

Visual Adaptability in Architecture

A Physical and Psychological Approach

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ABSTRACT: This paper deals with both physical and psychological dimensions of visual adaptability in architecture. The adaptive model of environmental comfort has been studied especially from the thermal point of view. Studies revealed that, when moving from one space to another, the sensation of thermal comfort at the arrival location is widely determined by prior exposure temperatures over the whole course. As all the senses work together in our perception of the environment, the movement between spaces with different environmental conditions has a considerable effect on our overall sense of comfort. Consequently, the main objective of this study is to investigate whether the adaptive model of thermal comfort can be extrapolated to a visual adaptive model. It may seem that when examining visual comfort conditions, users' sensation of the same stimulus is more pleasant by contrast if they come from higher or lower energy levels than if they come from similar or gradually reached environmental conditions. But this extrapolation is not immediate. On the one hand, thermal and visual environmental changes take place neither at the same speed nor at the same energy level. On the other hand, users' thermal and visual adaptation periods are not the same. The proposed methodology is based on an exhaustive observation of individual behavior performed with a sequenced exposure to different environmental conditions with controlled visual levels. The final outcome is the production of generic physical and psychological conclusions related to the experience of changing environmental conditions, since exposure time, expectation and predicted environmental conditions seem particularly important in the final sense of comfort. The results can be applied not only to general change in environmental conditions but also while walking through transitional spaces.

Keywords: visual comfort, adaptive approach, transitional, transient, survey.

INTRODUCTION

People have a natural tendency to adapt to changing conditions in their environment. This natural tendency is expressed in the adaptive approach to thermal comfort, as developed by Nicol and Humphreys [1]. However, this tendency is not solely applicable to thermal adaptation but it also encompasses all human beings' sensorial fields, being processes such as adaptation of vision or hearing fairly common in everyday life. These senses are particularly important when interacting with our environment and getting information on our environmental and architectural surroundings. Therefore, this paper takes an adaptive approach to visual comfort based on the potential extrapolation of some of the concepts from the most recent studies performed on thermal comfort, given that this is the field where the adaptive model has been developed the most.

With regard to thermal comfort, there are many contextual variables that play a role in the sense of comfort. Some of them are due to the environmental parameters that are dependent upon the climate, while others are due to user-dependent factors, be they social, physiological or psychological. Examples can include the users' kind of activity, clothing, anatomy or posture,

education or how the building and its facilities are used [1, 2]. In this sense, the time factor is particularly significant either in terms of the speed at which the environmental changes take place or the period needed by the user to get acclimated. What is more, from the physiological standpoint, human beings are particularly sensitive to the perception of changes in environmental stimuli. However, if the stimulus remains steady, humans may experience fatigue in the excitement of the sense receptors, thus leading to a decline in the perception of the stimulus. For this reason, some variability in the environmental conditions can come to be perceived more pleasant than being in environments with highly neutral or steady conditions [3, 4, 5, 6].

As Nicol and Humphreys state, if a change occurs that produces discomfort, people react in ways which tend to restore their comfort. According to their research, this can be done by two types of actions: changing the conditions to match their comfort and changing the comfort temperature to match the prevailing conditions [1]. In contrast to these more static situations, such as an office building or home, Chun and Tamura researched the thermal comfort in more dynamic situations, such as those that occur because a user is walking through a

transitional space. In this case, when thermal changes take place more quickly, what they call the “relative evaluation tendency” happens. Their findings revealed that thermal comfort at one point in a transitional space is determined by the relative temperature at that location compared to the average value of prior exposure temperatures [7].

To the contrary, regarding visual or acoustic energy, regardless of whether it is a situation with a static user and changing conditions or a more dynamic situation with a user in motion, visual and acoustic energy changes are more frequent and usually take place at a higher speed compared to thermal energy. In this sense, human beings’ response is much quicker, that is, their visual and auditory adaptation to the change takes place at a much higher speed than their adaptation to changes in temperature.

For this study, we experimented with the specific case of visual adaptation and the users’ response, setting aside the possible functioning of acoustic adaptation for future studies.

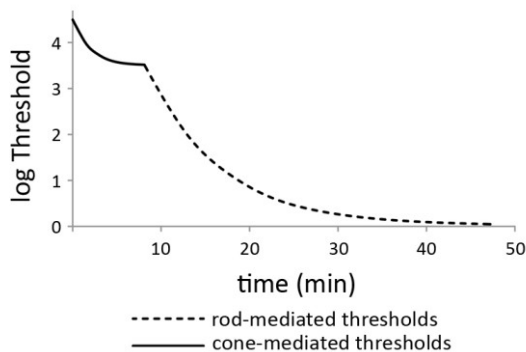


Figure 1: Schematic diagram of adaptation to the dark: the recovery of the visual threshold following bright-light adaptation as a function of the amount of time spent in darkness. (Version of a diagram from John E. Dowling [8].)

In this aspect, visual adaptation is due to a modification of the sensitivity of the eye’s receptive organs to the stimulus. In visual adaptation to both darkness and light, there is an initial mechanism which consists of the immediate change in the size of the pupil, which regulates the amount of light that reaches the retina via fluctuations in the aperture in a range of 1 to 16. Simultaneously, the sensitivity of the cones and rods (cells located on the eye’s retina that receive the light) also enlarge or shrink respectively due to the increase or destruction of the light-sensitive chemical substance. For this reason, adaptation to darkness takes around 5 to 10 minutes in the case of photopic vision (cones), while in the case of scotopic vision (rods) it takes approximately 20 to 30 minutes (Fig. 1). In the opposite sense,

adaptation to light is much quicker and takes place in just a few seconds [8, 9].



Figure 2: The visitor to this exhibition, who is circulating at a low level of light, adapts his vision to the illuminated work of art and then continues circulating at the same light level as at the start. (Version of a picture of Mario Gonzalo “Cachero” posted at: lalugareja.blogspot.com.)

There are many situations in our everyday lives when there is a momentary change in the light conditions, thus leading to a contrast towards greater light or darkness. Clear examples of this include looking out a window, stopping to look at the display window of a shop, walking around a museum (Fig. 2) and going from one room to another through a transitional space [10]. Given this, we wondered how this kind of change in the light levels affects the user’s visual comfort and the adaptation of their perception of light.

RESEARCH METHODS

The methodology used to examine this adaptive approach to light comfort is based on the conclusions yielded through laboratory surveys performed with a series of young architects. They are all 2011-12 “Architecture, Energy and Environment” Master’s degree students and 2011-2012 “Architecture and the Environment: Integration of Renewable Energies into Architecture” Master’s degree students at the School of Architecture of Barcelona (UPC).

Even though we do not discard the possibility of administering field surveys in the future, since this study examines visual comfort and we know that both the energy changes in light conditions and users’ visual adaptation take place at relatively quick speeds, in field surveys there is a lower ability to control the conditions and as a result a higher probability that the results might be distorted. Likewise, we chose to administer laboratory surveys since in this kind of survey not only can there be the predefined environmental conditions and a higher capacity for control but also the range of conditions that users consider comfortable tend to be stricter than in field surveys, where users have more chances to adapt to the environment.

Regarding the description of the design of the experiment, it was performed with 24 healthy individuals, eight men and 16 women between the ages of 24 and 36. The participants come from different countries in Europe and the Americas. Likewise, they are all architects and students in post-graduate courses related to environmental energies in architecture, so they all have some knowledge about light issues as well as a certain discernment regarding the units used to measure illuminance (lux).

The survey respondents were seated, as shown in Figure 3, in a room with multiple light scenes, of which three standard scenes were chosen: scene A, scene B and scene C. In the multiple runs of the experiment, these three light scenes produced average illuminance levels over a useful working surface (located 70 cm over the floor): A = 530 lux, B = 7.5 lux and C = 1 lux. The changes between the different light scenes took place almost instantaneously, since we used fluorescent lamps with quick switch control (Fig. 3).

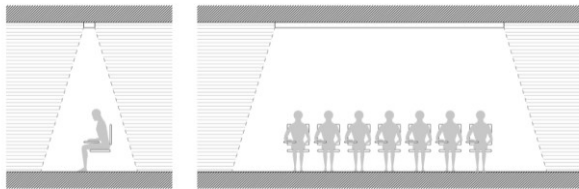


Figure 3: Upright projection and cross-section scheme of the location of the users in the room.

The difference in illuminances (average values in lux over the working surface) between what was seen by the survey respondents seated under the centre of the light source and those located at the ends was insignificant for low illuminance levels, on the order of 3 lux in medium levels and 170 lux at high levels (Table 1). In this sense, if we bear in mind that human perception follows a logarithmic relation, this difference in measured values at medium and high levels of light should be clearly unimportant in the different users' perceptions.

Table 1: Average, minimum and maximum illuminance levels measured (in lux) according to the light scene.

Scene	E_{AV} (lux)	E_{min} (lux)	E_{Max} (lux)
A	530	445	615
B	7.5	6	9
C	1	1	1

The 24 participants took part in four different experiments: experiment A1, experiment A2, experiment C1 and experiment C2. Each of the four experiments had three phases. The first phase began with a light scene with an initial illuminance value over the useful surface which remained constant over a certain period of time. The second phase began with an initial change in the light scene with a different illuminance value over the useful surface, which once again remained constant over a given period of time. Finally, the third phase began with a second change, which returned to the same light scene as in phase 1 (that is, with the same illuminance value over the useful surface as at the start), which once again remained constant over a given period of time.

The participants in the experiments were never given any complementary information on the experiment in advance. Thus, we tried to avoid their having any kind of predisposition or possible expectation in terms of the results.

Regarding the timeline of the experiments (Fig. 4), the first phase in the experiment required a prolonged period of time (10 minutes), since it was aimed at ensuring that the survey respondents' vision was accustomed to the initial light level. What is more, during this first phase, the respondents were informed about the existing light level on the useful working surface so that they could have a point of reference when later estimating the light level. During the entire process (all three phases) in each of the four experiments, the subjects were involved in doing Sudoku puzzles in order to keep them entertained and thus ensure that their vision was set on a specific area. Likewise, the fact that they were engaged with Sudoku puzzles, which have numbers of a certain size and color over a homogenous white background, enabled us to ensure that the assessment and estimate of the light levels that they would be requested later were always made with regard to the same point of reference.

After the ten minutes in phase 1 had elapsed, there was a change in the light scene, and therefore in the illuminance of the useful work surface, thus ushering in phase 2 of the experiment. This phase remained constant over a relatively short period of time (45 seconds). During this period, 30 seconds after having begun phase 2, the respondents were asked to assess the light level at that moment compared to the light level in the first phase. What is more, they were also asked to estimate the approximate illuminance (value in lux) on the working surface.

Forty-five seconds after phase 2 began, there was a second change in the light scene, going back to the illuminance of the useful working surface in the first phase and thus beginning phase 3 of the experiment. In

this phase, the respondents were once again asked to value the light level compared to the first phase, and to estimate the approximate illuminance (value in lux) over the working surface. As shown in Figure 4, they were asked this 2 seconds, 15 seconds and 4 minutes after the beginning of the third phase.

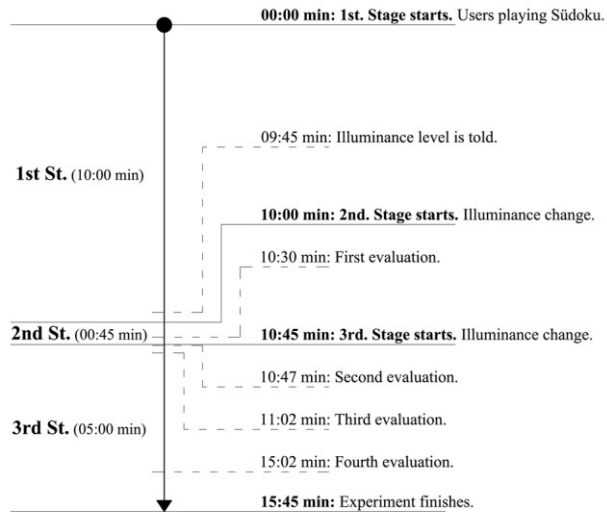


Figure 4: Scheme of the definition of the phases and time procedure of a standard experiment.

The respondents were asked two kinds of questions at the different points in the experimental process. First, in phases 2 and 3 they were asked to comparatively assess the illuminance level compared to the level in phase 1. To make this assessment, they used an adaptation for light of the ASHRAE scale and the Bedford Scale of Thermal Comfort (Table 2). Secondly, they were also asked to make in these phases an absolute assessment of the illuminance (estimated sensation in lux) on the working surface (bearing in mind that they knew the lux level in phase 1 in advance).

Table 2: 7-point visual sensation scale.

Vote	Assessment of the sensation of illuminance on the working surface
+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 as 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

In the specific case of experiment A1, there was a succession of A-B-A scenes, while in the case of experiment A2, there was a succession of A-C-A scenes. We shall see how both cases started with a given high level of illuminance (530 lux), then dropped to lower levels (7.5 lux and 1 lux, respectively) and then went back to the initial level (530 lux). Given this sequence, we predicted that the respondents' answers would reflect different assessments of their sensation of light according to whether phase 2 was closer to or further from the initial illuminance level.

In contrast, the C1 experiment (with a succession of C-B-D scenes) and C2 experiment (with a succession of C-A-C scenes) started with low illuminance levels (1 lux), which were then raised to higher levels (7.5 lux and 530 lux, respectively) and then went back to the initial level (1 lux) (Fig. 5). In this case, since the process was the opposite of experiments A1 and A2, we predicted that the responses would also be different since users' adaptation time to brighter or darker levels are different.

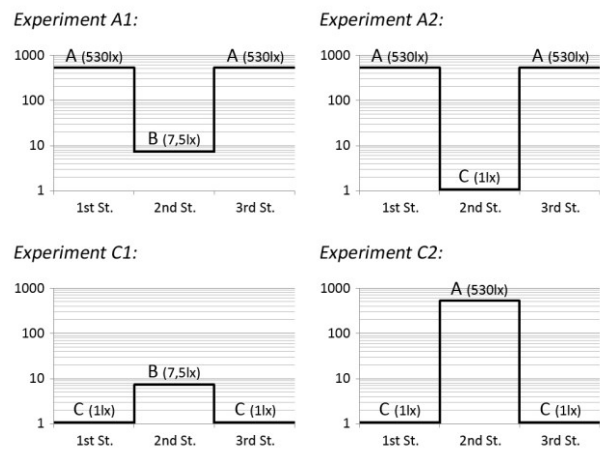


Figure 5: Scheme of the four experiments with their respective illuminance levels (lux) on the working surface.

The experiments were performed in March 2012, and the other environmental conditions were monitored throughout the entire experiment to ensure that they fell within acceptable comfort margins. In this way, we attempted to prevent these conditions from interfering in the perception of light and to minimize any possible effect of synesthesia. During the entire process, the temperatures were maintained within the range of 22.2° C to 22.4° C. The relative humidity ranged from 44% to 46.5%. Most of the time, the acoustic range was between 38 dB and 40 dB. The CO₂ levels were always kept within acceptable ranges, with values that spanning between 1100 ppm (parts per million) and 1305 ppm. What is more, the experiment was performed between 2.5 and 4 hours after the respondents had eaten. Finally,

we avoided any kind of external lighting during the experiment to prevent interference and a distortion in the results.

RESULTS AND DISCUSSION

Regarding the results of the experiment, there are two kinds of assessments to analyze.

The first is the comparative assessment, that is, the light level that the survey respondents perceived when going back to the original illuminance value after experiencing a clearly higher or lower level of light (experiments C1 and C2, and A1 and A2, respectively). By observing the results of all four cases (Fig. 6, 7), we can see how in all of them the respondents overestimated or underestimated the illuminance once the original lighting level was restored (when entering phase 3). That is, when there was a change in the illuminance level, the sensation of light exceeded the real value in the direction of the change. For example, experiment A1 starts with a high illuminance level of 530 lux, in the first change this level drops to 7.5 lux, and when the conditions return to the initial value of 530 lux, the respondents' sensation was a higher illuminance level than that value. What is more, in all the experiments we noted how in just a brief time (a few seconds), the respondents recovered their real sensation of light. In experiment A2 (530/1/530 lux), where the differences in illuminance values are greater than in A1, the effect of having a sensation of brighter light also occurs, although not so drastically. In experiment C2 (1/530/1 lux), whose sequence is the opposite of A2, the assessment of the sensation of light follows behavior quite similar yet opposite to that of experiment A2. Finally, in experiment C1 (1/7.5/1 lux), we noted how the respondents had little ability to discern the sensation of light, perhaps due to the similarity between the two illuminance levels.

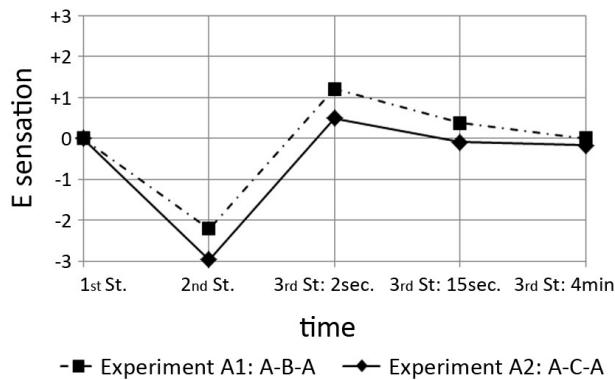


Figure 6: Visual sensation for each of the illuminances in experiments A1 and A2.

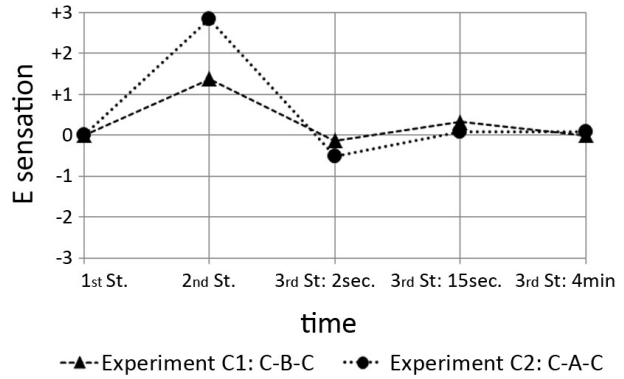


Figure 7: Visual sensation for each of the illuminances in experiments C1 and C2.

The second assessment to analyze is the absolute estimated value, that is, the illuminance level in lux that the survey subjects estimated once the initial value was restored. On this point we should recall that the survey respondents are all architects who are familiar with the units and that in all four experiments their point of reference is the respective illuminance values in phase 1. Likewise, they do not know that the illuminance in phase 3 has the same value as in phase 1. By examining the results in all four cases, we can see how the survey respondents displayed some variation in their assessments of the estimated lux values over the useful surface. For example, in the specific case of experiment A1, which had the most common average conditions, there is a standard deviation in all three assessments in phase 3 of 68, 68 and 71 lux over the estimated 580, 565 and 532 (Fig. 8). What is more, we should note that by carefully examining these results, there seems to be a kind of predisposition by some of the respondents to estimate the lux they assume there to be instead of the lux they estimated there to be. That is, some respondents distinguished between what they might know and the sensation they have. We also found that even though initially none of the respondents showed major signs of visual impairments, one of the subjects did show some signs. Following with the example of experiment A1, we can see how the estimate of illuminance is approximately 10% higher than the average illuminance. What is more, in this case it took around 30 seconds to recover half of this value (Fig. 9).

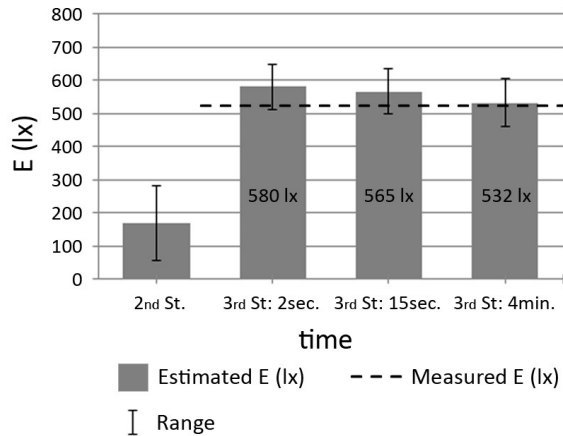


Figure 8: Assessment of the estimated illuminance in experiment A1.

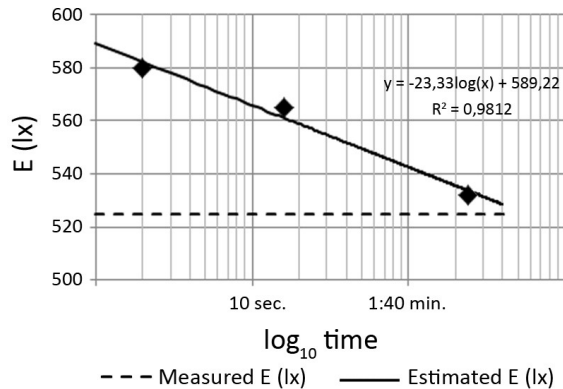


Figure 9: Trend in estimated illuminance (continuous line) in phase 3 of experiment A1, compared to the measured (dots).

Finally, even though this topic is being left for future studies, we can predict that in acoustics a similar overestimation and underestimation effect of the perceived decibels may occur after a change in the acoustic level, although a priori it seems that the acoustic adaptation might be a bit slower than adaptation to light yet substantially quicker than adaptations to temperature changes. In any event, the kind of experiment to be conducted must be carefully studied bearing in mind all the variables that can specifically influence this approach to acoustic adaptability, including the kind of noise, its informational content, its dynamic, etc.

CONCLUSION

This paper is an initial approach to the adaptive model of light comfort. Just as with the thermal model, the experiment in the visual field shows us how after a change in the illuminance level the sensation of light is influenced by prior exposure. When there is a change to a higher illuminance level, the light sensation exceeds the actual light level and the viewer has the sense of higher

illuminance. To the contrary, when the change is toward a lower level of light, the sensation is lower illuminance. What is more, in a relatively short period of time, the sensation gradually approaches the real value. The degree of overestimation or underestimation of the light sensation and the time needed to recover the real value are related to the magnitude of this change. These conclusions came from several laboratory experiments conducted with 24 subjects, all of them architecture graduates who were familiar with light magnitudes. The results can be applied in situations in which light conditions change and in circulation through transitional spaces.

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