VISUAL AND ACOUSTIC ADAPTABILITY IN ARCHITECTURE. EFFECTS OF LEVEL CHANGE IN USERS' SENSATION

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Summary

This paper deals with both physical and psychological dimensions of visual and acoustic adaptability in architecture. Studies revealed that, thermal comfort at one point in a transitional space is determined by the relative temperature at the location compared to the average temperatures the subjects had been exposed to. The objective of this study is to investigate whether these results can be extrapolated to visual and acoustic perception. The proposed methodology is based on observing individual behaviour with a sequenced exposure to different controlled visual and acoustic conditions. The results, which will be discussed, can be applied not only to general change in environmental conditions but also while walking through transitional spaces, where a well-designed gradient of environmental conditions could imply energy savings.

Keywords: visual and acoustic comfort, adaptive approach, transitional spaces

1 Introduction

The perception of the environment encompasses all human sensorial fields working together. Thermal, visual and acoustic senses are particularly important to obtain information on our environmental and architectural surroundings. Moreover, these senses are especially significant in our perception of global comfort [1].

Thermal, visual and acoustic comfort conditions have been widely studied, in particular from a static point of view. However, there are many situations in our everyday lives where environmental conditions are not static but dynamic; when users move around from one place to another, changes in environmental conditions take place faster.

Consequently, users' perceptive response and their ability to adapt to these environmental changes may have a major impact on the design of architectural spaces.

Studies by Nicol and Humphreys [2] dealt with an adaptive approach to thermal comfort with users in static situations and changing environments, such as those experienced while working in an office or staying at home. Their researches revealed that, if a change occurs that produces discomfort, people react in ways which tend to restore their comfort, by changing the conditions to match their comfort or by changing the comfort temperature to match the prevailing conditions. Other studies, like those by Chun and Tamura [3], dealt with more dynamic situations, such as when users are walking through a transitional space. In this case their findings revealed that, when moving from one space to another, the sensation of thermal comfort at the arrival location is strongly determined by the temperatures to which they have been exposed throughout this movement.

From here we wondered how changes in light or acoustic levels could affect users' visual and acoustic comfort and the possible adaptation of their perception to dynamic conditions. Regardless of whether it is a situation with a static user and changing conditions or a more dynamic situation with a user in motion, it is possible to say that thermal, visual and acoustic changes have different energy range widths. Furthermore, visual and acoustic changes usually take place at a higher speed and are produced more frequently than thermal ones. Finally, human response is also different, as users' time of adaptation due to physiology is very different for each sense.

Fig. 1 *User looking at a store window of a shop, an example of light condition change*

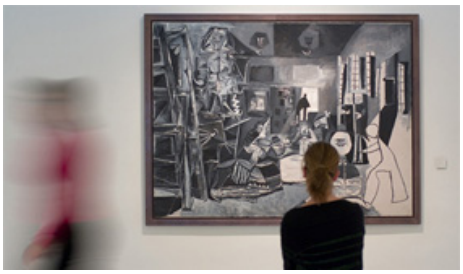

Fig. 2 *User looking at an illuminated work of art at Picasso Museum in Barcelona.*

There are many situations in our common life in which there is a momentary change in the light or the acoustic conditions, leading us to a contrast towards a greater or smaller visual or acoustic level. Some illustrative visual situations may be stopping to look at the display window of a shop or looking at a work of art while walking around a museum, whereas some acoustic example may be going from one shop to another while walking through a mall.

2 Research methods

A first approach is based on the results yielded from different laboratory surveys where the range of conditions that users consider comfortable tends to be stricter than in field surveys where users have more chances to adapt to the environment. The experiments were performed with a series of young architects exposed to different changes in the illuminance levels (lux) and acoustic levels (dB) in an interior static space. We discarded the field surveys, where it is more difficult to control the visual and acoustic conditions and consequently the probability that results might be distorted by other factors is higher.

Several series of visual and acoustic experiments were conducted where the survey respondents were asked to comparatively assess the light or the acoustic level perceived after experiencing a clearly higher or lower level. A seven-point visual or acoustic sensation scale based on the ASHRAE scale and the Bedford Scale of Thermal Comfort was used by participants to make this assessment.

Tab. 1 *7-point visual/acoustic sensation scale*

Vote	Assessment of the sensation of illuminance / acoustic level
+3	Much higher level than in phase 1
+2	Higher level than in phase 1
+1	Slightly higher level than in phase 1
0	Same level than in phase 1
-1	Slightly lower level than in phase 1
-2	Lower level than in phase 1
-3	Much lower level than in phase 1

2.1 Visual experiment

Two experiments were carried out on visual adaptability. The first one was conducted in Barcelona (Spain) in March 2012 and the second one in Antofagasta (Chile) in September 2012. In Experiment 1, using 24 subjects, visual adaptability was studied for changes between different average illuminance levels of 1, 7.5 and 530 lux on a working surface in the multiple runs of the experiment [4]. In Experiment 2, using 10 subjects, the average illuminance levels were readjusted to 8, 45 and 350 lux, in order to use more common values in architecture. In this way, although humans' visual sense follows a logarithmic perception of light, the proportion between the different illuminance levels becomes linear.

Fig. 3 *Three standard scenes on Experiment 1, with average illuminance levels of 1, 7.5 and 530 lux over the working surface*

Participants took part in several runs for each experiment. For each run, they were initially exposed to a constant illuminance level (level A) on the working surface that remained constant over a certain period of time (10 minutes) to ensure that the survey respondents' vision became adapted to the light level. A second illuminance level (level B) remained constant over a relatively short period of time (45 seconds). Finally, a third level (level C) was used and the respondents were asked to comparatively asses the final illuminance in relation to the light level at the beginning of the run (**Fig. 4, 6**).

This methodology was repeated in several runs combining different illuminance levels for each experiment. The participants in the experiments did not know in advance that the final illuminance level was the same as the one at the beginning.

2.2 Acoustic experiment

The experiment on acoustic adaptability was conducted only in Barcelona (Spain) in October 2012 using the same methodology with 75 subjects. Multiple runs were conducted, half with a pure tone (440 cps) studying adaptability to changes between different average acoustic levels of 73 dB, 78 dB and 82 dB, and half with white noise for changes between average acoustic levels of 78 dB, 86 dB and 88 dB.

For each run, subjects were initially exposed to a constant acoustic level (level X) for 10 seconds. A second acoustic level (level Y) remained constant for 12 seconds. Finally, a third acoustic level (level Z) was used and at this moment the respondents were asked to assess their perception of the acoustic level compared to the first. None of the participants knew that the levels at the beginning and end of the experiment were the same **(Fig. 8, 10).**

3 Results and discussion

3.1 Visual experiment

The results of the different runs of the two visual experiments show that in all of them the respondents overestimated or underestimated the illuminance once the lighting level was restored, and their sensation of illuminance always exceeded the level in the direction of the change.

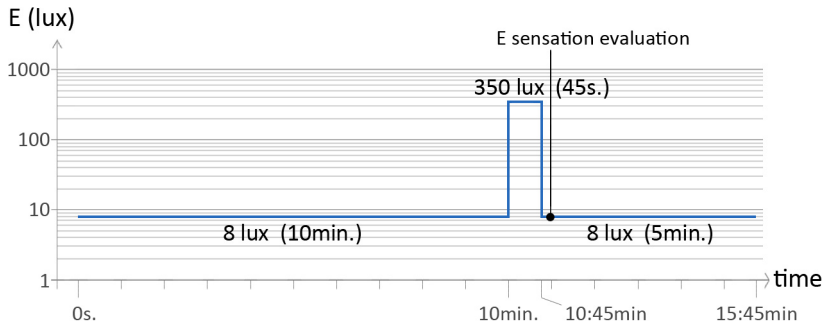

Fig. 4 *Scheme of one of the Visual rounds (8-350-8 lux)*

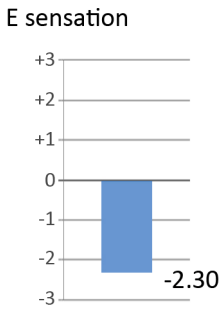

Fig. 5 *Visual main vote*

A run of Experiment 2 is shown in Figures 4-5. It started with an illuminance level of 8 lux, that increased to 350 lux and finally went back to the initial 8 lux. The respondents' sensation of illuminance on the working surface was lower (-2.30) than that measured and standard deviation was between -1.48 and -3.12 (**Fig. 5**).

A second run of Experiment 2 as an illustrative case of habitual architectural illuminance levels is shown in Figures 6–7. It started with an illuminance level of 350 lux, that dropped to 45 lux and finally went back to the initial 350 lux. The respondents' sensation of illuminance on the working surface was higher (+2.10) than that measured and standard deviation was between +1.78 and +2.42 (**Fig. 7**). This case could be, for example, people moving from one classroom to another, walking through a corridor, considered a transitional space.

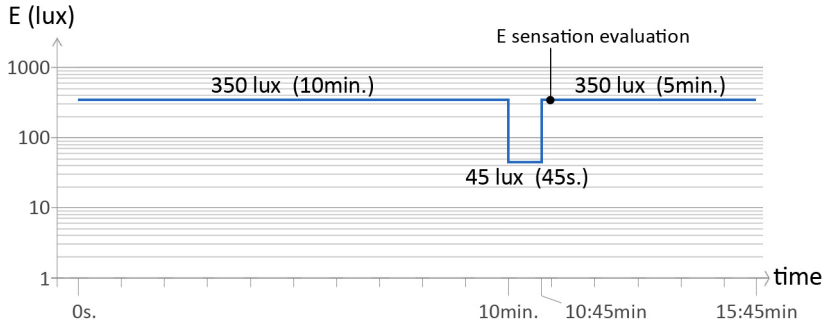

Fig. 6 *Scheme of one of the Visual rounds (350-45-350 lux)*

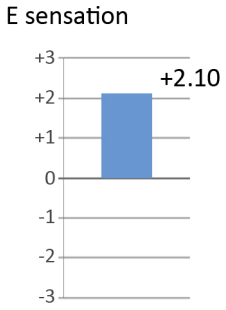

Fig. 7 *Visual main vote*

3.2 Acoustic experiment

Regarding the acoustic experiment, it can also be stated that in all of them the respondents perceived a higher or a lower acoustic level than the value measured when the original level was restored. Users' sensations exceeded the real value in the direction of the change in all runs of the experiment, regardless of whether a pure tone or white noise was used.

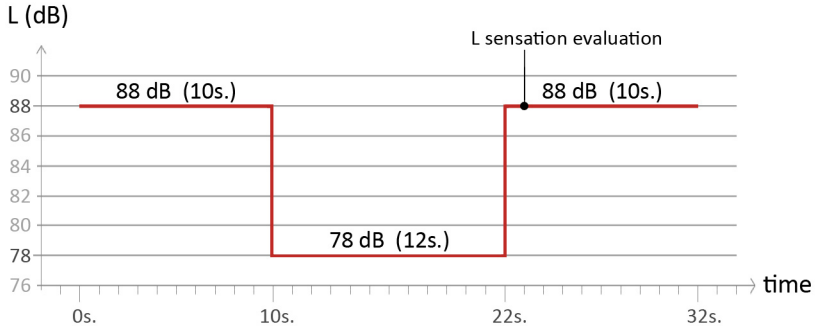

Fig. 8 *Scheme of one of the Acoustic rounds (88-78-88 dB)*

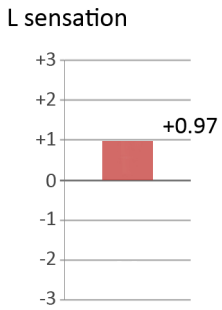

Fig. 9 *Acoustic main vote*

As an illustrative case, shown in Figures 8–9, we can use a run performed with a 88 dB white noise suddenly dropped to 78 dB, which after 12 seconds returned to the initial level of 88 dB. The respondents' acoustic sensation was slightly higher (+0.97) than the measured value and the standard deviation was between +0.01 and +1.93 (**Fig. 9**).

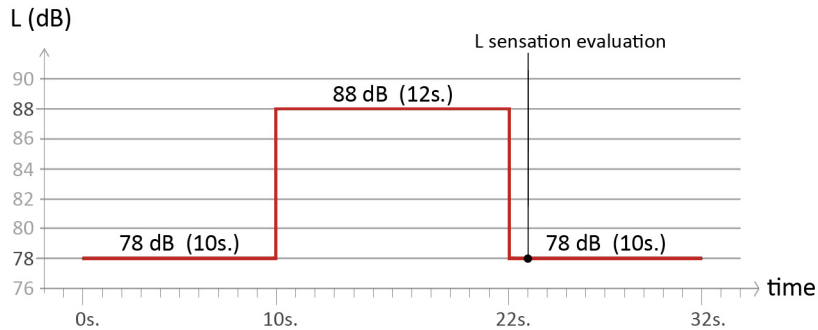

Fig. 10 *Scheme of one of the Acoustic rounds (78-88-78 dB)*

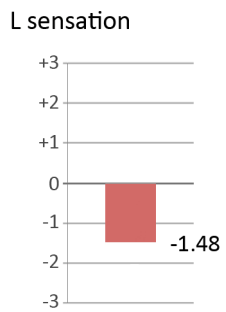

Fig. 11 *Acoustic main vote*

As a second illustrative case, shown in Figures 10–11, we can use a run performed with a 78 dB white noise suddenly increased to 88 dB, which after 12 seconds returned to the

initial level of 78 dB. The respondents' acoustic sensation was between "slightly lower" and "lower" (-1.48) than the measured value and the standard deviation was between -0.56 and -2.40 (**Fig. 11**). This may be a representative example for a common situation in a transitional space like moving from one shop to another through a noisy street.

4 Conclusions

This paper is an approach to visual and acoustic adaptability in architecture. The conclusions came from the observation of the results yielded through several laboratory experiments, where respondents were exposed to different lighting and acoustic level changes. The major conclusions are the following:

- An overshot in their perception can be observed in users when a change in the energy level occurs, whether illuminance or acoustic conditions.
- This overshot can be observed whether the change is to a higher energy level (where the user's sensation is higher than the existing level), or to a lower energy level (where the user's sensation is lower than the real value).

These early results could lead us to find out more about the transition lighting and acoustic conditions in order to apply it to improve designs of the gradient of environmental conditions in architectural transitional spaces. Adjusting the lighting or acoustic energy demand of architectural spaces would lead to potential energy savings as a consequence of designing for better conditions of comfort.

References

[1] SERRA, R., COCH, H. *Arquitectura y Energía Natural.* Edicions UPC, Barcelona, 1995, pp. 67–93.

[2] NICOL, J. F., HUMPHREYS, M. A. *Adaptive thermal comfort and sustainable thermal standards for buildings.* Energy and Buildings, 2002, Volume 34, Issue 6: pp. 563–572.

[3] CHUN, C., TAMURA, A. *Thermal comfort in urban transitional spaces*. Building and Environment, 2005, 40: pp. 633–639.

[4] ALONSO, C., LÓPEZ, J., COCH, H., SERRA, R. *Visual Adaptability in Architecture. A physical and psychological approach*. Proceedings of the PLEA 2012 Conference in Lima.

[5] DOWLING, J. E. *The Retina. An Approachable Part of the Brain*. Harvard University Press, 1987.

[6] OPTICAL SOCIETY OF AMERICA. *Handbook of Optics: fundamentals, techniques, and design*. Volume 1, 1994. McGraw-Hill Publishing Co.

[7] LÜSCHER, E., ZWISLOCKI, J. *Adaptation of the Ear to Sound Stimuli.* The Journal of the Acoustical Society of America, 1949, Volume 21, Number 2.

[8] CARTERETTEE C. *Loudness Adaptation for Bands of Noise*. The Journal of the Acoustical Society of America, 1956, Volume 28, Number 5.

[9] SCHARF, B., REEVES, A., GIOVANETTI, H. *Loudness reduction induced by a contralateral tone (L).* The Journal of the Acoustical Society of America, 2007, Volume 122 (1): pp. 35–37.