Visual performance of home offices: a case study

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Abstract. The design of the lighting systems in conventional office environments is typically supported by domain specialists. However, the same is not true of home offices, whose arrangements frequently result from ad hoc and do-it-yourself activities. This circumstance may have ramifications for occupants’ health, comfort, and productivity, given the recent significant increase in home officeing prevalence. In this context, the present contribution reports on a detailed case study of lighting conditions in a number of home office settings. Thereby, nine home offices (located in the city of Izmir, Turkey) were investigated. The home offices serve a variety of professionals. The study involved measurements under daylight and electrical light conditions. Moreover, simulations were conducted to explore improvement opportunities. The investigation results point to a highly uneven level of performance across the selected cases. The visual conditions were found to be generally better under daylighting conditions, despite some instances of excessive illuminance. Electrical lighting analysis results reveal in many cases insufficient light levels due, in part, to unsuitable types and positions of the luminaires. Simulation-based optimization exercises suggest that the visual conditions in the studied home offices can be considerably improved via changes in the number and types of the luminaires.

1. Introduction
The design of conventional office environments is often supported by domain specialists in lighting. This is to ensure that working spaces are not only sufficiently illuminated but also feature high levels of visual comfort [1, 2]. Home offices, on the other hand, do not typically benefit from specialists’ input. Home office arrangements frequently result from ad hoc circumstances and do-it-yourself activities. It should thus not come as a surprise, if they would display insufficient attention to the visual performance and comfort criteria. As such, this can lead to health, comfort, and productivity problems, given the recent significant increase in home officeing prevalence. In this context, the present contribution reports on a detailed case study of lighting conditions in a number of home office settings. Thereby, nine home offices (located in the city of Izmir, Turkey) were investigated in view of the visual conditions with regard to daylighting and electrical lighting. The study involved measurements under daylight and electrical light. Moreover, simulations were conducted to explore improvement opportunities.

2. Method
In the present study, nine different home office spaces, including twelve work places, were selected. These home offices are located in the city of Izmir, Turkey and are used by a variety of professionals (lawyers, journalists, freelance IT-professionals, as well as architects and industrial designers). The geometry, layout, and photometric properties of the relevant surfaces of the work areas were documented, together with the position and properties of windows and luminaires. Table 1 includes the schematic plans of these nine home offices and therein the locations of the twelve working areas (denoted as A, B1, B2, C, D, E, F, G, H1, H2, H3, and I).
Short-term measurements during daytime and night-time were carried out in each office. Thereby, the extent of the grids for illuminance measurements was dimensioned following the EN 12464-1 standard [2]. The horizontal task illuminance level measurements covered for each work station an area of about 4 m² to 7.5 m² in terms of an orthogonal grid (dimensions 20 × 20 cm to 25 × 30 cm). This facilitated also the derivation of the light distribution uniformity over the working area.

In order to assess different lighting conditions, the measurements were conducted at two different times in the day. During daytime, only illuminance levels due to daylight were measured, whereas in the evening hours only electrical light levels were measured. Given the considerable dynamics of daylight levels, short-term measurement results have only limited utility. Consequently, daytime measurements included also outdoor horizontal illuminance levels in order to estimate the daylight factor at the work areas (understood in the present paper as the ratio of the indoor to outdoor illuminance levels measured under overcast sky conditions). Moreover, illuminance measurements were conducted to determine surface reflectance properties and estimate glare levels under electrical lighting conditions. The results were expressed in terms of the following indicators: mean illuminance (E_m) over the task area, illuminance uniformity (U_e), and daylight factor (DF). Moreover, for night-time conditions, the Unified Glare Rating (UGR) was derived for the occupants’ default position (i.e., for assumed default view direction). Note that no shading elements were deployed during the measurements.

The studied home offices are used by a number of professionals that perform different types of tasks. Table 2 entails the minimum illuminance, maximum UGR as well as minimum illuminance uniformity requirements according to the EN 12464-1 standard [2] listed for different tasks.

To examine possible improvement options, the lighting simulation application DIALux [3] was used. Thereby, detailed 3D models of the home offices were generated considering geometry, furniture, as well as the relevant properties of luminaires, windows, and room surfaces. The reliability of the simulation models was assessed via comparison of the measured and simulated illuminance levels for the existing conditions in the home offices.

In order to improve the electrical lighting conditions, alternative configurations were examined via simulation. The resulting visual performance due to these alternatives pertaining to the number, location, and arrangement of the luminaires was virtually examined using the field arrangement feature of the employed simulation application [3].

3. Results and discussion
The investigation results point to a highly uneven level of performance across the studied home offices. During daytime, the measured daylight levels at the work places were directly related to the position and orientation of the windows. Table 3 provides an overview of the measured daylight factors in the studied home offices. In some cases (B2, D, G, I), the daylight factor across the task area was rather high (> 5%). In these cases, the working area was positioned directly in front of a window. From the purely visual comfort point of view, this situation can be presumably ameliorated using appropriate shading elements (e.g., roller shades, curtains). However, associated thermal risks (overheating) may have to be addressed as well, for instance, via exterior blinds. In some of the other cases (A, B1, F, H2, H3), the daylight factors were rather low (below 1%). This finding can be explained again when we consider the position of the respective working areas with regard to the windows.

The results of the night-time lighting condition, including only electrical lighting, show that the mean illuminance levels at the working areas were insufficient in the twelve studied work places (see Figure 1). The analysis of the results suggests that insufficient light levels are primarily due to luminaires suitability (for the visual task at hand) and positioning issues. Likewise, in most cases, illuminance uniformity levels at the working areas did not meet the minimum standard requirements (see Figure 2). Furthermore, in a number of cases (B1, B2, E, F, H2, H3), the derived UGR values for the existing conditions in the home offices were found to be considerably higher than the recommended maximum values (see data included in Table 4).

To address the potential for improvement with regard to these shortcomings, possible improvement options (including more suitable luminaries and a better arrangement of those) were examined. To this end, the aforementioned field arrangement feature of the deployed simulation tool [3] was deployed.
The results of this simulation-based optimization exercise are illustrated in Figure 3 (post-improvement mean task illuminance levels), Figure 4 (post-improvement illuminance uniformity levels), and Table 4 (post-improvement UGR values). These results underline the considerable improvement potential of the visual conditions (as reflected in the post-improvement values of the above visual performance indicators) via changes in the number, type, and location of the luminaires.

Table 1. Schematic plans of the studied home offices and the working areas.
Table 2. Minimum illuminance, maximum UGR, and minimum uniformity requirements (according to the EN 12464-1 standard [2]).

| Home office | Type of work tasks                        | $E_m$ [lx] | UGR | $U_o$ |
|-------------|------------------------------------------|------------|-----|-------|
| Home offices | A  | CAD workstations                        | 500        | 19   | 0.6   |
| Home offices | B1, E, F, I | Writing, typing, reading, data processing | 500        | 19   | 0.6   |
| Home offices | B2, D | Technical drafting                      | 750        | 16   | 0.7   |
| Home offices | C  | Computer room                           | 300        | 19   | 0.6   |
| Home offices | G  | Private tutoring                        | 300        | 19   | 0.6   |
| Home offices | H1, H2, H3 | Sewing, fine knitting, stitching       | 750        | 22   | 0.7   |

Table 3. Measured daylight factor at the working areas.

| Home offices | A  | B1  | B2  | C   | D   | E   | F   | G   | H1  | H2  | H3  | I   |
|-------------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| DF [%]      | <1 | <1  | >5  | 4.7 | >5  | 1.2 | <1  | >5  | 1.7 | <1  | <1  | >5  |

Figure 1. Mean illuminance levels (electrical light only) at the working areas (red dots = field measurements, bars = minimum standard recommendation).

Figure 2. Illuminance uniformity levels (electrical light only) at the working areas (red dots = field measurements, bars = minimum standard recommendation).
Figure 3. Mean illuminance levels after improvement (electrical light only) at the working areas (green dots = simulated values after improvement, bars = minimum standard recommendation).

Figure 4. Illuminance uniformity levels after improvement (electrical light only) at the working areas (green dots = simulated values after improvement, bars = minimum standard recommendation).

Table 4. Calculated UGR values for existing conditions (UGRex), UGR values after improvement (UGRimp), together with the recommended maximum UGR values for the respective functions (UGRreq).

|       | B1 | B2 | E  | F  | H2  | H3  |
|-------|----|----|----|----|-----|-----|
| UGRreq| 19 | 16 | 19 | 19 | 22  | 22  |
| UGRex | >30| >30| >30| 26 | 29  | >30 |
| UGRimp| <10| <10| 18 | 14 | 21  | 21  |

4. Conclusion
We presented the results of a visual performance assessment of a number of home offices used by different professionals and for different tasks. The short-term measurements of the daylight availability imply significant differences among the cases. As far as results based on daylight factor can be trusted, both insufficient and excessive levels could be detected in different working areas. Thereby, as it could be expected, the proximity to the windows represents the main influencing factor. The nature of the buildings’ envelope, the properties of the existing windows, and the layout constraints with regard to available space may dictate the position of the working areas. Whereas insufficient daylight availability may be compensated by the deployment of electrical lighting, care should be given with regard to availability and suitability of shading opportunities in those cases where proximity to windows may cause visual discomfort (glare) and overheating risk.
Assuming common code-based visual performance mandates represent the applicable benchmark, the existing electrical lighting solutions in all home offices have to be characterized as unsatisfactory. Task illuminance levels were found to be consistently and significantly below the recommended values. Moreover, with a few exceptions, the uniformity levels were found to be below the recommended ranges. In half of the cases, the calculated UGR values were found to be significantly higher than the maximum recommended values.

A simulation-based exploration of the potential for improving the visual conditions was found to be promising. Through a number of measures that are arguably both practical and feasible (repositioning the luminaires as well as application of different luminaire types), conditions relevant to the aforementioned visual performance criteria could be considerably improved.

The presented study is of course limited in many aspects. Only a small number of home office instances could be assessed and all of these are located in the same urban and climatic context. This simply means that the results cannot be suggested to be either representative or generalizable. Nonetheless, viewed as a pilot study, the results can encourage a closer look at visual conditions in home offices. In-depth studies in this direction appear to be both important and urgent, given recent critical developments that have led to a global tendency toward home-officing. Specifically, the present study can provide input to needed efforts to formulate practical guidelines for the conception and realization of appropriate lighting solutions for home offices.

References

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