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# Experimental Biases in Discomfort Glare Evaluations

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*ABSTRACT: The multiple criterion scale developed by Hopkinson is extensively utilised to analyse the subjective degree of discomfort due to glare. Using a luminance adjustment procedure, the brightness of a glare source is adjusted to reveal four levels of discomfort, typically: just imperceptible, just acceptable, just uncomfortable, and just intolerable. In many experimental studies, observers are requested to attend to each level of discomfort in ascending order, from the lowest to the highest criterion. There are, however, reasons to believe that assessments made using adjustments might be affected by the initial anchor, i.e. the setting of the variable stimulus before an adjustment is made, and by order effects, this influencing the reported thresholds of discomfort. To investigate anchor bias and order effects, two Hopkinson-like multiple criterion adjustment experiments were performed, respectively with three different initial anchors and three order sequences (ascending, descending, and randomised). The results revealed substantive bias due to anchor and order effects, primarily at lower glare criteria. This demonstrates the need for caution when interpreting subjective evaluations of discomfort due to glare and estimating the robustness of glare indices derived from studies that used models fitted to data obtained with Hopkinson's multiple criterion scale and luminance adjustment procedure.*
*KEYWORDS: Discomfort Glare, Experimental Bias, Luminance Adjustment, Anchor Bias, Order Effects*

## 1. INTRODUCTION

This paper critically synthesises research studies by the authors focusing on the design of experiments carried out to explore the evaluation of discomfort due to glare [1, 2]. Discomfort glare is a psychological sensation causing distraction or annoyance, which is associated with a luminance, or luminance contrast, within the visual field of an observer that is sufficiently greater than that to which the eyes can adapt [3]. Many studies have sought to characterise this discomfort, leading to the proposal of several glare models and indices. Among these, there are three fundamental studies. Hopkinson [4] used an experimental procedure whereby the brightness of a light source was incrementally adjusted to the points at which observers suggested that a visual scene represented four specific thresholds of discomfort glare, the multiple criterion scale (MCS). In its most typical form, the MCS features the following criteria: Just Imperceptible (JImp), Just Acceptable (JA), Just Uncomfortable (JU), and Just Intolerable (JInt). Luckiesh and Guth [5] also used an adjustment procedure to determine one threshold, the Borderline between Comfort and Discomfort (BCD). Petherbridge and Hopkinson [6] later established an empirical relationship between the discomfort reported by observers and lighting parameters: the Glare Constant. Various glare indices have been developed from these fundamental studies, such as the Illuminating Engineering Society Glare Index (IES-GI) [7] and the Unified Glare Rating (UGR), which is currently recommended by the Society of Light and Lighting [8], the Illuminating Engineering Society of North America [9] and the International Commission on Illumination [10]. The Daylight Glare Index (DGI) [11] was also developed using a procedure similar to [4]. The purpose of glare indices is to provide robust predictions of the discomfort reported by an observer in a luminous environment. However, since the studies on which glare indices are based have mostly used fixed-order luminance adjustment, in this paper we discuss the potential influence of two sources of experimental bias on errors between predicted and actual discomfort: 1) anchor; and, 2) order effects.

## 2. ANCHOR BIAS

### 2.1 Adjustments and heuristic anchoring

When observers use an adjustment procedure to make judgements of a variable stimulus, it has been proposed that the final setting might be influenced by the initial stimulus; this phenomenon is known as anchoring [12]. Anchors can affect a large range of assessments, such as responses to general knowledge questions, economic evaluations, etc. When making a subjective judgement, different starting points lead to different values, which tend to be biased towards the initial settings. Anchoring has been demonstrated also in lighting studies [13], providing reasons to believe that the adjustment procedure traditionally used in glare experiments might be biased towards the initial luminance setting. If this proves correct, the results from the fundamental studies mentioned above – and, hence, the subsequent glare indices – might provide an incorrect estimate of the relationship between background and target luminance associated with each glare criterion. To test this hypothesis, an experiment was designed to confirm whether the initial luminance setting of a variable stimulus (anchor) influences the luminance associated with a given discomfort glare sensation.

**2.1 Experimental design and procedure**

Discomfort from artificial lighting was investigated in a laboratory test, using a procedure designed to explore whether an anchor bias could be detected. The setup of the testing apparatus (Figure 1) was informed by previous studies by the authors [14].

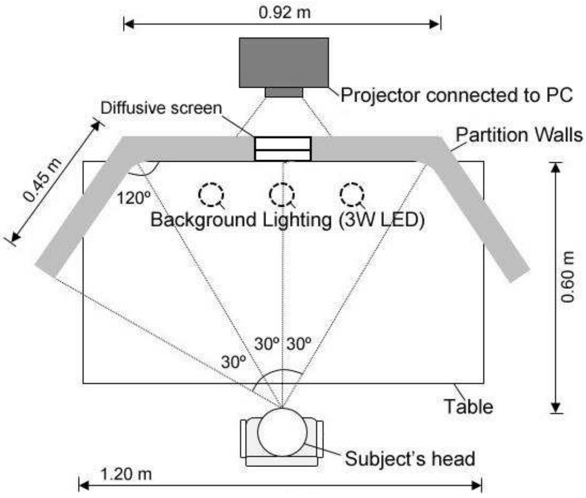


*Figure 1. Plan of the testing apparatus*

The testing apparatus was semi-hexagonal in plan. The interior surfaces (2.7m in height) were painted matte white, and three 3W LED lamps produced a background lighting with a constant luminance distribution of 65 cd/m$^2$. A desk with a diffusive white surface was mounted within the wooden partitions. The subject's head position was set at a height of 1.2m, facing a diffusive screen (0.08m x 0.04m) made from three sheets of translucent paper and mounted in front of a projector connected to a computer. The diffusive screen subtended an angle at the eye of 0.009 steradians and provided a variable luminance in the range between 200 and 32,000 cd/m$^2$. The source luminance could be progressively increased using the relative brightness function of an image editing software. To test the hypothesis that different initial source luminances lead to different adjustment settings for the same level of glare sensation, test subjects were asked to provide judgements under three initial settings corresponding to a low, medium, and high anchor. Since no established luminance value could be applied to specify these anchors, the luminance associated to each of the following IES-GI discomfort glare criteria were used [15], respectively: Just Imperceptible (Low anchor); Borderline between Comfort and Discomfort, or BCD (Medium anchor); and Just Uncomfortable (High anchor). The Just Uncomfortable criterion was used for the high anchor to avoid any potential harm to participants (Table 1).

*Table 1. Definition of the three initial anchors*

| Anchor | Luminance [cd/m$^2$] | IES-GI | Glare Criterion |
|---|---|---|---|
| Low (L) | 1,627 | 10 | Just Imperceptible |
| Medium (M) | 5,414 | 18.5 | BCD |
| High (H) | 8,999 | 22 | Just Uncomfortable |

During the experiment, participants were asked to make judgements of visual discomfort using the IES-GI glare criteria [15]. Since it was considered that each criterion could be open to self-interpretation due to the abstraction caused by the assessment, to aid subjects giving more meaningful judgements the criteria were linked to time-span descriptors [16].

At the start of the experiment, the brightness of the diffusive screen was set to one of the initial luminance anchors chosen at random. Participants directed their gaze towards the centre of the diffusive screen and were asked whether they would like the experimenter to increase, decrease, or keep constant its brightness to reach a glare sensation of Just Imperceptible (JImp). Once the lowest of the four criteria was set, the luminance of the screen was increased at a controlled pace and subjects were asked to indicate when the other criteria – Just Acceptable (JA), Just Uncomfortable (JU), and Just Intolerable (JInt) – were reached. The IES-GI was calculated from the recorded luminances. After making the initial four evaluations, participants were given a short relaxation period (two minutes) before continuing the experiment starting with a different luminance anchor. The test procedure was again repeated until the subject had provided all four levels of glare sensation under each of the three different luminance anchors. Twenty-two subjects participated to this experiment, recruited via an online advertisement. The sample comprised 8 males and 14 females, with a mean age of 29.6 years (SD=3.75).

**2.2 Results**

Table 2 presents the mean source luminance and standard deviation of the diffusive screen for each glare criterion under the three anchors (L, M, H). Initial inspection of the data shows that mean values increase when considering a higher anchor for each glare criterion, suggesting that adjustments were made closer to the luminance of the initial setting.

*Table 2. Mean source luminance (and standard deviation)*

| Anc. | Mean source luminance (SD) [cd/m$^2$] | | | |
|---|---|---|---|---|
| | JImp | JA | JU | JInt |
| L | 1,784 (1,031) | 3,043 (1,534) | 4,517 (2,027) | 8,238 (4,135) |
| M | 3,192 (1,341) | 4,350 (1,982) | 5,858 (1,982) | 10,130 (3,388) |
| H | 5,663 (2,923) | 7,224 (3,037) | 9,031 (3,232) | 13,548 (4,858) |

Figure 2 presents the mean IES-GI values calculated for the four glare criteria provided by test subjects under the three anchors. According to Hopkinson [15], IES-GI benchmarks for each glare criterion are, respectively: No glare≤10; 10≤JImp≤16; 16≤JA≤18.5; 18.5≤BCD≤22; 22≤JU≤28; JInt≥28.

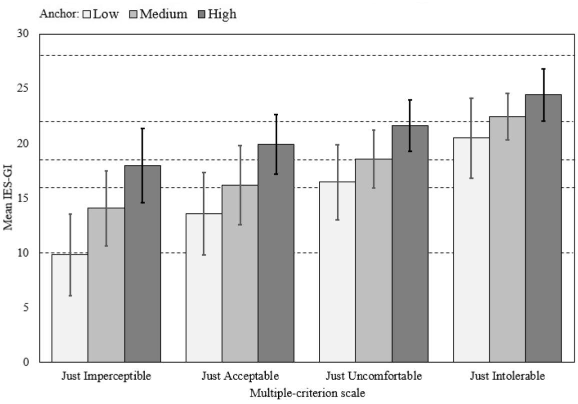


*Figure 2. Mean IES-GI for the luminance anchors and the four glare criteria (error bars show standard deviations)*

Figure 2 confirms the tendency for the IES-GI to be consistently influenced by the luminance anchors for all glare criteria. Differences in mean IES-GI across the three anchors also appear to decrease at higher levels of discomfort glare. Null hypothesis significance testing (NHST) was performed to determine if differences between groups were statistically significant. However, since NHST is dependent on both the size of the sample and on the magnitude of the influence under testing, emphasis of the analysis was placed on the effect size (i.e., a standardised measure of the difference across the independent variable) and not only on the statistical significance [17]. Since data were not normally distributed and differences in variance were not significant, a parametric repeated-measures Analysis of Variance (RM-ANOVA) was run to compare glare indices across the three anchors. The RM-ANOVA demonstrated that the differences in mean values of IES-GI across the three anchors for all glare criteria were all highly significant and with substantive effect sizes, ranging between large ($\eta p^2 \geq 0.71$ for Just Imperceptible) and moderate ($0.25 \leq \eta p^2 < 0.64$ for all other glare criteria).

Post-hoc testing was then performed, comparing against each other all combinations between anchors. Statistical significance of differences was calculated using one-tailed paired t-tests to identify the variations detected in the RM-ANOVA. Bonferroni corrections were applied in consideration of the experiment-wise error rate caused by the alpha level inflating across multiple pairwise comparisons. The interpretation of the outcome was derived from the benchmarks given by Ferguson [18] for small, moderate, and large effect sizes (d≥0.41, 1.15 and 2.70, respectively). Table 3 reports the results of the post-hoc t-tests providing, for each MCS glare criterion, the comparison between initial anchors, the mean and standard deviations for the IES-GI, the mean differences (ΔM) and their statistical significance (NHST), and the effect size (Cohen's d).

*Table 3. Paired comparison t-tests and effect sizes*

| MCS | Comparison | M(SD) | M(SD) | $\Delta M^{NHST}$ | d |
|---|---|---|---|---|---|
| | Low v. Medium | 9.81 (3.74) | 14.07 (3.43) | -4.26*** | -1.18 |
| JImp | Low v. High | 9.81 (3.74) | 17.97 (3.40) | -8.16*** | -2.28 |
| | Medium v. High | 14.07 (3.43) | 17.97 (3.40) | -3.90*** | -1.14 |
| | Low v. Medium | 13.57 (3.78) | 16.17 (3.58) | -2.60** | -0.71 |
| JA | Low v. High | 13.57 (3.78) | 19.92 (2.73) | -6.35*** | -1.93 |
| | Medium v. High | 16.17 (3.58) | 19.92 (2.73) | -3.75*** | -1.18 |
| | Low v. Medium | 16.45 (3.44) | 18.55 (2.66) | -2.10* | -0.68 |
| JU | Low v. High | 16.45 (3.44) | 21.61 (2.36) | -5.16*** | -1.75 |
| | Medium v. High | 18.55 (2.66) | 21.61 (2.36) | -3.06*** | -1.22 |
| | Low v. Medium | 20.47 (3.67) | 22.47 (2.13) | -2.00** | -0.67 |
| JInt | Low v. High | 20.47 (3.67) | 24.42 (2.40) | -3.95*** | -1.27 |
| | Medium v. High | 22.47 (2.13) | 24.42 (2.40) | -1.94*** | -0.86 |

*Bonferroni corrections: *weakly significant **significant; ***highly significant; n.s. = not significant*
*d<0.41 = negligible; 0.41≤d<1.15= small; 1.15≤d<2.70 = moderate; d≥2.70 = large*

The inferential data show that the sign of the mean differences and the effect sizes are consistently negative, therefore signalling higher values of IES-GI when participants adjusted the luminance of the glare source starting from a higher anchor. All differences were statistically significant and with a substantive effect size, hence confirming that, when the initial anchor was higher, test subjects made adjustments to higher luminance settings for the same level of reported glare sensation. The effect of the anchor on the glare settings also appear to be stronger when considering a larger difference in the luminance of the initial anchor. In fact, comparisons between the 'low' and 'high' anchors produced the largest differences in mean IES-GI and effect size for every glare criterion. The findings also show that, when considering higher levels of visual discomfort, the differences in mean and the effect sizes reduce across comparisons, suggesting that the influence of the initial anchor decreases at higher glare sensation. However, this might have occurred since participants were instructed to make adjustments using only a sequence of increasing glare stimulus. Conversely, the experimental procedure did not consider how adjustments could have influenced the outcome of the study if other order sequences had been used.

## 3. ORDER EFFECTS

### 3.1 Experimental design and procedure

Based on these results, a further experiment was designed to explore whether order effects in a luminance adjustment procedure could be detected under controlled laboratory conditions. The same testing apparatus described above was used (Fig. 1).

During the experiment, participants were asked to make judgements of discomfort glare using the same MCS criteria utilised by Petherbridge and Hopkinson [4] with the ascending-only order sequence from where the Glare Constant formula was derived. Three different order sequences were used:

- Ascending: JImp, JA, JA, JInt
- Descending: JInt, JU, JA, JImp
- Randomised: the order of criteria was shuffled.

Comparing the luminances set for each criterion in the three sequences would demonstrate whether or not order had any significant effect. A repeated-measures design was used. At the outset of the experiment, the diffusive screen was set to an initial luminance corresponding to an IES-GI of 10 (Just Imperceptible). This anchor was used only for the first trial, and then the luminances set by test participants became the anchor for the subsequent setting. For each trial, the experimenter adjusted the luminance of the glare source at a controlled pace according to the participant's instruction (increased, decreased, or kept at its current brightness) to reach a glare sensation corresponding to each of the four predefined criteria, in the order described in one of the three sequences. The test procedure was repeated until the participant had provided all four criteria of glare sensation under each of the three sequences, these being presented in a random order. Twenty participants (different from the previous experiment) volunteered to this test, recruited via an online advertisement. The sample included 7 males and 13 females, with a mean age of 24.2 (SD= 5.76).

### 3.2 Results

Figure 3 shows the mean source luminance and standard deviation of the glare source at the point in which participants reported each criterion of glare sensation under the three order sequences.

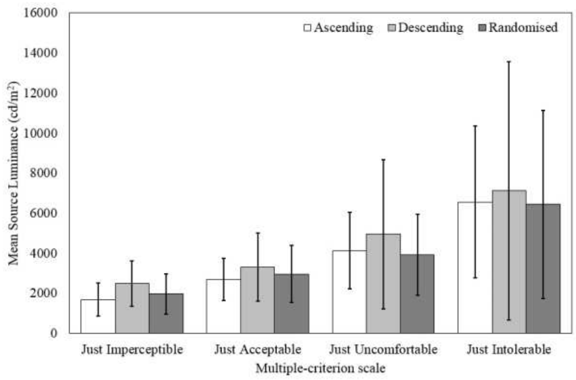


*Figure 3. Mean source luminances and standard deviations for the four discomfort glare criteria under the three orders*

Visual inspection of the plots suggests that mean source luminances were higher when adjustment settings were made using a descending sequence for each glare criterion. The standard deviations become consistently larger when assessments were made at higher levels of discomfort across all three sequences.

Null Hypothesis Significance Testing (NHST) was used to determine if the differences in source luminance were statistically significant. Emphasis of the analysis was again placed on the effect size and not only on the *p*-value. A repeated-measures Analysis of Variance (RM-ANOVA) was performed to compare against each other the source luminance settings for each criterion of reported glare sensation across the three order sequences. The results of the RM-ANOVA showed that the differences across the independent variable (order sequence) were highly significant for the Just Imperceptible criterion, weakly significant for Just Acceptable and not significant for the other two glare criteria. The differences detected had a substantive effect size ranging from moderate ($0.25 \leq \eta p^2 < 0.64$ for JImp) to small ($0.04 \leq \eta p^2 < 0.25$ for JA and JU). Not substantive differences were found for the Just Intolerable criterion ($\eta p^2 < 0.04$). In the data, the magnitude of the effect decreased at higher levels of discomfort. Hence, the effect of order on the luminance settings made by test participants appeared to be weaker for higher glare criteria, confirming the observations from Figure 2. Post-hoc testing was performed to compare all combinations of order sequences for each glare criterion. Statistical significance of the differences was calculated using two-tailed paired t-tests to determine the locations of the differences detected in the RM-ANOVA. The effect size was estimated by the Pearson's r (Table 4).

*Table 4. Paired t-test comparisons across order sequences*

| MCS | Comparison | $M(SD)_1$ | $M(SD)_2$ | $\Delta M^{NHST}$ | r |
|---|---|---|---|---|---|
| | Asc. vs. Des. | 1,676 (829) | 2,484 (1123) | -807*** | -0.69 |
| JImp | Asc. vs. Ran. | 1,676 (829) | 1,972 (1005) | -296* | -0.36 |
| | Des. vs. Ran. | 2,484 (1123) | 1,972 (1005) | 511** | 0.44 |
| | Asc. vs. Des. | 2,686 (1065) | 3,317 (1707) | -631** | -0.54 |
| JA | Asc. vs. Ran. | 2,686 (1065) | 2,962 (1419) | -276* | -0.27 |
| | Des. vs. Ran. | 3,317 (1707) | 2,962 (1419) | 354* | 0.29 |
| | Asc. vs. Des. | 4,130 (1905) | 4,044 (3718) | -815** | -0.27 |
| JU | Asc. vs. Ran. | 4,130 (1905) | 3,922 (2034) | 207 n.s. | 0.18 |
| | Des. vs. Ran. | 4,044 (3718) | 3,922 (2034) | 1,022** | 0.38 |
| | Asc. vs. Des. | 6,562 (3783) | 7,116 (6459) | -554 n.s. | -0.16 |
| JInt | Asc. vs. Ran. | 6,562 (3783) | 6,443 (4702) | 120 n.s. | 0.03 |
| | Des. vs. Ran. | 7,116 (6459) | 6,443 (4702) | 674 n.s. | 0.21 |

*Asc.= Ascending, Des.= Descending, Ran.= Randomised*
*Bonferroni corrections: ***highly significant; **significant; *weakly significant; n.s.= not significant; r<0.20= negligible; 0.20≤r<0.50= small; 0.50≤r<0.80= moderate; r≥0.80= strong*

Table 4 reports the results of the t-tests, providing, for each glare criterion, the comparison between order sequences under examination, the mean (M) and standard deviations (SD) of the glare source luminance for each sequence, the differences between means (ΔM), their statistical significance (NHST), and the effect size (Pearson's r).

Inspection of descriptive and inferential statistics shows no consistent directionality of the sign for the mean differences and the effect sizes across all comparisons, this being consistent with the adoption of a two-tailed hypothesis. Out of the twelve comparisons, the differences between mean values of source luminance are highly significant in one case, significant in four cases, weakly significant in three cases, and not significant in four cases. For all settings made to the highest criterion of discomfort (Just Intolerable), the effect of order sequence was not statistically significant. The differences detected were mostly of substantive magnitude, with effect sizes ranging from moderate ($0.50 \le r < 0.80$ in two cases) to small ($0.20 \le r < 0.50$ in seven cases). Negligible effects were detected for three comparisons ($r < 0.20$).

## 4. DISCUSSION AND LIMITATIONS

Two experiments were designed to study the potential influence of sources of experimental bias on errors between predicted and actual discomfort due to glare: 1) anchor; and, 2) order effects.

From the anchor effects experimental data, Table 5 displays, for each MCS level of glare sensation, the anchor used, the mean IES-GI, and the corresponding glare criterion based on Hopkinson's scale [15].

*Table 5. Initial anchor and corresponding glare criteria*

| MCS | Anchor | Mean IES-GI |
|---|---|---|
| JImp | Low | 9.81 (No Glare) |
| | Medium | 14.07 (Just Imperceptible) |
| | High | 17.97 (Just Acceptable) |
| JA | Low | 13.57 (Just Imperceptible) |
| | Medium | 16.17 (Just Acceptable) |
| | High | 19.92 (BCD) |
| JU | Low | 16.45 (Just Acceptable) |
| | Medium | 18.55 (BCD) |
| | High | 21.61 (BCD) |
| JI | Low | 20.47 (BCD) |
| | Medium | 22.47 (Just Uncomfortable) |
| | High | 24.42 (Just Uncomfortable) |

The results of the anchor effects experiment show that, for the same level of glare sensation across the three anchors, the mean values of IES-GI correspond to different discomfort glare criteria (on Hopkinson's scale). This demonstrates that, when luminance adjustment are performed from different anchors, the final settings can vary considerably. This finding questions the alleged precision of glare index values from artificial light sources calculated to estimate the levels of visual discomfort perceived by an observer.

Inferential analysis of the data from the order effects experiment confirmed that the sequence of tests had substantive influence on the final settings made by participants for the same level of discomfort glare. The order effect on glare settings appeared to be larger at lower levels of glare sensation.

Before drawing conclusions on the theoretical and design implications of these results, some methodological limitations need to be acknowledged. Among these, it should be noted that in the anchor effects experiment the mean IES-GI values presented in Table 5 are all lower than the corresponding discomfort criterion for the same reported level of glare sensation, regardless of the anchor used. Although it is difficult to determine the reasons for this, it is likely that glare evaluations were influenced by the available range of the variable stimulus. In fact, in the experimental procedure, the maximum luminance was set at 32,000 cd/m$^2$. If a lower or higher maximum luminance had been used, the results could have been different. The study of range bias needs to be the object of further work.

For the order effect experiment, it must be considered that the ascending sequence was used to replicate the test methodology used in the mentioned fundamental glare studies [4, 5, 6], the descending sequence was adopted as its reverse procedure, and the randomised sequence was used as a potential good practice to overcome order effects [19]. The Ascending vs. Randomised comparison, therefore, should reveal the differences in results between a study that uses Hopkinson's approach in terms of scale and procedure and one that follows good experimental practice. This comparison suggests that the magnitude of the order effect was significant and substantive (non-negligible effect size, $r > 0.20$) for Just Imperceptible and Just Acceptable, but not for the other two glare criteria.

One might question whether combining the data obtained under an ascending and a descending order, and using the mean as best estimate, might lead to results that are in accordance with those achieved under a randomised sequence. Randomised orders are, in fact, generally considered the most robust experimental approach. Where this is not possible, taking the mean of results gained using lower and upper anchors may provide the best estimates [20].

To offer an initial exploration of such hypothesis, the mean source luminances of the glare source corresponding to the adjustment settings made for the four discomfort glare criteria under the ascending and descending orders were combined and then compared to the mean source luminance settings made by test subjects under the randomised sequence. Figure 4 illustrates the results of the comparison in terms of mean source luminances, standard deviations, and mean differences. At the lowest two criteria of discomfort glare, the plots show a relatively small difference in mean source luminance between the combined and the randomised sequences (respectively, ΔM= 68.11 and 38.93 cd/m$^2$). At higher glare criteria, the mean luminance values obtained from the combined data are larger than the adjustment settings made under the randomised sequence (with differences, respectively, of ΔM= 615.08 and 436.24 cd/m$^2$).

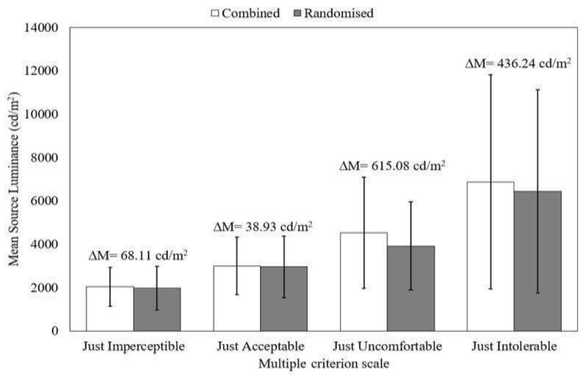


*Figure 4. Mean source luminances for the four glare criteria under the combined and the randomised test sequences.*

This was to be anticipated considering that, as shown in Figure 3, at lower levels of visual discomfort, the mean source luminance values under the randomised sequence fell between the mean values recorded for the ascending and descending orders. Conversely, at higher discomfort glare criteria, the adjustment settings made under the ascending and descending orders were both performed at higher luminances than the randomised sequence.

Further testing could not be performed to analyse the statistical and practical significance of the differences detected since, due to the methods used for the collection of our data, the assumption of independence could not be met. In fact, the statistical significance of the differences cannot be calculated when the luminance settings given by the same test participant in separate conditions (e.g., ascending and descending orders) are combined. However, these initial observations can be useful for future experimental designs, particularly in the presence of constraints in terms of time and resources.

## 4. CONCLUSION

While it is not common in discomfort glare research to question the procedures used to derive experimental data in fundamental studies, there is a need to identify key sources of methodological bias to address current limitations of glare models [21].

In this context, the results of two experiments, conducted under artificial lighting controlled laboratory conditions, provided statistically significant and practically relevant evidence that: 1) luminance adjustments used to test the level of discomfort due to glare from a bright light source are biased by the initial luminance setting (anchor); (2) a luminance adjustment experimental procedure is influenced by order effects, particularly at lower glare criteria.

These results suggest the need to critically review the test methodology used in glare studies that have used luminance adjustments from only a low initial glare source setting (anchor bias) and uniquely under an ascending sequence of glare stimulus (order effect). Conversely, this study demonstrates the importance of providing strong reasoning when specifying experimental design and procedures for glare evaluations, and suggests a need to question the robustness of current indices for discomfort glare.


## ACKNOWLEDGEMENTS

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## REFERENCES


1. Kent MG, Fotios S, Altomonte S (2017). Discomfort glare evaluation: The influence of anchor bias in luminance adjustments. *LR&T*, doi.org/10.1177/1477153517734280.
2. Kent MG, Fotios S, Altomonte S (2018). Order effects when using Hopkinson's multiple criterion scale of discomfort due to glare. *Build Env*, 136: 54-61.
3. CIE (2011). *CIE S 017/E:2011 ILV: International Lighting Vocabulary*. CIE: International Commission on Illumination.
4. Hopkinson RG (1940). Discomfort glare in lighted streets. *Trans Illum Eng Soc*, 5(1-9): 1-32.
5. Luckiesh M, Guth SK (1949). Brightnesses in Visual Field at BCD. *Illum Eng*, 44: 650-670.
6. Petherbridge P, Hopkinson RG (1950). Discomfort glare and the lighting of buildings. *Trans Illum Eng Soc*, XV: 39-79.
7. Robinson W, et al. (1962). The development of the IES Glare Index System. *Trans Illum Eng Soc*, 27(1): 9-26.
8. SLL (2012). *Code for lighting*: Society of light and lighting.
9. IESNA (2010). *Lighting Handbook*. New York: IESNA.
10. CIE 177-1995. *Discomfort glare in interior lighting*. CIE.
11. Hopkinson RG, Bradley RC (1960). A study of glare from very large sources. *Illum Eng*, 55(5): 288-294.
12. Chapman GB, Johnson EJ (1999). Anchoring and values construction. *Org Beh & Hum Dec Proc*, 79 (2): 115-153.
13. Logadottir A, Christoffersen J, Fotios S (2011). Investigating the use of an adjustment task to set the preferred illuminance. *LR&T*, 43: 403-422.
14. Kent MG, Altomonte S, Tregenza PR, Wilson R (2015). Discomfort glare and time of day. *LR&T*, 47: 641-657.
15. Hopkinson RG (1960). Note on use of indices of glare for a code of lighting. *Trans Illum Eng Soc*, 25(3): 135-138.
16. Velds M (2002) User acceptance studies to evaluate discomfort glare in daylit rooms. *Sol Ener*, 73(2): 95-103.
17. Altomonte S, Schiavon S (2013). Occupant satisfaction in LEED and non-LEED buildings. *Build Env*, 68: 66-76.
18. Ferguson CJ (2009). An effect size primer: a guide for clinicians and researchers. *Prof Psych*, 40(5): 532-538.
19. Field A, Hole G (2013) H*ow to design and report experiments*. London: Sage.
20. Gescheider GA (1997). *Psychophysics: The fundamentals*. New Jersey: Lawrence Erlbaum Associates.
21. Fotios S (2018). Correspondence: New methods for the evaluation of discomfort glare. *LR&T* 50: 489-491.