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Exploring factors influencing visual comfort in an aircraft cabin

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ABSTRACT

Visual stimulus might influence comfort of passengers in air travel. For a better understanding of the visual comfort, it is crucial to identify the constructs of the visual stimulus in the cabin and the contributions of different elements. A two-step approach was adopted in this study where in the first step, several creative sessions were executed for exploring the effect of different elements in the cabin regarding their impact on visual comfort. To inspire the participants, all creative sessions were held in a Boeing 737 cabin where participants were free to explore and had an immersive experience. All identified elements in the creative session were collected and grouped to different categories, that is use as input for the second step, which is an online survey investigating a possible hierarchy of the impact of those categories of elements on visual comfort. Eight were summarized and the three most influential categories were lighting, colour and the space arrangement. These were significantly different from other categories, namely the seat shape, the pattern, the windows, accessories and existence of advertisements. Regarding the gender and the age of the participants, we did not find significant differences regarding the preferences.

KEYWORDS

Aircraft interior, visual comfort, user involvement

Introduction

Offering a high level of comfort and reducing the level of discomfort of passengers will increase the competitive advantage of the airlines (Ahmadpour et al., 2016) as there is a strong correlation between comfort experience and willingness to fly with the same airline (Bouwens et al., 2018). Comfort "*is seen as a pleasant state or relaxed feeling of a human being in reaction to its environment*" (Vink & Hallbeck, 2012), and it consists of many constructs including the product, the environment, the physiological, physical and mental state of the subject influenced by his/her interactions with the environment. Visual comfort is "*a subjective condition of visual well-being induced by the visual environment*" (ECS., 2002), and it is an important construct of the overall comfort. For instance, lighting, as a visual stimulus, is considered as one of the most influential factors of comfort (Krist, 1993),(Bubb et al., 2015).

Passing through the pupil, sensed by photoreceptors in the retina, transmitted by the optic nerve, the visual signal passes to the nervous system (Land, 2020). Signals received by the eyes are processed by different areas of the brain. For instance, the parahippocampal place area (PPA) is highly activated when the task is related to the physical environment, such as buildings and place scenes (Epstein & Kanwisher, 1998). The PPA is also considered highly related to identifying social context tasks (Hurley, 2008). However, the PPA did not play a major role in sensing human faces, which are carried out by the fusiform face area (FFA)(Kanwisher et al., 1997).

Visual perception might be a conscious and/or subconscious process (Orlandi, 2014). The high level brain activities involved in the vision process of the complex tasks indicate that the visual perception has strong physiological effects (Balcetis & Lassiter, 2010), subsequently it influences the perceived comfort and discomfort of users in different contexts. For instance, in previous studies, it was suggested to have daylight through windows to reduce stress (Boyce et al., 2003). Lighting designers also used dynamic stage lighting to affects the perception for a better experience (Yu, 2015). For instance, Konis (Konis, 2014) found that despite the frequent subjective responses of visual discomfort from windows, occupants in the perimeter zones generally left a portion of the vision window unshaded to maintain visual connection to the outdoors.

Poor illumination conditions or over exposure to strong lights may cause discomfort in the eyes, influencing eye (Than, 2010) health in the long term (Wang et al., 2020). As a result, studies regarding lighting conditions in the working environment concern mainly screen involvement, are conducted by many researchers in the past decades (Saito et al., 1993),(Carlucci et al., 2015). For instance, they concluded that glare should be eliminated because it is one of the main causes of errors, fatigue, and accidents in the working environment (Velds, 2002) (Kim & Kim, 2010)(Wolska & Sawicki, 2014). Besides, patterns in the light might influence the visual comfort as well, though the shape of window and sunlight patterns might have limited to no impact on visual comfort and interest in offices when workers are preoccupied performing typical office work. Only the fractal and striped patterns negatively influenced view quality compared to the homogenus condition (Abboushi et al., 2020).

Different spectra of the light also have different effects on the perception. Psychologists discussed the impact of different colours on human cognition and behaviour in different social contexts (Elliot & Maier, 2014). To describe feelings triggered by different colour combinations, colour harmony was defined as '*colours seen together to produce a pleasing affective response*', for instance, positive emotions can be evoked by looking at a painting (Sartori, 2014). Intensity and colour spectrum often have a combined effect on the comfort of the user, e.g. in the use of a computer screen, a warm (3000K) and high intensity (1500 lux) desktop light might reduce the visual and cognitive fatigue of the user and improve the comfort of the user (Han et al., 2021).

In summary, the visual environment can influence human's perception in different ways. While travelling, passengers often do not have a clear cognitive task and they have more spare time to explore the environment, therefore, the visual experience is an important construct of their overall comfort. However, most studies regarding visual comfort are focusing on lighting in buildings and the visual effects on the screen. Factors besides lighting in a physical environment, especially in a specific context, aircraft cabin, are not fully explored (Carlucci et al., 2015).

This paper aims to explore the factors that influencing visual comfort in an aircraft cabin and the hierarchy of the factors for giving an overview of the impact of different factors, especially the factors besides lighting condition, regarding visual comfort.

Methods

To explore the constructs of visual comfort in the aircraft cabin, a two-step approach was adopted. In the first step, we held several creative sessions to explore the types of factors that may influence the visual comfort in the cabin. Based on this exploration, we grouped the identified factors and conducted an online survey, where more participants were invited.

Step 1: Creative sessions

As the first step, three creative sessions were hosted in a Boeing 737 cabin equipped with different types of seats. 12 participants who had the experience of travelling by airplanes in the past three years were invited. Their age varied from 23 to 39. Each session had four subjects and a researcher hosted and moderated the session. All the sessions follow the following procedure:

- The researcher welcomes the participants, explains the purpose and the protocols of the session;
- Participants sign the consent forms;
- Participants are encouraged to try different seats in the cabin freely to look at the cabin from different perspectives;
- Participants sit together to talk about their feelings on visual experience in the cabin;
- Participants check the pictures of different aircraft cabins prepared by the researcher before the session and discuss the visual comfort of different aircraft cabins;
- Participants cluster the pictures base on their experience regarding visual comfort.
- Participants discuss and summarize critical elements of visual comfort.
- Participants try to categorize the elements based on the discussions.

A complete session was often finished within 1.5 hours. Figure 1 shows the materials prepared for the session and in the creative session, participants were summarizing visual comfort factors base on their experience. After finishing all sessions, the categories and elements summarized by the three groups were merged. Some elements were only mentioned by some groups, the times of being emphasized were recorded as well.

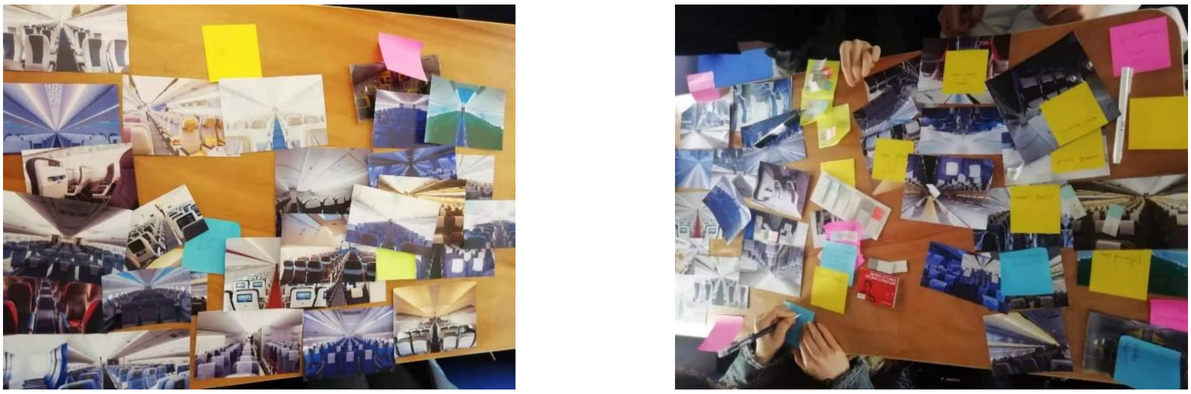

Figure 1: (a) A sample of the materials that used for the creative session, (b) Participants are summarizing the factors of visual comfort

Step 2-online survey

After three creative sessions, the researcher summarized all the elements mentioned by the participants, and they are used as the input of the online survey. In the survey, pictures used in sessions were grouped based on different factors as collage(s) (Fig.2) and presented to subjects regarding each categories. After viewing this collage, participants were asked about the importance of the factors regarding visual comfort. The importance of each category for visual comfort experience was evaluated by a 7-point Likert scale (1 stands for not important all and 7 stands for very high importance). 30 responses from people aged 23-38 (22 females and 8 males) were collected. None of the participants has colour deficiency but the vision of five participants was not corrected(have myopia but not wear glasses).

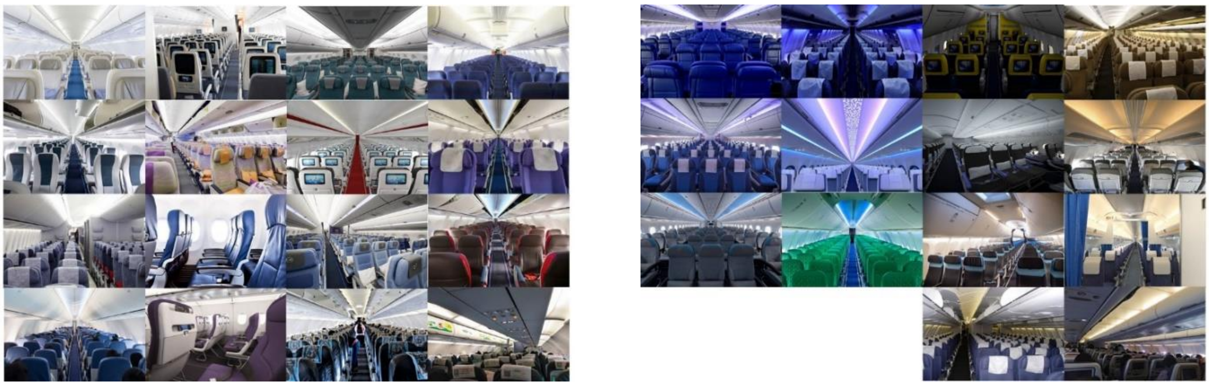

Figure 2: Examples of the collages used in online survey

The mean and standard deviation of the rank was calculated for each factor. All the elements within the same category were averaged to get the scores for different categories. A Shapiro Wilk test was conducted to check the normality of each category. Besides the category 'Existence of advertisements', the preference of the participants are normally distributed. T-tests were conducted between every two categories except category 'Existence of advertisements'. Wilcoxon rank tests were conducted between 'Existence of advertisements' and other categories. Two categories are considered significantly different when $p<0.05$. Spearman correlation coefficient was calculated between age and 'Existence of advertisements'. Pearson correlation coefficient were calculated between age and other categories. Kendall correlation coefficient were calculated between gender and all the categories.

Results

The results of the creative sessions are presented in Table 1. Among all factors, the three most influential elements are lighting brightness (6.07 of 7), lighting colour(6.03 of 7) and colour harmony, including contrast and combination (5.93 of 7).

Table 1: Elements and categories summarize from co-creation sessions and mean score of each element from online survey (higher score is of more importance for visual comfort)

Merged results of three co-creation sessions			**Results of the online survey**	
Categories	**Elements**	**Number of groups mentioned**	**Mean scores (in a scale between 1 to 7)**	**SD**
Colour	Colour harmony(contrast &combination)	3	5.97	1.08
	Hue	3	5.50	1.09
	Lightness	3	5.53	1.38
	Saturation	3	5.27	1.44
	Seat colour	3	5.80	1.35
	Carpet colour	2	4.80	1.42
	Ceiling colour	1	5.53	1.33
Pattern	Seat cloth pattern	3	4.97	1.60
	Lighting pattern	1	5.37	1.45
	Carpet pattern	1	4.17	1.79

	Integration of the pattern	1	4.77	1.82
Lighting	Brightness	3	6.07	0.96
	Colour	3	6.03	1.02
	Temperature	3	5.73	1.18
	Diffuseness	2	5.43	1.48
	Amount of natural light (from window)	1	5.43	1.56
Seat shape	Thickness of backrest	3	4.70	1.66
	Size	2	5.70	1.46
	Fluffiness	2	4.70	1.53
	Round edges	3	4.63	1.83
	Headrest	3	4.27	1.79
	Seat materials	3	5.37	1.40
Windows	Size	2	5.30	1.34
	Position	1	5.40	1.33
	Amount	2	5.17	1.46
Space arrangement	Aisle width	2	4.67	1.66
	Openness of sight	3	4.90	1.60
	Seat allocation	1	4.60	1.43
	Integration of luggage rack	1	4.53	1.82
	Alignment	2	4.80	1.72
Accessories (Pillows, screens)	-	1	4.27	1.84
Existence of advertisements	-	1	3.93	2.05

When looking into categories, ‘Lighting’ is considered the most important (5.74/7), and ‘Existence of advertisements’ is considered the least influential factor(3.93/7). Significant differences are found between ‘Lighting’ and ‘Space arrangement’(p=0.017), ‘Seat shape’(p=0.006), ‘Pattern’(p=0.004), ‘Windows’(p=0.002), ‘Accessories’(p<0.001) and ‘Existence of advertisements’(p<0.001). The category ‘Colour’ is significantly larger than ‘Seat shape’(p=0.049), ‘Pattern’(p=0.031), ‘Windows’(p=0.014), ‘Accessories’(p=0.002)and ‘Existence of advertisements’(p<0.001). The category ‘Space arrangement’ is significantly larger than ‘Accessories’(p=0.045) and ‘Existence of advertisements’(p=0.005) but smaller than ‘Lighting’(p=0.017). We did not find strong correlations between age, gender and the preference towards different categories (Table 2).

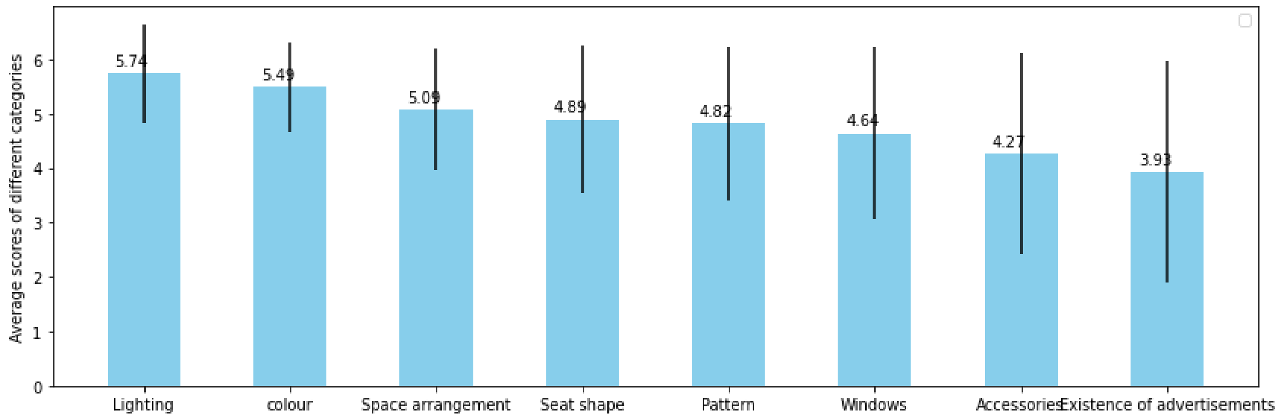

Figure 2: The preference of participants regarding different categories from online survey(n=30)

Table 2: Correlations between gender, age and the eight categories

	Lighting	colour	Space arrangement	Seat shape	Pattern	Windows	Accessories	Existence of advertisements
Age	0.235	0.398	0.324	0.369	0.329	0.275	0.199	-0.202
Gender	0.212	-0.045	-0.015	0.165	0.187	-0.297	-0.023	-0.159

Discussion

Lighting is the most influential category for visual comfort in this study. Light is already listed as one of the six most essential factors that determine perceived comfort and discomfort in past studies of Bubb et al. (2015), Krist et al. (1993) and Bouwens et al. (2018). Colour is the second most important factor for visual comfort, and "harmonic colour combinations" are an essential factor of this category. This can be related to the psychological effects of colours and different combinations (Elliot & Maier, 2014). Space arrangement is also essential for visual comfort in an aircraft cabin. This is not often mentioned for visual comfort in other contexts (Carlucci et al., 2015),(Frontczak & Wargocki, 2011). The reason could be that the space in aircraft space is a cramped (Bagshaw & Illig, 2018), and in a view, the focal distance of different elements might be quite different, which led to fatigue in a long exposure (Shibata et al., 2011).

According to a previous study, preference towards visual environment differs among different age groups (Veitch & Newsham, 2000). However, in this study, no strong correlations were found, which is perhaps due to the limited age ranges of the participants or the limited number of participants. Besides, the imbalanced gender in the survey might also "cover" different preferences of other gender(s).

In this study, creative sessions involving users are used as a method to define the factors influencing visual comfort. As one of the most effective tools in the early stage of the design, it allows users to point out what they need and helps researchers understand the situation in a more effective and efficient way (Sanders & Stappers, 2012). However, due to the limited sample size, the results can be greatly influenced by personal experience of the participants (Rahman, 2016). Thus, a quantitative approach, the survey, intended to provide more data, was conducted in the second step to validate the results of creative sessions (Kelle, 2006). The number and the diversity of the participants influence the quality of the result. In the future, we will continue collecting data for a better classification and more precise hierarchy.

Conclusion

The specific context of an aircraft cabin is a unique environment for the exploration of visual comfort. In this study, a two-step approach is used to study different factors of that may influence visual comfort in an aircraft cabin. The identified factors were summarized to eight categories through creative sessions. A proposal of the hierarchy of factors influencing visual comfort is given where the lighting, the colour(s) and the space arrangement are the most influential factors. It is suggested to improve visual comfort in an aircraft cabin, designers might address the lighting, the colour and the space arrangement first, followed by the seat shape, the pattern, the windows and accessories and advertisements.

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