Colour and Colorimetry
Multidisciplinary Contributions

Vol. XVII A

Edited by Andrea Siniscalco

GRUPPO DEL COLORE
ASSOCIAZIONE ITALIANA COLORE

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Colour and Colorimetry. Multidisciplinary Contributions. Vol. XVII A
Edited by Andrea Siniscalco
Published by Gruppo del Colore - Associazione Italiana Colore
Research Culture And Science Books series (RCASB), ISSN: 2785-115X

ISBN 978-88-99513-18-4
DOI: 10.23738/RCASB.006

Piazza C. Caneva, 4
20154 Milano
C.F. 97619430156
P.IVA: 09003610962
www.gruppodelcolore.it
e-mail: segreteria@gruppodelcolore.org

Published in the month of December 2022

Colour and Colorimetry. Multidisciplinary Contributions
Vol. XVII A

Proceedings of the 17th Color Conference.

Meeting in collaboration with:
Associação Portuguesa da Cor (PT)
Centre Français de la Couleur (FR)
Colour Group (GB)
Forum Farge (NO)
Suomen väriyhdistys SVY (FI)
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 ISBN 978-88-99513-18-4

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8. Color and Design

Fly in color. A chromatic "model" for the cabin of a commercial aircraft

Germak Claudio[1], Gabbatore Stefano[1]
[1]Politecnico di Torino – Dipartimento di Architettura e Design, Viale Mattioli 39 – 10125 Torino
Contatti: claudio.germak@polito.it, stefano.gabbatore@polito.it

Abstract
The European research CASTLE (Cabin System Design Towards Passenger Wellbeing) puts the passenger's perception of well-being at the center of a prototype commercial aeronautics project. From this point of view, the evaluation of ergonomics and the travel experience become the objectives of an analysis of the space/context in which color, integrated with the functional components, of the shape and materials, becomes a tool for the concept design of the cabin space. The methodological approach developed therefore entrusts color to a primary role in defining the state of well-being and identity of the cabin space, through a "color model" that can be scaled in relation to the colors that each company will choose for its own color image.

Keywords: CMF design (colors, materials, finishes), UXD user experience design, HCD human centered design

Introduction

There are two factors that have the greatest impact on the flight experience. The first is the characteristics of each passenger (habits and behaviors), while the second is represented by the relationships that the passenger establishes with the components of the cabin in the different phases of flight. Therefore, the approach of a conscious designer will be to consider holistically the different components to improve the overall flight experience that is evaluated through the comfort indices. Referring to the evaluations of two well-known scholars of passenger comfort, Vink and Hallbeck, it is agreed that the difference between comfort and discomfort depends on the interaction between the "person" (which has its own characteristics), the "furniture component" (from the seat to the carpet) and the "task" expected by the person in that specific flight phase.

Comfort is affected by a set of elements that each person evaluates with a different weight according to their perception and which can be divided into four macro-groups (Di Salvo and Germak, 2019) to be addressed in a holistic way, i.e., without a specific hierarchy:

- "accessibility to services", i.e. the offer of conditions designed for passengers to find or choose their seat, to receive information and orient themselves, to have contact with the outside world (extended view);
- - "physical ergonomics", determined by the postures and movements necessary to perform an action, from sitting to accessibility to adjustments, for example, related to "proxemics", understood as the control of personal and social space (Ahmadpour, 2013);
- - the "psychological microclimate", i.e., the set of environmental components such as noise and vibrations, heat, humidity and the smell of the air, functional light (Ong, 2013);
- "the visual identity" of the space, determined by its size, organization and lighting, and of the surfaces of each piece of furniture, the perception of which is strongly correlated to the effects produced by ambient light and colors.

In recent years, all these elements have been the basis of design research for the aeronautical industry, even if individually evaluated according to different hierarchies (Torkashvand, Stephane and Vink, 2019). For example, the different relevance that the authors Bubb and Vink attribute to anthropometry in terms of ergonomics of posture and movement is known. In Bubb's assessment, anthropometry appears as the last of the factors that contribute to the perception of well-being, after smell, lights, vibration, noise and climate; evaluation overturned by Vink's analysis. These evaluations do not appear on a smaller scale aspect concerning the configuration of the cabin space and the relationships between these and the flight context. Aspects that, on the other hand, the most recent literature highlights as fundamental components of the design for the habitability of the cabin and which are influenced by the habits, behaviours and cultures to which passengers belong (Yao, Song and Vink, 2021). The integrated design of these "visual" aspects therefore concerns the setting up of the cabin as a complex space with which passengers interact during the flight phases. Today, the design makes use of overall perceptual evaluations on the four macro-groups described above, among which the visual identity is strongly influenced by light and color.

Fly in color. The importance of a color design

Some designers have been able to create, through lights and colors, real experiential environments, able to involve the passenger and mitigate the traditional visual discomforts related to air travel, such as the claustrophobic feeling generated by the small size of the space and the perceptive insecurity determined by the tunnel effect linked to the prevailing longitudinal dimension of the cabin. Other designers still push this research towards the creation of virtual relationships with the outside, such as in the simulations of artificial skies projected on the ceiling and multimedia effects involving side walls and partition walls (Bagassi et al., 2015).
Fly in color (Bianco, 2018) thus becomes a metaphor for the importance of color choices guided by a design project that integrates the different perceptual dimensions attributed to color: psychological, visual, functional and cultural.

Based on these considerations, the UXD PoliTo Team, in collaboration with the well-known design firm Pininfarina, has devised a cabin set-up concept aimed at reducing the tunnel effect and the claustrophobic one, integrating different design tools with each other: the configuration of the space in "virtual rooms" delimited by lighting elements and by the chromatic tonal variation of the seats in groups of three rows, the chromatic interaction of the back wall with the carpet and the sinuosity of the lining surfaces that envelop the space without continuity.

The areas of investigation on the influence of color are: the psyche, which investigates the factors of harmony/contrast, lightness/heaviness, heat/cold, liveliness or tediousness; the visual, which detects the incidence of contrasting factors between light and dark, the saturation of the surfaces and the feeling of proximity or distance; the function, perceived as an index of hygiene or a signaling/informative element; finally, culture, an area that often associates the color choices of the cabin components (mainly the seats) with the colors of the flag, logo and airline's territory (Fig. 1).

Based on our recent semi-immersive simulations of color cabin arrangements, it appears that there is no perceptual hierarchy between these four areas. The perception of color is in fact highly subjective and linked to the passenger's previous experience, to his cultural context and to the attention he pays to the search for the motivation and meaning of a specific color. Even in the field of university teaching, we see every day how the chromatic project is one of the foundations of basic design, which cannot be separated from the theory of configuration, which must deal in an integrated way with the components of form, material and color. (Anceschi, 2006)

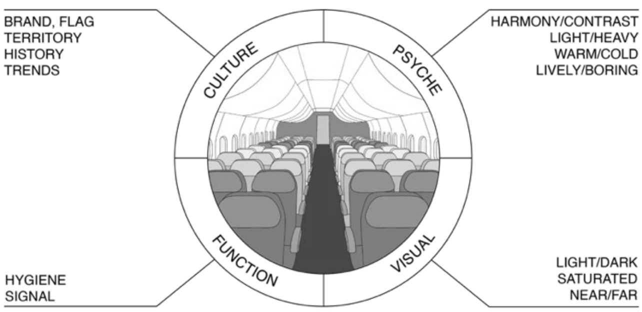
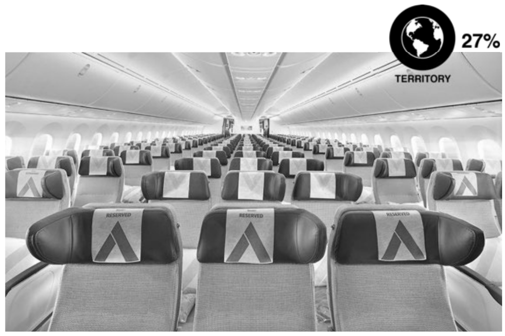


Fig. 1 – The four perceptual components of color in a commercial aircraft cabin.

In the cabin chromatic project these attentions are still little considered, so much so that most airlines choose the color of their set-up not on the basis of a perceptive project, but for other reasons. From our analysis carried out in 2019 on the top 30 companies in the world according to SkyTrax (British research company), it is noted that the companies show a chromatic choice based on:

a. *color brand/flag* (47%), relating to the color scheme of your brand or flag. It is a chromatic choice that is not always intuitive but in the case of saturated and contrasting colors it can translate into a lively, dynamic and not boring space. Obviously, the opposite is also true, with the risk of strong impact color associations and tiring over time, as in the case of RyanAir with its highly memorable yellow and blue hues;

b. *color culture* (27%), oriented towards the use of colors and textures referring to the company's traditions and territory. It is an appreciated chromatic choice that enriches the perception of the setting with cultural meanings. An example in this sense is that of the Etihad company which uses colors that reflect the warm colors of the territory (sand) and the sea (blue);



c. *color context* (26%), aimed at communicating the perception of an interior space as a place of innovative technologies (see Apple Store) or prestige through harmonious colors and light colors. It is a chromatic choice with a historicized character and which requires control over the monotony and the balance between colors that follow the principle of gravity for which the heavy masses are at the bottom and with dark and saturated colors, the light ones at the top and with lighter colors and less saturated. Among the well-known examples is the AirBus Jets 350XWB designed by Pininfarina, in which the dominant white is contrasted by blue points on the seats and on the carpet.

Other data collected concern, again within the 30 companies of the SkyTrax report, the prevalent use of colors in the components that have the greatest impact on the color perception by the passenger: seats and headrests, corridor and cabin surfaces, the latter normally in homogeneous color between side and bottom walls. Obviously, the detection takes place regardless of the use of brand/flag colors, culture or context and in any case shows a prevalent adoption of shades of blue and gray with dominant red/brown. In fact, from the interviews conducted with the companies, a trend towards very cautious color projects emerges that refer to the known psychological effects activated by some colors considered relaxing and that seek harmony through the scaling of the tonality (Fig. 2).

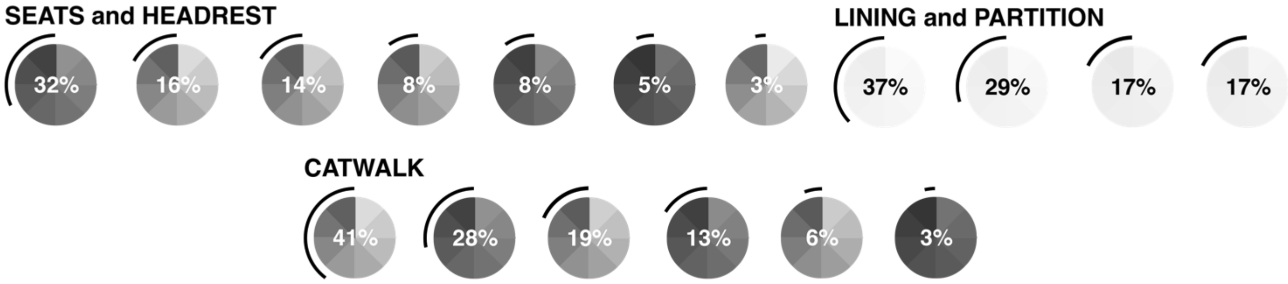


Fig. 2 – Prevalence of colors in the outfitting components of the 30 aircraft selected by the SkyTrax 2019 report.

The chromatic setting of the space/context

Among the uncomfortable situations most perceived by the passenger, the sensation of suffocation due to the narrowness of space and the insecurity related to the lack of perception of the end of the fuselage, the so-called "tunnel effect", are highlighted. We are helped by some considerations consolidated by Gestalt research, normally applied for the perceptual evaluation of the traditional built space. It must be said that some of these principles must be further re-elaborated in consideration of the atypical space of the fuselage, which is long, narrow and with a macroscopic impact of the backrest part of the seats. In addition, the perception of chromatic comfort can sometimes be influenced, at a functional level, by the difficulty of movement both in accessing the seat and in proceeding along the corridor. Some studies (Jaglraz, 2011) suggest using Gestalt principles to evaluate the perceptual variability when not the colors vary but the contrast between them, thus obtaining effects of enlargement, narrowing, lengthening, approach (Fig. 3).

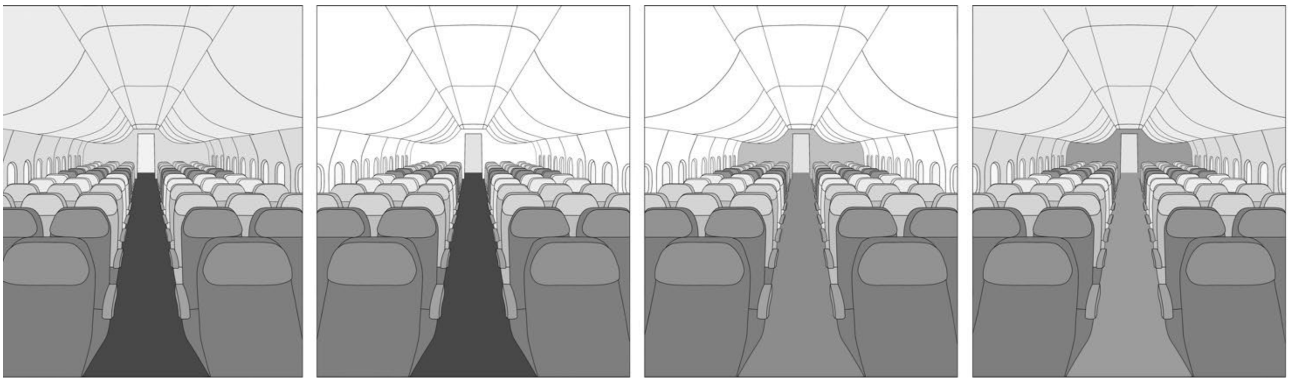


Fig. 3 – Gestalt perception of possible color combinations for the cabin space.

In association with these principles, going down to the scale of the seat, it was also understood how some color combinations of this component, extracted from the models compared in the SkyTrax study, affect both the dimensional perception and the static/dynamism of the space (Fig. 4):

a. the use of scalar shades on the horizontal rows of the seats, starting from the darkest in contact with the windows, gives a perception of "widening" of the cabin through the balance of the colors, which also varies according to the day/night time slot on the way of the light coming or not from the windows;

b. the chromatic organization of the seats for columns, in alternating dark/light colors leads to an effect opposite to that described above, highlighting the length of the cabin and thus also increasing the "tunnel effect";

 ISBN 978-88-99513-18-4

c. the “random” arrangement of shades in nuance gives a perception of homogeneity between rows and columns but at the same time a lively and dynamic aspect due to the contrast between the colors;

d. also, the organization by groups of rows with repetition of scalar shades considerably reduces the tunnel effect, giving at the same time a dynamic but balanced aspect in which attention must be paid to the chromatic choice for the back wall, as seen in figure 3.

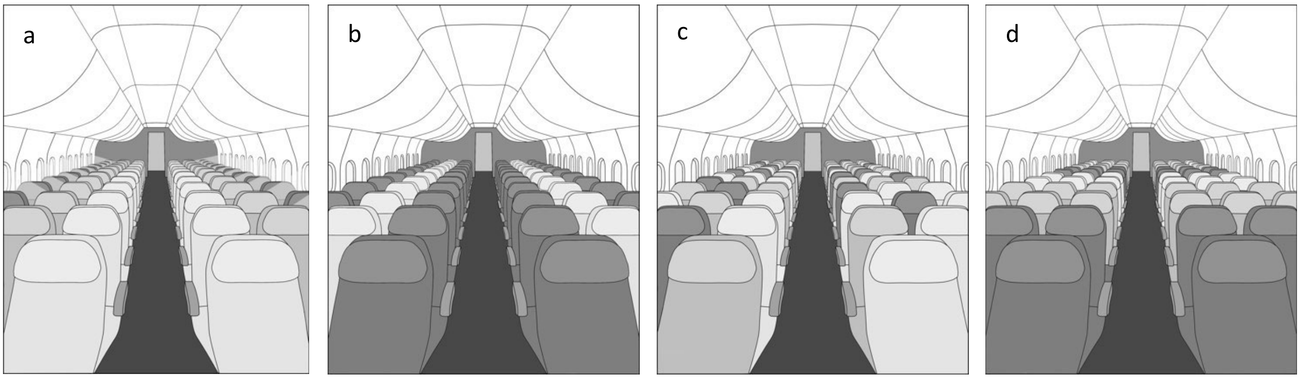


Fig. 4 – Gestalt perception of possible color combinations of the seats.

The CASTLE chromatic model

Considering as objectives the improvement of the perceptive comfort of the cabin through the color and the possibility that this can be declined in accordance with the specific identity of each individual company, the CASTLE model is not based on the priority identification of some colors over others but on the concept of color combination. To reduce the tunnel effect and the search for a dynamic identity of the space, the model proposes the creation of "rooms" defined by a scalar and rhythmic variation of the shades of the seats, accompanied by a luminous perimeter of groups of windows and PSU (passenger service unit). The design of the different components (side and back walls, ceiling, seats and carpet) immediately integrates color as a fundamental tool for recognizing the "rooms".

In a first co-design activity with "personas" (20 males and 20 females), chosen as a sample of ideal types of passengers by age, profession and nationality, the perceptual impact of the "room model” declined in different colors. The test was conceived as a meta-project evaluation of the subdivision into “rooms”, set up with different colors and scaled shades, based on the colors most used in the solutions described in the SkyTrax comparative report. The test was carried out with the projection of the cabin in real size on a large screen (7x4 m) and the personas standing, simulating his entry into the cabin from the service area.

During the session, the passenger was asked to evaluate how the space and environment were perceived in terms of stress, comfort, harmony, elegance and safety, giving these factors a value from zero to five. Furthermore, in the second part of the session, to evaluate the dynamism of the chromatic combinations, different sequences of scalar shades were proposed, for a maximum of 12 hypotheses visible for ten seconds each (Fig. 5).

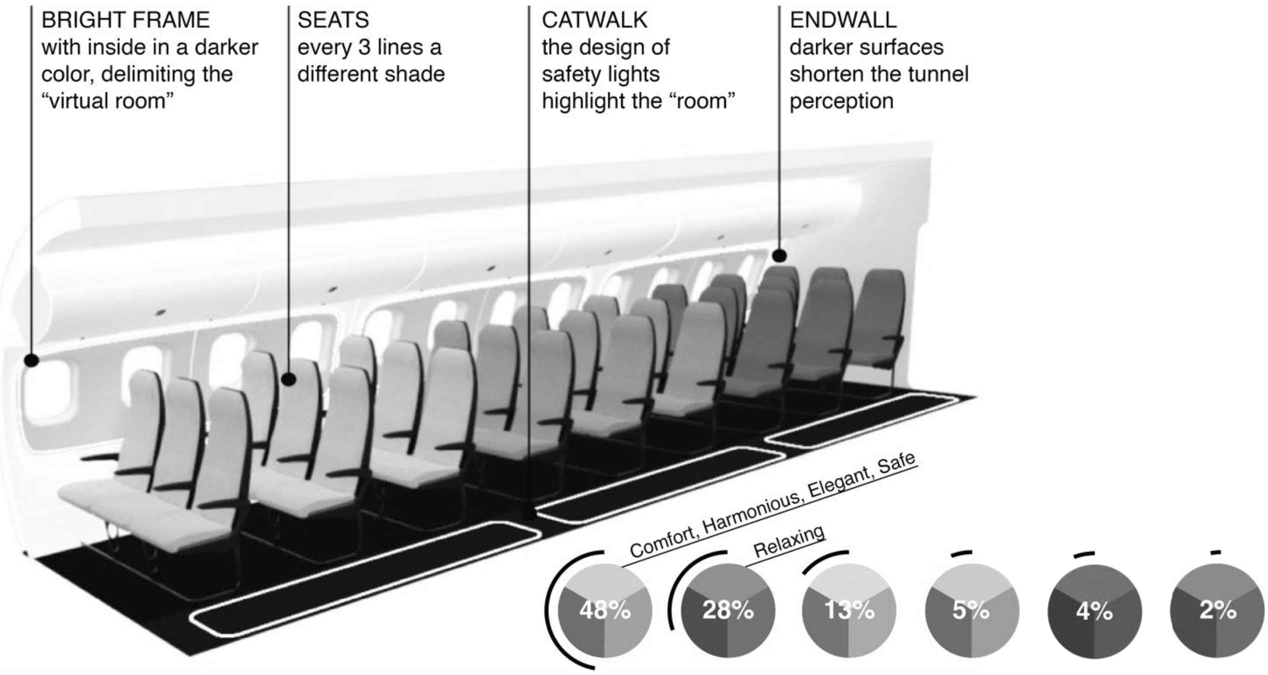


Fig. 5 – Summary diagram of the elements characterizing the color in the cabin and the percentages of appreciation of the different shades.

The influence of light

The contemporary approach to the design of passenger cabins considers the physical chromatic research integrated with that of light. The research therefore integrates, in a holistic way, the different parameters referring to the design of the luminaires, the color rendering of the light sources and the evaluation of consumption for the purposes of energy sustainability, a very important fact in flight. The light in the cabin must ensure two conditions of a functional and expressive nature: to make actions and movements operable safely and to characterize the perception of an environment consistent with the different phases of flight with adequate intensity and colors. In addition, the lighting design must also immediately deal with the design concept of the cabin space. This is to ensure both an average homogeneous illuminance coefficient, without glare and shadows, and a perception of light comfort in the two conditions, opposite or intermediate, of active lights or off lights.
Being a short/medium range aircraft, in which there are no specific flight phases such as meal or sleep, the lighting concept includes LEDs with standard color temperatures and intensity control managed by an onboard computer.
Based on the "CASTLE chromatic model", the measurements and lighting engineering evaluations therefore concerned the control of the average illuminance values on the surfaces colored in shades of dove gray, the preferred shade for the chromatic evaluation test. The sectioning of the system allows you to activate separately, also by intervening on the intensity, the 3 types of luminaires for ambient lighting: linear ceiling; wall frames every 4 windows to delimit the "virtual room"; frames of the PSU (passenger service unit) (Fig. 6).

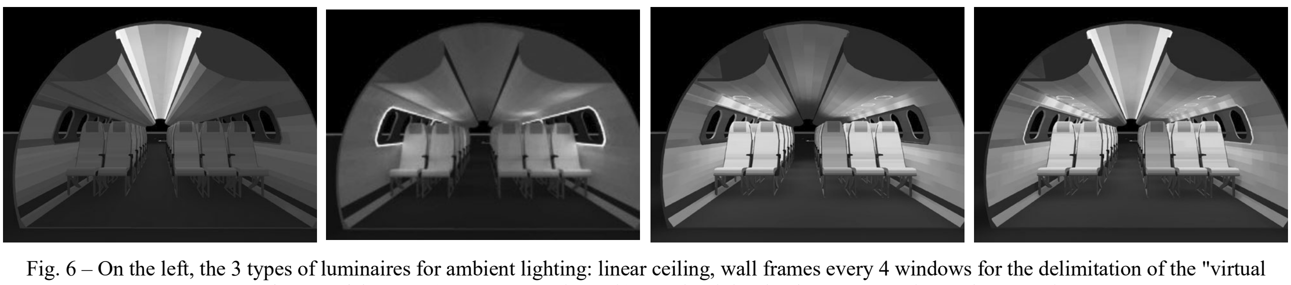


Fig. 6 – On the left, the 3 types of luminaires for ambient lighting: linear ceiling, wall frames every 4 windows for the delimitation of the "virtual room", frames of the PSU (passenger service unit); On the right, the three types active at the same time.

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Results and conclusions

A prototype is currently under construction (a section of the cabin which is functioning and mounted on a vibrating plate) equipped with all the components required by the cabin concept design, including the “chromatic model” with scalar shades grouped in the “virtual rooms”. In the autumn of 2022, the concept design will be validated through final tests with users and potential customers of the aircraft, based on the perception of the various parameters that contribute to flight comfort: structural/vibrational, functional relating to accessibility and movement, airiness and cabin lighting, validity of the concept design in the definition in "virtual rooms" and relative "chromatic model".

Precisely the "chromatic model" opens to further research developments. On the one hand, an in-depth study of the relationships between color and texture of the seats will be initiated (introducing the parameters of roughness and three-dimensionality of the fabrics), through Eye-Tracking tests that can be carried out with the user samples already selected. On the other hand, the prototype will allow an exploration of the opportunities offered by RGB LEDs. The environmental contribution provided by these sources today is still under study but presents excellent research opportunities to improve cabin comfort in relation to both the activities to be performed in the different phases of flight, and the color rendering of the surfaces, in particular walls and seats. The well-known layout of the Boeing 737 Sky Interior, in this sense, works a bit like a gym for the chromatic combinatorial possibilities offered by the colored light sources.

In collaboration between the DAD (Architecture and Design) and DENERG (Energy "Galileo Ferraris") departments, specific research has been launched on the use of colored light (RGB LED) in flight with an original approach. The chromatic variation of the light is in this case related, in the access, take-off and landing phases, to the temperature and humidity conditions of the external environment, to reduce the perception of sudden changes in temperature (Fig. 7).

Fig. 7 – The preparation of the CASTLE cabin (concept design in collaboration with Pininfarina) with white light LEDs and possible variation of intensity and color through RGB LEDs.

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References

Akkerman, S. and Vink, P. (2018). Improving airplane boarding time by illumination guidance. In *Congress of the International Ergonomics Association* (pp. 220-224). Springer, Cham. https://doi.org/10.1007/978-3-319-96071-5_23

Ahmadpour, N., Robert, J.M. and Pownall, B. (2013). The dynamics of passenger comfort experience: understanding the relationship between passenger and the aircraft cabin interior. In *The International Conference of Canadian Aeronautics and Space Institute, CASI Aero, Toronto*.

Anceschi, G. (2006). Basic Design, fondamenta del design. *L'ambiente dell'apprendimento–Web design e processi cognitive* (pp.57-67). McGraw-Hill.

Bagassi, S., Lucchi, F. and Persiani, F. (2015). Aircraft preliminary design: a windowless concept. *5th CEAS*, 20015, pp.7-11.

Bianco V. (2018). *Volare a colori. La percezione del colore in cabina come elemento influenzante il benessere*. Supervisor: Germak, C., Di Salvo A., Giuliano L., Master's degree thesis in Systemic Design, Politecnico di Torino.

Bubb, H., Bengler, K., Grünen, R., and Vollrath, M. (2015). *Automobilergonomie.* Wiesbaden, Germany: Springer Vieweg.

De Crescenzio, F., Bagassi, S., Asfaux, S., & Lawson, N. (2019). Human centred design and evaluation of cabin interiors for business jet aircraft in virtual reality. *International Journal on Interactive Design and Manufacturing (IJIDeM), 13*(2), 761-772.

De Jong, A.M. and Vink, P. (2005). 7 Reducing Discomfort in Installation Work. In *Comfort and design: principles and good practice* (pp. 85-93). CRC Press, London.

Di Salvo A., Germak C. (2019). The extended comfort. Analysing the flight journey through a design-oriented approach, in "*XXV International Congress of AIDAA Italian Association of Aeronautics and Astronautics"*, Roma, 9-12 September 2019, p. 935

Jaglarz, A. (2011). Perception and illusion in interior design. In *International Conference on Universal Access in Human-Computer Interaction* (pp. 358-364). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-21666-4_39

Torkashvand, G., Stephane, L. and Vink, P. (2019). Aircraft interior design and satisfaction for different activities; A new approach toward understanding passenger experience. *International Journal of Aviation, Aeronautics, and Aerospace*, *6*(2), p.5. Embry-Riddle, Florida.

Vink, P. & Hallbeck S. (2011). *Comfort and discomfort studies demonstrate the need for a new model*. Elsevier Ltd and The Ergonomics SocietY. https://doi.org/10.1016/j.apergo.2011.06.001

Winzen, J., Albers, F., & Marggraf-Micheel, C. (2014). The influence of coloured light in the aircraft cabin on passenger thermal comfort. *Lighting Research & Technology, 46*(4), 465–475.

Yao, X., Song, Y. and Vink, P. (2021). Exploring factors influencing visual comfort in an aircraft cabin. In *3rd International Comfort Congress 2021,* Nottingham.

Zhang, L., Helander, M.G. and Drury, C.G. (1996). Identifying factors of comfort and discomfort in sitting. *Human factors, 38*(3), pp.377-389. https://doi.org/10.1518%2F001872096778701962