasians felt more discomfort glare than Asians. At last, Huang and Wang developed the DGI_{China} (Huang, 2016) on the basis of the DGI to provide a discomfort glare index consistent with Chinese people's visual characteristics. The thresholds of the DGI_{China} scale are higher than those of the DGI, which implies that Chinese people might tolerate higher discomfort glare than Hopkinson's study subjects.

These observations suggest that discomfort glare indices might not be applied universally. This study aims to determine the existence of differences between the discomfort glare perceptions of people coming from different cultures. In this paper, first results on the difference between Belgians and Chileans are summarised. A field study was conducted in two countries (Chile and Belgium) to assess whether or not discomfort glare perception would vary depending on the culture, and therefore on the lighting environment to which subjects are used. Measures of the lighting environments and subjective visual discomfort assessments have been collected simultaneously from 73 Belgian and 80 Chilean office workers. The measures consisted in luminance maps of the field of view created with High Dynamic Range (HDR) Imaging, whereas the subjective assessments were gathered from a questionnaire submitted to the participants. In total, 288 visual discomfort assessments and luminance maps were collected. Comparison between the Belgian and Chilean datasets through statistical analyses showed that Chilean participants perceive discomfort glare differently than Belgian ones. It is therefore hypothesised that existing discomfort glare predictors are not suited for Chilean subjects accustomed to a type of lighting environment varying from the European one. The second part of the study will further investigate this hypothesis by extending the results with a Japanese sample.

2 Method

The method developed and used in this study to collect in-situ visual discomfort assessments has been inspired by previous discomfort glare studies (Konis, 2014, Hirning, 2013, Van Den Wymelenberg, 2010, Wienold, 2006). The method consists in collecting almost simultaneously measures of the lighting environments and subjective glare evaluations of day-to-day scenes with visual discomfort due to daylighting, and more specifically with discomfort glare, in real office buildings in Chile and in Belgium. These countries have been chosen due to the climate and culture differences requirements and given the local presence of competent teams in the field of daylighting.

2.1 Study sites and periods

The study took place in real office buildings in Chile and Belgium. The primary advantage of in-situ data collection in comparison to controlled laboratory studies is the ability to survey occupants who are performing real work tasks, in their day-to-day environment. Distractions and interferences coming from an unusual or artificial environment is therefore avoided. Field studies present the additional benefits of enabling a broader range of interior space configurations to be considered, and of collecting a large sample of participants without requiring too much of their time. Moreover, since the study had to take place under clear sky conditions, this choice allowed for a more spontaneous configuration. On the opposite side, field studies have the disadvantages of not being controllable and of offering a smaller probability of very discomforting glare situations.

The office buildings where the Chilean study took place were 4 government buildings located in 3 cities: Antofagasta (latitude: -23.65, longitude: -70.4) where 55% of skies per year are CIE clear skies (Piderit, 2014); Concepción (latitude: -36.83, longitude: -73.05) where 35% of skies per year are CIE clear skies; and Punta Arenas (latitude: -53.17, longitude: -70.93) where 28% of skies per year are CIE clear skies. In Belgium, the study took place in 6 university buildings of the city of Louvain-la-Neuve (latitude: 50.67, longitude: 4.61) where 11% of skies per year are CIE clear skies. All buildings were multiple floors buildings with open-plan spaces and individual office rooms. Only the occupants from the upper floors having their desk next to a façade window west-, south- or east-oriented were surveyed, so that the amount of daylight is maximised.

To maximise the probability of glaring situations from daylight and to provide stable lighting conditions for the measures, the study had to take place under clear sky conditions. Moreover, both countries had to be investigated around the same season, to avoid a potential seasonal effect. It has already been observed that subjects have a higher acceptance of the presence of sunlight in winter than in summer (Christoffersen, 2000) and are more sensitive to glare source brightness during fall than during summer (Van Den Wymelenberg, 2013). Therefore, the study was conducted during 10 days with clear skies in March (end of summer) 2017 in Chile and during 9 days with clear or clear turbid skies from June to August (summer) 2017 in Belgium.

2.2 Study participants

Visual discomfort assessments were collected from 153 office workers in 4 cities (Table 1). Each participant could perform the survey only once and made two subjective assessments, which resulted in a total of 288 assessments collected (some assessments had to be disregarded due to unstable lighting conditions). Since the time plan of the study was depending on the weather conditions, the participants were not aware of the day of the survey.

Table 1 – Descriptive statistics of the survey sample

City	Number of participants	Number of glare evaluations	Male/female proportion	Mean age (SD)
Concepcion	22	43	0.36/0.64	42 (11)
Punta Arenas	30	58	0.53/0.47	41 (8)
Antofagasta	28	53	0.43/0.57	44 (10)
Louvain-la-Neuve	73	134	0.40/0.60	39 (11)

Participation in the study was voluntary, and the permission of individual participants was not granted until the time of the survey. Every effort was made to survey all participants available at the time of the study. Before undergoing the survey, each participant was working on a real work task, which involved working on a computer screen for the majority of their work hours.

2.3 Study design

The study was designed in order to be the least intrusive for the participants and bring the least possible modification to their working environment. The aim was to avoid drawing participants' attention on glare so that they do the assessment as they would in everyday life.

To analyse discomfort glare perceptions, subjective glare assessments and measures of the lighting environment have to be made for each studied lighting situation. Subjective glare assessments were made through a questionnaire filled by the participant on the computer screen, whereas the lighting environment was recorded through luminance maps created on the basis of HDR Imaging. Since both the assessments and measures could not be made at the exact same place and time, two options were considered: either subjective assessments are made simultaneously to the measures but the camera lens is set next to the participant instead of at the participant's eyes location (Konis, 2014, Painter, 2009), or subjective assessments and measures are collected for the exact same field of view but one after the other (Van Den Wymelenberg, 2010, Hirning, 2013). To minimise intrusion during the subjective glare assessment and error due to camera displacement –which can be as high as 20% for a 25° angle displacement (Fan, 2009)- it was decided to take the lighting environment measures directly after the subjective assessment under constant lighting conditions.

Moreover, since people usually do not work under discomforting conditions, the probabilities that a subject undergoes a discomfort glare situation during the survey were low. Therefore, the participants were asked to evaluate two visual discomfort situations. The first situation is the one the participant was working in when the instructor entered the office. The second lighting situation was created by opening the shading devices and turning off artificial lighting when possible. It was therefore essential to conduct the study under clear sky conditions, to capture stable LDR sequences and intensify discomfort glare from daylight.

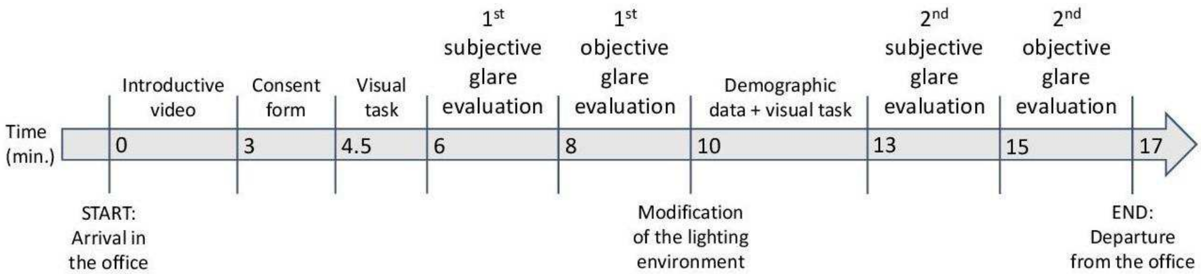

Figure 1 – Study timeline

The timeline of the study (Figure 1) began with a 3-minutes introductory video shown to the participant to provide some explanations on the process. Every participant was therefore given the same amount of information. They started the questionnaire on the computer screen with a short visual task (Landolt's rings). The participants were then asked to make a first visual discomfort assessment for the lighting situation in which they were working, which was directly followed by the measures of the lighting environment taken by the instructor. The lighting environment was modified by opening shading devices and turning off artificial lights, and the participant had to answer a series of questions about demographic, physiological, and psychological characteristics. This part of the questionnaire also serves as adaptation time to the new lighting situation. Eventually, the same process as the one used for the first visual discomfort assessment was reproduced to collect the second glare assessment. One survey lasted approximately 17 minutes and the instructor stayed in the room for the entire process.

2.3.1 Glare measurements

To represent the physical lighting conditions associated with a visual scene, a set of predictors was selected. These predictors were chosen following results from prior research and current lighting design guidance. They include glare metrics, namely the DGP, the DGI, the CGI, the DGI_{mod}, and the UGP, as well as the vertical illuminance at eye level (E_v) and the median luminance in the scene (L_{med}). These predictors were derived from luminance maps. The logarithmic transformations of the vertical illuminance at eye level (log_{Ev}) and the median luminance in the scene (log_{Lmed}) were also added to the list of predictors. The physiological sensation of brightness is indeed acknowledged to increase proportionally to the logarithm of the stimulus intensity, like many other physiological sensations (e.g. sound) (Konis, 2014).

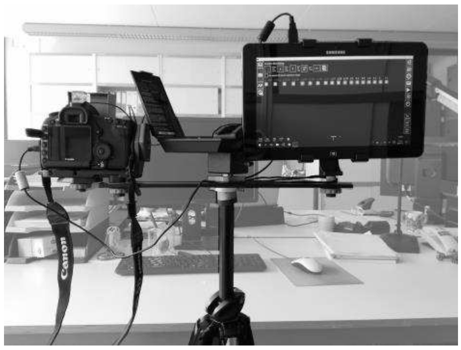

Figure 2 – Study equipment set-up: camera and fisheye lens, vertical illuminance sensor, and tablet computer on a tripod

For each glare evaluation made by a participant, a luminance map was created, which contained the luminance distribution of the participant's field of view. Luminance maps are acquired from calibrated HDR images. The technique consists in capturing multiple exposures of a scene, namely Low Dynamic Range (LDR) images, and merging them in an HDR image with a higher range of luminance (Inanici, 2006, Pierson, 2017b, Reinhard, 2006). For this study, LDR images were captured with a Canon EOS 5D Mark II digital camera mounted on a tripod with a double support (Figure 2). A Sigma EX DG 8mm f/3.5 fisheye lens was fixed to the camera, and the projection of the lens was determined as equisolid-angle. The camera was connected to a tablet computer with the qDslrDashboard software for remote control during the bracketing of LDR images. Moreover, a Kodak WRATTEN 3.0 Neutral Density (ND) filter was inserted between the lens and the camera sensor when the sun was in the field of view to avoid pixel overflow. To calibrate the HDR images, two spot luminance values were recorded before and after each LDR sequence on grey targets with a Konica Minolta luminance meter LS-110. Each HDR image was generated with the hdrgen command (Ward) in Radiance using a sequence of around 15 LDR images captured with an f/5.6 or f/11 aperture. The generation and calibration of HDR images from commercially available equipment is a tedious process. From the capture of multiple exposure images, to the calibration adjustment by spot luminance measurement, the steps required to generate luminance maps have been explained in another publication (Pierson, 2017b).

A Hagner digital luxmeter EC1-X was placed above the camera lens to measure vertical illuminance at eye level (E_v) before and after each LDR sequence. If the deviation between the two in-situ measures (before and after the LDR sequence) was higher than 15%, the glare evaluation was removed from the dataset. Therefore, a total of 15 glare evaluations had to be disregarded due to unstable lighting conditions. On average, the vertical illuminance deviation between the two illuminance measurements was 2%. In the remaining dataset, each luminance map was checked against the mean vertical illuminance (E_v). On average, the image-calculated illuminance values were within 4% of the measured values, but could potentially go up to 15% of error.

Potential glare sources were detected in the luminance maps using the Evalglare tool from Radiance (Wienold, 2006). The method to detect glare sources used in this study is the default one implemented in the findglare tool of Radiance. It consists in defining as a glare source any luminance value which is seven times greater than the average scene luminance. The aforementioned predictors were derived on the basis of these potential glare sources for each luminance map.

2.3.2 Subjective glare assessments

Subjective visual discomfort assessments were made by the subjects through a questionnaire displayed on their computer screen. The questionnaire was structured as follows:

- First visual task (Landolt's rings)
- Perception of current visual discomfort and glare in the first lighting scene
- Modification of lighting conditions and questions related to demography (age, sex, etc.), physiology (eye colour, chronotype, etc.), and psychology (mood, physical state, etc.)
- Second visual task (Landolt's rings)
- Perception of current visual discomfort and glare in the second lighting scene

The questionnaire was designed to be easy to fill for every participant and to avoid answers requiring much interpretation. The most important parts of the questionnaire were the perceptions of visual discomfort and glare. Two scales were used to assess whether discomfort glare was being experienced at the time of the survey (Table 1). The first scale is based on the four-point semantic scale of Konis' study in San Francisco (Konis, 2014). The second one is a five-point modified De Boer's scale which enables the participant to rate glare from imperceptible to intolerable (Iwata, 1992). For below statistical analyses, the four-point semantic scale was used. The questionnaire also investigated demographic, physiological and psychological factors which may have an influence on discomfort glare perception. Only factors that participants could assess for themselves were collected, amongst which the gender, the age, the culture, the iris pigmentation, the vision correction, the chronotype, the self-assessed glare sensitivity, the caffeine ingestion, the physical state, the fatigue, and the mood. The attractiveness of the view through the window, as another potential influencing factor, was also assessed. The room temperature and the time of the day were recorded by the instructor since they might as well have an influence on discomfort glare perception (Pierson, 2017a).

Table 2 – English, French and Spanish translations of questions related to visual discomfort

English	French	Spanish
At the moment, are you satisfied with the lighting conditions in your office?	*En ce moment, êtes-vous satisfait(e) des conditions lumineuses dans votre bureau ?*	*¿En este momento, está satisfecho(a) con las condiciones de luz en su oficina?*
• *Unsatisfied* • *Rather unsatisfied* • *Rather satisfied* • *Satisfied*	• *Insatisfait* • *Plutôt insatisfait* • *Plutôt satisfait* • *Satisfait*	• *Insatisfecho* • *Más bien insatisfecho* • *Más bien satisfecho* • *Satisfecho*
At the moment, do you feel discomfort due to glare?	*En ce moment, ressentez-vous une gêne due à l'éblouissement ?*	*¿En este momento, tiene molestias por deslumbramiento?*
• *No, no discomfort* • *Yes, a small discomfort* • *Yes, a moderate discomfort* • *Yes, a significant discomfort*	• *Non, pas de gêne* • *Oui, une faible gêne* • *Oui, une gêne modérée* • *Oui, une gêne importante*	• *No, ninguna molestia* • *Sí, un poco de molestia* • *Sí, una molestia moderada* • *Sí, una molestia significativa*
At the moment, how would you rate glare in your field of view?	*En ce moment, comment évalueriez-vous l'éblouissement dans votre champ de vision ?*	*¿En este momento, cómo evalúa el deslumbramiento en su campo de visión?*
• *Intolerable* • *Uncomfortable* • *Acceptable* • *Perceptible* • *Imperceptible*	• *Insupportable* • *Inconfortable* • *Acceptable* • *Perceptible* • *Imperceptible*	• *Insoportable* • *Incómodo* • *Aceptable* • *Perceptible* • *Imperceptible*

The questionnaire was originally written in French for the Belgian survey, and later translated to Spanish for the Chilean survey. The translation of the questions related to visual discomfort assessment can be found in Table 2.

3 Data analysis and results

Statistical data analyses were used to investigate the influence of culture on discomfort glare perception. For this study, the difference in discomfort glare perception between Chilean and Belgian participants was investigated.

3.1 Office visual environments

At first, the visual office environments in each city were investigated and compared in terms of vertical illuminance at eye level and median luminance in the field of view. Overall, the median luminance values were similar in the four cities.

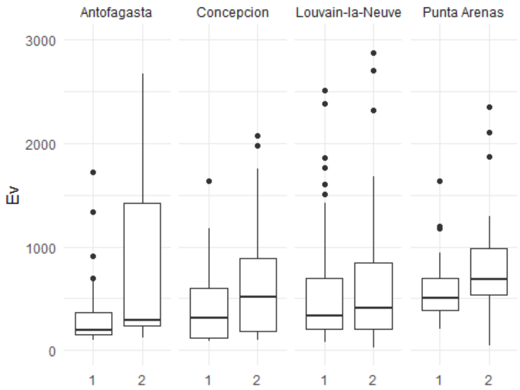

Figure 3 – Boxplots of E_v for first and second assessments in each city (5 outliers were removed from the graph due to too high E_v values)

The vertical illuminance values, though, showed several differences (Figure 3). Vertical illuminance (E_v) was, on average, higher in Punta Arenas. This can in part be explained by the configuration of the surveyed buildings which are 10-stories high in a city where buildings are not taller than 3-stories. The solar angle which was around 37° at the time of the survey in Punta Arenas compared to around 55° in the other cities could also explain a higher vertical illuminance at eye level. Furthermore, the low means of vertical illuminance in Antofagasta might be surprising since it is the city with the clearest sky. It was observed that participants in Antofagasta often worked with shading devices closed, due to the large probability of being glared at one point during the day in this desertic region. The first visual assessment in Antofagasta was thus made in a mostly artificially lit office environment. Furthermore, the large distribution of vertical illuminance for the second glare evaluation in Antofagasta is probably due to the presence of the sun in the field of view for several scenes.

Table 3 – Descriptive statistics for glare predictors for each culture

		Belgian dataset				Chilean dataset			
Predictor	Unit	Median	SD	Min.	Max.	Median	SD	Min.	Max.
DGP	-	0.195	0.084	0.006	0.417	0.205	0.107	0.01	1
DGI	-	9.524	6.87	0	24.413	13.955	5.426	0	24.948
CGI	-	17.566	8.813	0	39.947	19.699	7.237	0	53.173
DGI_{mod}	-	10.757	6.887	0	25.221	14.476	5.098	0	24.865
UGP	-	0.473	0.263	0	1.133	0.549	0.216	0	1.358
E_v	lux	370	594	20	2874	501	2494	50	29614
log_{Ev}	lux	2.569	0.405	1.309	3.459	2.7	0.435	1.705	4.471
L_{med}	$cd \cdot m^{-2}$	68.097	71.029	1.896	357.061	56.542	68.626	2.338	521.617
log_{Lmed}	$cd \cdot m^{-2}$	1.833	0.354	0.278	2.553	1.752	0.352	0.369	2.717

To run the following statistical analyses, it was decided to use the entire dataset, namely the first and second visual discomfort assessments. Therefore, the assessments for which the participants responded that the glare came from artificial light were removed from the dataset ($N_{assessments\_remaining}$ = 278). The predictors selected for the glare measurement are mostly aimed at evaluating discomfort glare from daylight. They are summarised in Table 3, along with descriptive statistics. These descriptive statistics were evaluated on the new dataset.

3.2 Spearman correlation

The suitability of the selected glare predictors as discomfort glare prediction models was investigated for the Belgian and Chilean datasets. Spearman correlation factors (rho) and the significance level of their p-values (SL_{pval}) were evaluated between the subjective assessments made on the four-point semantic scale and each one of the nine glare predictors evaluated from the luminance maps (Table 4). A Bonferroni correction was applied to the significance level of the p-values to account for the multiple predictors studied. The corrected significance levels go from very high (*** = [0; 0.000143[), to high (** = [0.000143; 0.00143[), to moderate (* = [0.00143; 0.007143[). P-values above 0.007143 (.) are not significant.

Table 4 – Spearman correlation factors between subjective assessments and glare predictors

Culture	N	Statistics	DGP	DGI	CGI	DGI_{mod}	UGP	E_v	L_{med}
Belgian	129	rho	0.375	0.311	0.344	0.327	0.318	0.377	0.34
		SL_{pval}	***	**	***	**	**	***	***
Chilean	149	rho	0.226	0.215	0.226	0.264	0.194	0.241	0.253
		SL_{pval}	*	.	*	**	.	*	*

Belgian assessments demonstrate a better correlation than Chilean ones with every glare predictors. The vertical illuminance at eye level (E_v) was the best glare predictor of the

Belgian discomfort glare assessments with a correlation factor of 0.38. The low correlation factors of the Chilean dataset could be due to several reasons. The first one is that the 3 cities might have different behaviours with respect to discomfort glare perception, and should be treated as 3 separate sub-cultures within the scope of this study. Spearman correlation factors were therefore evaluated for 3 sub-datasets of the 3 Chilean cities. The average of these correlation factors for Antofagasta, Concepcion, and Punta Arenas are respectively 0.31, 0.22, and 0.13. These factors cannot be interpreted since they are not significant, and the number of observations per city is very small for some levels of the glare scale (Table 5). Another explanation for the low correlation of Chilean subjective assessments with glare predictors could be that the glare predictors are not adapted to this dataset. None of the selected glare indices used in this study was developed using a sample of South American participants; most of them were developed on the basis of European subjects' glare assessments. The perception of discomfort glare for Chilean people could vary from the one in Europe, and could therefore not be well predicted by the selected glare predictors.

To further study this possibility and since the number of assessments in some levels of the four-point semantic scale is very low (Table 5), the subjective assessments were transformed into a binary classification. The categories "Small discomfort", "Moderate discomfort", and "Significant discomfort" were grouped in the "Discomfort" logical category (1 = Discomfort), whereas the "No discomfort" category remained unchanged (0 = No discomfort). The "Discomfort" category should, however, not be related to the "Disturbing" level in other glare scales, since it comprises the "Small discomfort" category.

3.3 Logistic regression

Logistic regression models were generated for both culture and for each predictor with the generalised linear model function (glm, with binomial family and logit link function) in the R programming language. The logistic regression models are used in this case to derive a probability function for subjects experiencing discomfort from glare. The formula used for each logistic regression includes one glare predictor as the independent variable (Eq.1).

Discomfort binary scale ~ Discomfort glare predictor (1)

The resulting estimate coefficients (est) and significance level of p-values (SL_{pval}) can be found in Table 6. Since both the Chilean and the Belgian datasets were not perfectly balanced between the two logical categories, cut-off points had to be defined as the borderline values of the binary classification predicted by the model, namely the borderline values between "No discomfort" and "Discomfort". The cut-off points were obtained by minimising the false positive rate while maximising the true positive rate. A confusion matrix could then be determined for each model, and performance indicators could be computed such as the accuracy of the model (ACC), the sensitivity or true positive rate (TPR), and the specificity or true negative rate (TNR) (Table 6).

Table 5 – Descriptive statistics for glare predictors for each culture

Culture	Statistics	DGP	DGI	CGI	DGI_{mod}	UGP	E_v	$\log_{Ev}$	L_{med}	$\log_{Lmed}$
Belgian	est	11.723	0.101	0.095	0.106	2.954	0.001	2.134	0.006	1.932
	SL_{pval}	***	**	**	**	**	**	***	.	*
	ACC	0.659	0.62	0.628	0.643	0.605	0.659	0.659	0.69	0.69
	TPR	0.598	0.524	0.524	0.634	0.549	0.598	0.598	0.683	0.683
	TNR	0.766	0.787	0.808	0.66	0.702	0.766	0.766	0.702	0.702
Chilean	est	5.825	0.077	0.062	0.093	1.763	0.001	1.282	0.01	1.396
	SL_{pval}	.	.	.	*	.	*	*	*	.
	ACC	0.604	0.611	0.624	0.631	0.617	0.611	0.611	0.617	0.617
	TPR	0.529	0.586	0.614	0.728	0.643	0.743	0.743	0.628	0.628
	TNR	0.671	0.633	0.633	0.544	0.595	0.494	0.494	0.608	0.608

As can be seen in Table 6, the best glare predictors for the Belgian dataset are the DGP, and the logarithmic transformation of the vertical illuminance at eye level, although almost all predictors are significant. This is not the case for the Chilean dataset as most of the glare indices selected cannot predict the discomfort glare perceptions of this dataset. This observation confirms what could already be noticed from the Spearman correlation analysis (Table 4): Chileans most probably have a different perception or acceptance of discomfort glare from daylight than Belgians, and by extension, Europeans. Therefore, indices developed for a European population might not be applicable to subjects accustomed to other types of climatic and indoor conditions. This is better observable in Figure 4, as the Chilean curve is flatter than the Belgian one. The split between the DGP values corresponding to the "Discomfort" and "No discomfort" categories for the Chilean subjective assessments is not as pronounced as for the Belgian subjective assessments, causing the two categories to overlap. The approximation of the logistic curve for the Chilean sample is less suited to a binary classification and flattened.

Table 6 – Number of assessments per glare category (A = No discomfort; D = Significant discomfort)

City	A	B	C	D
Antofagasta	21	24	5	3
Concepcion	18	9	12	0
Punta Arenas	31	20	4	2
Louvain-la-Neuve	82	28	15	4

4 Conclusion

An in-situ study has been conducted in two countries (Belgium and Chile) to study the influence of culture, namely the climatic and indoor conditions to which a subject has been accustomed during the major part of his life, on discomfort glare perception. Concurrent subjective visual discomfort assessments and measures of the lighting environments have been collected from 153 office workers during the summer months (2017) under clear sky conditions. Glare predictors have been derived from the luminance maps created with the technique of HDRI. Statistical analyses have been performed to compare the glare predictors to the participants' glare assessments. On one hand, all selected glare predictors (DGP, DGI, CGI, DGI_{mod}, UGP, E_v, $\log_{Ev}$, L_{med}, $\log_{Lmed}$) presented a moderate correlation factor (Table 4) with the Belgian subjective assessments made on a four-point discomfort semantic scale, with the DGP being the most suited index for this dataset. On the other hand, the correlations of the Chilean assessments with the selected glare predictors were either low or non-significant.

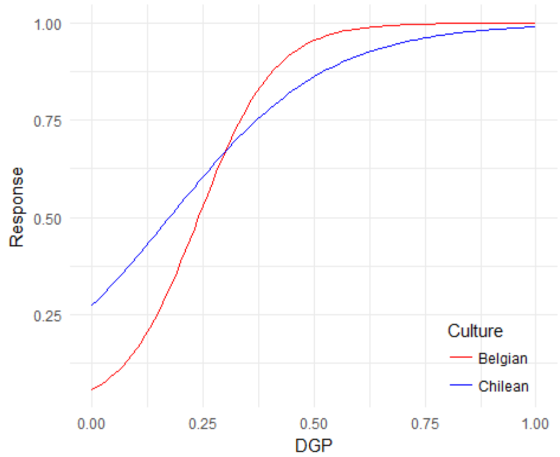

Figure 4 – Logistic regression curves of the DGP model for Belgians and Chileans

The difference in discomfort glare perception between the two cultures was further studied through logistic regression models, for which the glare scale ratings were transformed into a binary one ("No discomfort-Discomfort"). In view of the significance level of each glare predictor estimate in the Chilean regression models (Table 6) and of the Chilean logistic regression curve for the DGP model (Figure 4), it was observed that the Chilean subjective assessments were not consistent with regards to the selected glare predictors. It is therefore hypothesised that these glare predictors are not relevant to describe the Chilean discomfort glare perceptions, since these Chilean perceptions vary compare to Europeans.

More in-depth analyses are required to confirm this hypothesis and to compare the results of this study with the observations made in existing literature on the difference in glare perception between European and Asian subjects. The next steps of this study on the influence of culture on discomfort glare perception will focus on deepening the data analysis. The glare predictors will be re-evaluated on the basis of the luminance maps with the task area method from Evalglare. This method uses the average luminance of a defined task area to determine the glare sources in the field of view. Furthermore, more glare predictors such as the PGSV and the L_{40band} will be investigated. A sample of Japanese participants will also be collected in Tokyo and compared to the actual datasets. Last but not least, other potential influencing factors (Pierson, 2017a) will be analysed, and independency will be checked since the effect of culture might be overlapping with another factor unknown until now.

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