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Analysis of a questionnaire for visual comfort assessments: Effects of question formats

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Abstract: This study tests two sets of questionnaires to collect subjective lighting assessments. The questionnaires, one using semantic differentials and the other using Likert-type statements, were presented to 48 participants to compare the differences due to the question format. Experiments were performed in a climate chamber simulating an open-plan office. In a randomized order, participants were exposed to three temperatures (20 °C, 25 °C, and 30 °C) while the artificial lighting was constant (550 lux, 3200 K). Light perception, visual comfort, and acceptability were assessed through 13 items using 7-point scales. Overall, the statement format had higher internal consistency than the semantic differential format. Questions about visual comfort seemed to be reliable under both questionnaire formats, while further development of questions about perception is needed to increase their internal consistency. Although most of the answers were not different due to the questionnaire format ($n_{average}$= 61.5%), 38.5% of the answers were different, and the changes were small or moderate and statistically significant in eight items. Further analysis compared the effect of the temperature on lighting evaluations. Our results contribute to a better understanding of the implications of formulating questions on subjective responses and might help develop questionnaires for the field of visual comfort.

Keywords: visual comfort, visual perception, visual acceptability, questionnaire.

1. Introduction

Lighting surveys are powerful tools to collect data about occupants' perception, satisfaction, acceptability, and needs. For years, researchers in daylighting and lighting have been asking people in different ways with such purposes (Allan *et al.*, 2019). The assessment of glare has drawn the attention of many researchers and therefore, it is possible to find comprehensive literature about the development and adjustments of the glare scale to ensure a better understanding of the participants (Fotios, 2018; Fotios and Kent, 2021). Although a consensus about questions and scales, among other aspects, seems nonexistent, Fotios (2018) conducted a broad review of category rating scales and summarized some recommendations for the design of questionnaires for research in lighting.

This study tested two sets of questionnaires used to collect subjective assessments about perception, visual comfort, and acceptability of the visual environment.

2. Method

The data presented in this paper is part of a more extensive experiment. Forty-eight healthy subjects (50% females) participated in a series of controlled experiments performed in a climate chamber with no windows to the surrounding space (except a small porthole in the chamber door) or to the outside. The chamber set-up simulates an office environment with six workstations, including computers.

In a randomized order, each participant was exposed to three temperatures (Cool= 20 °C, Neutral= 25 °C, and Warm= 30 °C) while the artificial lighting was constant [550 lux (+- 50 lux), 3200 K). The duration of each experimental session was 120 min. After the first 30 min (adaptation period), the participants remained seated until the end of the session (90 minutes more, Figure 1). Participants answered five rounds of digital questionnaires after regular intervals using their computers. Two sets of questionnaires were presented in two rounds under each condition.

Adaptation	Exposure period			
	Round 1		Round 2	
30 min	18 min	54 min	72 min	90 min
120 min				

Figure 1. Experimental session design.

2.1. Questionnaires

Two separate questionnaires, composed of 13 items using 7-point scales, presented two formats for asking the participants about their lighting perceptions (6 items), comfort (6 items), and acceptability (1 item). In one of the questionnaires, semantic differentials were used, while the other questionnaire asked for the degree of agreement to diverse statements, as Van Den Wymelenberg and Inanici (2014) implemented. Perception questions were based on Amorim *et al.* (2022), in which seven light descriptors were used to investigate participants' perceptions. The second section asked about visual comfort in terms of color, light level, distribution, glare, and an overall assessment of the visual environment. One last question asked about the acceptability of the visual environment. Figure 2 presents the two formats used for the questionnaires.

2.2. Data analysis

The internal consistency or reliability of the scales was assessed through Cronbach's Alpha (α) coefficient (Cronbach, 1951). To interpret the results, we followed the recommendations of George and Mallery (2003), presented in Table 1. The analyses were conducted separately for each temperature and questionnaires administration round.

Table 1. Interpretation of Cronbach's Alpha (α)

Internal consistency	Cronbach's α	Internal consistency	Cronbach's α
Excellent	$0.9 \leq \alpha$	Questionable	$0.6 \leq \alpha < 0.7$
Good	$0.8 \leq \alpha < 0.9$	Poor	$0.5 \leq \alpha < 0.6$
Acceptable	$0.7 \leq \alpha < 0.8$	Unacceptable	$\alpha < 0.5$

To examine the differences in participants' answers due to the question format (semantic differentials vs. agreement with the statements), we used non-parametric tests for repeated measures. Thus, Wilcoxon signed-rank tests were run to examine differences between each question. Furthermore, the effect of air temperature changes on lighting assessments was examined within each type of questionnaire using Friedman's ANOVA. Statistical analyses were conducted in R software (R Core Team, 2021).

Semantic differentials

Perception

Q1 How do you perceive the color of the lighting in the room?
[Cold ○ ○ ○ ○ ○ ○ ○ *Warm]*
1 2 3 4 5 6 7

Q2 How do you perceive the color of the room surfaces?
[Distorted ○ ○ ○ ○ ○ ○ ○ *Natural]*

Q3 How do you perceive the room?
[Dark ○ ○ ○ ○ ○ ○ ○ *Bright]*

Q4 How do you perceive the light distribution in the room?
[Uneven ○ ○ ○ ○ ○ ○ ○ *Uniform]*

Q5 How do you perceive the glare, if any, caused by the lamps?
[Perceptible ○ ○ ○ ○ ○ ○ ○ *Imperceptible]*

Q6 Overall, how do you find the visual appearance of the room?
[Not pleasant at all ○ ○ ○ ○ ○ ○ ○ *Very pleasant]*

Comfort

Q7 How do you find the color of the lighting in the room?
[Very Uncomfortable ○ ○ ○ ○ ○ ○ ○ *Very Comfortable]*

Q8 How do you find the appearance of the surfaces' colors?
[Very Uncomfortable ○ ○ ○ ○ ○ ○ ○ *Very Comfortable]*

Q9 How do you find the lighting level/amount of light in the room?
[Very Uncomfortable ○ ○ ○ ○ ○ ○ ○ *Very Comfortable]*

Q10 How do you find the light distribution in the room?
[Very Uncomfortable ○ ○ ○ ○ ○ ○ ○ *Very Comfortable]*

Q11 How do you find the glare, if any, caused by the lamps?
[Very Uncomfortable ○ ○ ○ ○ ○ ○ ○ *No glare]*

Q12 Overall, how do you find the visual environment of the room?
[Very Uncomfortable ○ ○ ○ ○ ○ ○ ○ *Very Comfortable]*

Acceptability

Q13 At this moment, how do you judge the visual environment?
[Unacceptable ○ ○ ○ ○ ○ ○ ○ *Acceptable]*

Statements

Perception

Q1 The color of the lighting in the room is Warm
[Very strongly disagree ○ ○ ○ ○ ○ ○ ○ *Very strongly agree]*
1 2 3 4 5 6 7

Q2 The color of the surfaces seems natural, without distortion
[Very strongly disagree ○ ○ ○ ○ ○ ○ ○ *Very strongly agree]*

Q3 The room seems bright
[Very strongly disagree ○ ○ ○ ○ ○ ○ ○ *Very strongly agree]*

Q4 The light is distributed evenly in the room
[Very strongly disagree ○ ○ ○ ○ ○ ○ ○ *Very strongly agree]*

Q5 There is imperceptible glare in the room caused by the lamps
[Very strongly disagree ○ ○ ○ ○ ○ ○ ○ *Very strongly agree]*

Q6 Overall, the visual appearance of the room is very pleasant
[Very strongly disagree ○ ○ ○ ○ ○ ○ ○ *Very strongly agree]*

Comfort

Q7 The color of the lighting in the room is very comfortable
[Very strongly disagree ○ ○ ○ ○ ○ ○ ○ *Very strongly agree]*

Q8 The appearance of the surfaces' colors is very comfortable
[Very strongly disagree ○ ○ ○ ○ ○ ○ ○ *Very strongly agree]*

Q9 The amount of light in the room is very comfortable
[Very strongly disagree ○ ○ ○ ○ ○ ○ ○ *Very strongly agree]*

Q10 The light distribution in the room is very comfortable
[Very strongly disagree ○ ○ ○ ○ ○ ○ ○ *Very strongly agree]*

Q11 The lamps do not cause glare
[Very strongly disagree ○ ○ ○ ○ ○ ○ ○ *Very strongly agree]*

Q12 Overall, the visual environment of the room is very comfortable
[Very strongly disagree ○ ○ ○ ○ ○ ○ ○ *Very strongly agree]*

Acceptability

Q13 At this moment, the visual environment is acceptable
[Very strongly disagree ○ ○ ○ ○ ○ ○ ○ *Very strongly agree]*

Figure 2. Questions using semantic differentials (left) and agreement with the statement (right). The numerical values of the scales were not presented to the participants.

3. Results

3.1. Internal consistency

We tested the internal consistency of the applied scales by considering the entire questionnaire (13 items or questions) and the Perception and Comfort sections independently (6 items each). The analyses were run separately for each condition and round of the administration of the questionnaires. Table 2 presents these results.

Both questionnaires showed good or excellent reliability (α > .8). Items about comfort appear to have good or excellent reliability as well. Nevertheless, perception items had lower Cronbach's α, indicating questionable or even poor internal consistency, especially for the Cool condition (20 °C). Thus, the items considered for the perception have little interrelatedness (Cortina, 1993). Overall, Cronbach's α was slightly higher when using the statements' format (shaded columns in Table 2).

Table 2. Internal consistency of the entire set of the questionnaire and Perception and Comfort sections.

Condition and admin. round		Entire questionnaire (13 items)		Perception (6 items)		Comfort (6 items)	
		Semantic differentials	Statements	Semantic differentials	Statements	Semantic differentials	Statements
		Cronbach's α	Cronbach's α	Cronbach's α	Cronbach's α	Cronbach's α	Cronbach's α
Warm	1st	.89	.91	.60	.69	.90	.91
	2nd	.90	.90	.68	.69	.88	.89
Neutral	1st	.90	.89	.62	.65	.90	.88
	2nd	.91	.90	.66	.64	.91	.89
Cool	1st	.86	.91	.45	.66	.89	.91
	2nd	.88	.90	.57	.65	.88	.91

3.2. Differences between semantic differential questionnaires and statements agreement

The percentage of answers that were not changed and those that were different in each questionnaire are presented in Table 3. Changes were considered as an "increase" or "decrease" in the rating by subtracting the difference between the semantic differential and statements ratings. Thus, increases were when the answer's rating using statements was higher than the rating with semantic differentials. A decrease in the answer means a lower rating when using statements and higher ratings when using semantic differentials. Only when asked about the perception of the surfaces' colors (Q2), less than half of the answers (46.5%) were with the same rating in both questionnaires. Comparing the changes in the answers, items Q4, Q11 and Q13 (Figure 2) had more answers with a lower rating when statements were presented (light green in Table 3). For the remaining items of the questionnaires, there were more answers with higher ratings (increased) using the statement format.

Table 3. Participants (%) did not change the answers, and participants with different answers.

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
No change	51.4%	46.5%	56.9%	70.1%	53.5%	60.1%	58.3%	62.2%	60.8%	64.9%	71.9%	75.0%	68.4%
Increased	37.2%	29.5%	29.5%	12.5%	24.7%	30.6%	30.6%	21.2%	22.6%	21.5%	13.5%	16.0%	11.5%
Decreased	11.5%	24.0%	13.5%	17.4%	21.9%	9.4%	11.1%	16.7%	16.7%	13.5%	14.6%	9.0%	20.1%

Increase/Decrease = Semantic differential rating – Statement rating

Table 4. Differences between questionnaires: summary of statistics and p-value for Wilcoxon signed-rank tests

Item	Semantic Differentials				Statements				*p-value* (effect size)
	Median	Mean	SD	IQR	Median	Mean	SD	IQR	
Q1	5	5.01	1.06	1	5	5.38	1.05	1	.000 (r= - .39)
Q3	6	5.65	0.92	1	6	5.83	0.94	1.25	.000 (r= - .23)
Q6	5	4.40	1.38	2.25	5	4.67	1.37	3	.000 (r= - .32)
Q7	5	4.74	1.30	2	5	5.00	1.28	2	.000 (r= - .28)
Q9	5	4.74	1.54	3	5	4.87	1.54	2	.000 (r= - .12)
Q10	6	5.32	1.32	2	6	5.43	1.23	1	.032 (r= - .13)
Q12	5	4.51	1.41	3	5	4.62	1.43	3	.012 (r= - .15)
Q13	5.5	5.15	1.42	2	5	5.06	1.38	2	.024 (r= - .13)

For each of the 13 items, we tested whether participants' answers were different due to the question format (Table 4). Wilcoxon signed-rank tests showed significant differences in participants' answers to the items Q1- perception of light color, Q3- perception of light levels, Q6- visual pleasantness, Q7- comfort with the color of the light, Q9- comfort with light levels, Q10- comfort with the light distribution, Q12- comfort with overall visual environments, and Q13- acceptability. Although, even with significant differences, we found small differences, especially in comfort assessments (Q9, Q10, Q12 and Q13), due to the format of the questions. Except the comparison of Q13, even when the median values were equal in both groups, the tests reported significant differences, which can be explained by variations in the distribution, as shown in Figure 3.

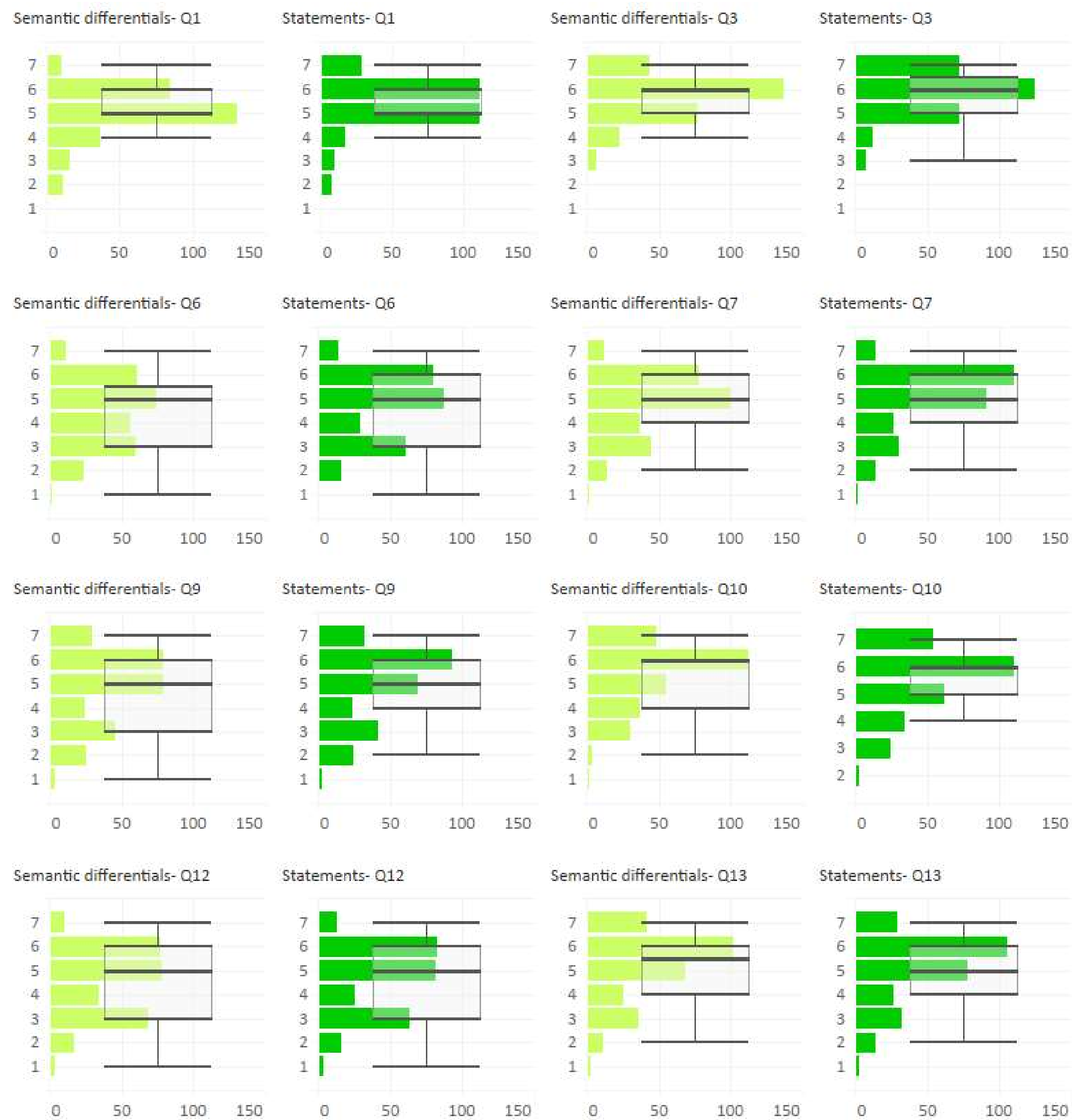

Figure 3. Differences due to the questionnaire format. Frequencies and boxplots of the items with significant differences.

3.3. Differences due to changes in air temperature

Some studies investigating the effect of temperature on visual assessments have shown an interaction between these two domains (te Kulve *et al.*, 2016; Toftum *et al.*, 2018; Brambilla *et al.*, 2020). With both questionnaires and under the specific lighting conditions, the perception of the color of the light (Q1) was significantly affected by the air temperature ($p < .0001$ for semantic differentials; $p < 0.01$ for statements). Using semantic differentials, the post hoc tests indicated that light was perceived as warmest under Neutral and Warm thermal condition [Cool vs. Neutral (Observed dif. = 35; Critical dif. = 33.17, $p < .05$) and Cool vs. Warm (Observed dif. = 35; Critical dif. = 33.17, $p < .05$)]. When using statements, the perception of the color of the light was significantly different only between Cool vs. Warm conditions (Observed dif. = 37; Critical dif. = 33.17, $p < .05$) (Figure 4). Although we found significant differences in items Q5, Q6, Q12, and Q13 of the statements questionnaire, post hoc tests did not confirm these.

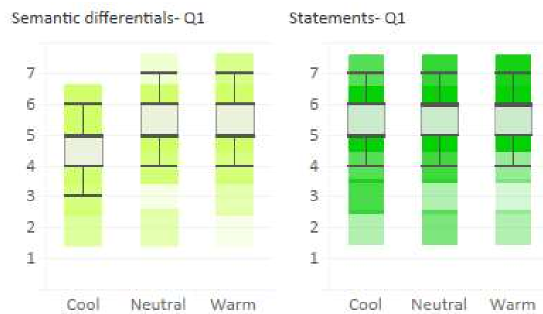

Figure 4. Differences in perception of the color of the light (Q1) under each thermal condition.

4. Conclusion

From this brief study, we reached three conclusions:

1. Overall, questionnaires using the statements format had a higher Cronbach's Alpha coefficient, indicating that this questioning format might have higher internal consistency than the semantic differential format. Questions about visual comfort seemed to be reliable with both questionnaire formats. However, perception items presented lower internal consistency. Therefore, further development of questions about perception is needed to increase their internal consistency and, consequently, the reliability of the results.
2. Although most of the answers were not different due to the questionnaire format ($n_{average}$= 61.5%), an average of 38.5% of the answers were different due to the questionnaire format, which represented an increase of the answer rating for most of the questions. Additionally, changes in the answers were small or moderate and statistically significant in eight items (Table 4).
3. Under the tested conditions, changes in air temperature significantly affected the perception of the color of the light. Differences in the perception of glare, the overall appearance of the room and comfort, and acceptability of the visual environment seemed to be significant; however, there was not enough evidence to confirm significant differences between the conditions when running the post hoc tests.

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