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***Abstract*—Medication errors in hospitals can lead to life threatening situations. In the process of medication care, many errors can occur. Good lighting might prevent some of these errors. The study presented in this paper investigates whether the light condition can contribute to improve the visual performance in hospitals. The specific focus is on the area where medication is being sorted and prepared for patients at the ward. Light measurements, a survey among nurses and a visual acuity test demonstrates that the amount of light has an influence on the visual performance but that nurses do not seem to be aware of this.**

***Index Terms*—hospital errors, Patient safety, medication-rooms, light conditions, nurses**

INTRODUCTION

Medication dispensing follows a long route before it reaches the patient. In this process human mistakes are easily made. This can result in life threatening situations. According to Jones [1] patients are at risk due medication errors. These errors are caused by difficult-to-read medication labels, the increasing age of the nursing population and the poorly lit work environments. Appropriate lighting enhances the visual performance. Mistakes in medication could for example originate from insufficient lighting, disadvantageous spectral distribution or distracting lighting. Since the main focus in a hospital lies with the patients, keeping dim lighting during night check-ups enhances the patients sleep but at the same time pose challenging light conditions for nurses to perform their visual tasks. These tasks include, but are not limited to, reading the dose, telling apart different pills and checking whether the infusion is still working properly. The impact of the light conditions becomes even larger for average aged and older nurses whose vision is deteriorated by presbyopia or eye fatigue. Therefore it is crucial to provide a lighting situation that enhances the visual performance of nurses managing medication. Graves and colleagues [2] performed a semi-structured interview among 16 registered nurses in a hospital. They inquired about their attitude towards the influence of light on their work performance. They concluded that most nurses are unaware of how light can enhance the patient safety and on how they can influence their own light condition. Although several studies stress the importance of good lighting for preventing medication errors, actually only one research paper was found which assessed the influence of light on a medication related task, in this case capillary refills [3]. This study among 309 care professionals found that a statistically significant amount of less errors occurred between capillary refill assessments in (day) light conditions than in dim light conditions. The number of undetected refills during the light conditions was 3.9% while under dim conditions it was 66.7%. Since the two different light conditions occurred during daytime and nighttime respectively, it remains unclear whether these large differences can be solely attributed to the visual performance or whether stress or reduced alertness during the evening/night might have an impact as well. In a study on the influence of daylight and darkness on medication errors by nurses in Alaska, the researchers concluded that darkness was one of the four predictors of the risk of medication error [4]. More than half of all medication errors occurred during the first 3 months of the year. Interesting is that there was a 2-months delay between the level of darkness and the rate of errors. This would indicate that medical errors are not only related to the visual performance.

The research presented in this paper focusses on the preparation and dispensing of medication. The main research questions is to assess the attitude of nurses towards the lighting conditions in the hospital they work and relate that to the actual light condition. The second question is to what extent impacts the current light level the nurses' visual performances.

METHOD

In two different hospitals (henceforth called H1 and H2) in the Netherlands the current light conditions in the medication rooms of different wards were measured. A survey among hospital nurses was conducted, enquiring about

their perception of the light conditions with a special focus on their activities related to the medication process. A visual acuity (VA) test was carried out on two positions in the medication room where the preparation and sorting of medication takes place. The two positions represent a darker and a brighter light condition respectively.

The lighting design and room lay-out of the medication-rooms in H1 were all identical, except from the Intensive Care unit. In H2 not every medication room and lighting design was similar. For this reason, the study was carried out in wards with a different lay-out and lighting design, on three different floors of the same building volume (these will be referred to as H2-A, H2-B, H2-C). The activities related to the medication process were similar in both hospitals. All measured medication rooms had no window connected to daylight, except the IC-unit in H1.

A. Test Locations

Hospital H1 was completed in 2013; its design complies with the healing environments principle. The key concept behind healing environments is that the interaction between patient, care professionals and its environment positively contributes to the healing process and/or wellbeing [5]. One example of applying this principle is that the medication rooms on all different wards are at the same in position, and have the same size and lay-out. The only exception to this rule is the medication room of the Intensive care (IC) -unit. The other hospital (H2) was completed in 1973. Since they were in the middle of a large renewal project, some of the wards had recently been renovated. The measurements took place in three different wards; two non-renovated (H2, A and H2, C) and one renovated (H2, B). **Napaka! Vira sklicevanja ni bilo mogoče najti.** shows the floor plan and layout of the medication-room of the different wards.

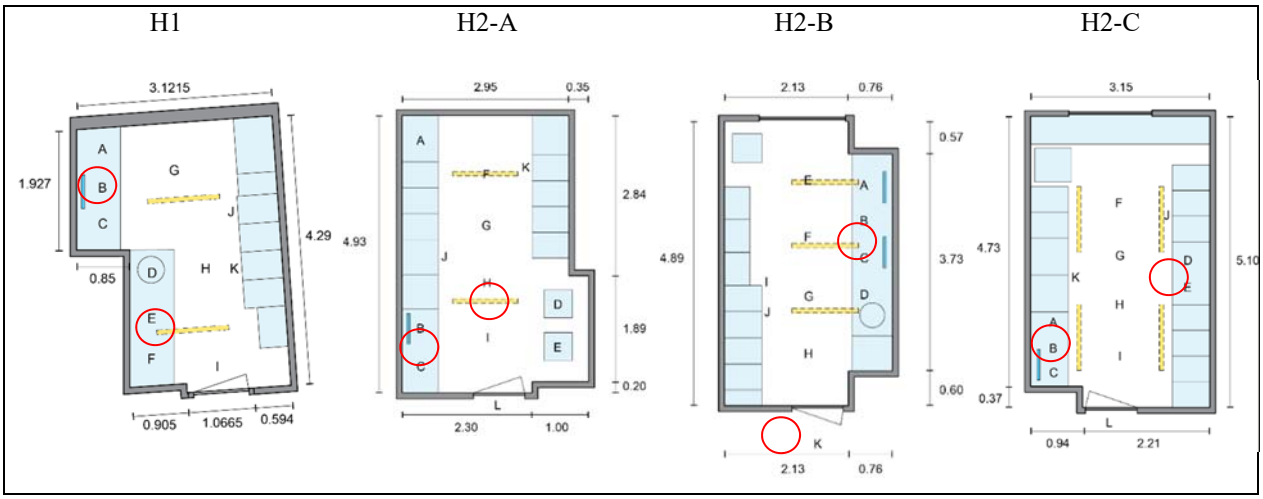

Figure 23 Layout medication rooms H1, H2-A, H2-B, H2-C, the letters represents the measurement positions. Positions J and K and for room H2-B, I represents a vertical measurement position at eye-height. The yellow lines indicate the position of the luminaires in the ceiling. The VA-tests were performed at the positions indicated with the red circle. In H2-B no dim position was identified and therefore this measurement was performed at the nurses' station.

B. Participants

With the approval of the head of the ward, nurses on duty were asked to voluntary participate in the study which took ~45 minutes of their time.

i. Survey

In total 29 participants (26 Female, Mean age 31.7 a, SD 10.8 a), worked in different hospitals (31.3% in H1, 68.7% in H2). The mean work experience was 10.7 a (SD 10.3 a).

ii. Visual acuity test

The total number of people who participated in the VA-tests was 32. 28 female and four male. Mean age was 33.3 a, SD 10.6 a), worked in different hospitals (37.5% in H1, 62.5% in H2). The mean work experience was 10.9 years (SD 10.2 a). Of the 17 participants who wore glasses or contact lenses, 8 of them were corrected for farsightedness or both farsightedness and myopia.

C. Survey

A survey was conducted to establish the attitude towards the lighting. This survey was executed as a structured interview. This approach allowed to confirm that the questions, especially the ones about the lighting characteristics, were interpreted correctly.

D. Visual Acuity Test

The VA was tested with a two-sided 'Logarithmic visual acuity chart 2000 "new etdrs" ' by Precision Vision®. One randomly chosen side was used for the darker condition and the other for brighter light condition (see **Figure 23** for the test positions). The reading distance was kept 40 cm, measuring from eye to chart. The lighting on the chart, per individual test was measured since the lighting was not identical in all medication rooms nor at all measured positions.

In H1 the average illuminance on the two task areas was 240 lx and 610 lx. In H2, the illuminances in H2-A were 190 lx and 280 lx, in H2-B were 252 lx and 808 lx and in H2-C, 310 lx and 560 lx. The difference between both lighting conditions are presented in **Figure 24**.

The results are presented in LogMAR (**Log**arithm of the **M**inimum **A**ngle of **R**esolution). An observer who can resolve details as small as 1 minute of visual angle, scores LogMAR 0 (the base-10 logarithm of 1 is 0). A value of 0 indicates normal vision, a negative value indicates that smaller details are readable (better vision) while a positive value indicates worse vision. In this study, the value of the smallest correctly read sentence was used. The VA of the nurses was tested with the vision correction they used at that time.

E. Light Measurements

Light measurements were performed in the different medication rooms. The following aspects were measured:

1. The illuminance (E) and the correlated colour temperature (T_{cp}) were measured on the relevant task areas (see **Figure 23**): Horizontally at the desk(s), on the floor as well as horizontally and vertically close by the storage closets for medication. For the VA-test, the E and the T_{cp} were measured on the chart on the positions where testing took place. The illuminance spectrometer Konica Minolta CL-500A was used to take the measurements.
2. The luminance distribution inside the rooms was determined by using a Canon EOS50D digital single-lens reflex camera with a Sigma 4.5 mm fisheye lens and the software BPS-Radiance-image (2014)

F. Analysis

Data statistics were carried out in Microsoft Excel (2013). A one tailed paired t-test was used to identify whether a significant difference in VA was found between the results under the darker and the brighter condition. A p-value < 0.01 was considered significant. IBM SPSS statistics 23 was used to analyse a correlation between the VA and illuminance and VA and T_{cp}. A Pearson one-tail test was therefore carried out.

RESULTS

A. Light Conditions In Relation To The Attitude Towards Lighting

The nurses expressed no explicit complaints on the amount of light in the medication room. 81% considered the lighting good. Although the measurements revealed a rather large difference in horizontal illuminance at desk level between the different medication rooms, this was not experienced as such by the nurses (see Table 1). The correlated colour temperature was considered cold by 38 % of the participants while 6% found it warm. The remaining 56% were neutral. The measured T_{cp}, in all medication rooms was < 3100 K. A T_{cp} of 3000 K is considered warm white while a T_{cp} of 4000 K is considered cool white. When asked about the amount of daylight, 40% wanted to have more daylight, one person wanted less daylight, while the rest considered the amount of daylight in the ward good. Due to the lay-out of the wards, the patient rooms are connected to two sides of a hallway with the nurses station centred in the hallway with at the end a window. The patient rooms all have windows.

TABLE 1 AVERAGE HORIZONTAL ILLUMINANCE IN THE MEDICATION ROOMS

	Average horizontal illuminance [lx]		Perceived light condition by nurses (number of participants)
	Desk	***Floor***	
Recommended[6]	500	100	
H1	397	325	Good (8) Dim (1)
H2-A	195	315	Dim (2) Good (3) Bright (1)
H2-B	839	483	Dim (1) Good (6) Bright (1)
H2-C	521	773	Good (6)

B. Visual Acuity

Each participant was asked to participate in a VA-test on a relatively dark and a bright position in the medication room. Since not all medication rooms were identical the light conditions and the difference between both light conditions are not identical either. Figure 24 shows the VA difference per participant indicating the difference in illuminance between the dark and light condition. Figure 25 displays the difference between the VA per participant set-out against the age of the participants. For both graphs, a negative value indicates better vision under the higher illuminance while a positive indicates the opposite. A value of 0 indicates no difference.

Interpreting the graphs reveals, that most participants (15 out of the 32) had a score under zero, indicating that the VA was better under the highest illuminance. For 14 participants the score remained the same and 3 participants scored better under the dark conditions. A paired samples t-test allowed to compare the visual acuity results under the darker and the brighter condition, within subjects. There was a significant difference between VA under the darker condition (M=0.04, SD=0.01) and the brighter (M=-0.01, SD=0.01) condition; (t(31)=3.30, p=0.001). When performing a Pearson test, no significant correlation was found between VA and illuminance level, and VA and T_{cp}.

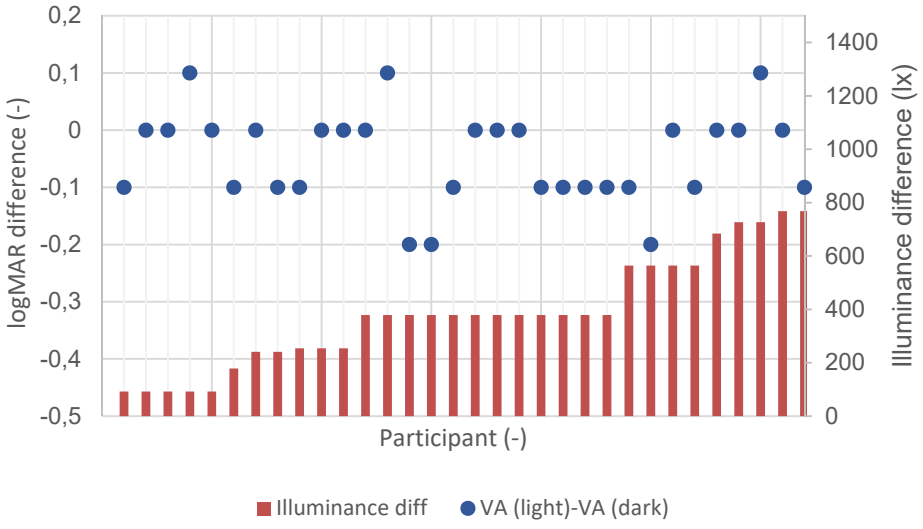

Figure 24 Difference in VA per participant and illuminance. The bars indicate the difference in illuminance between the darker and the lighter condition.

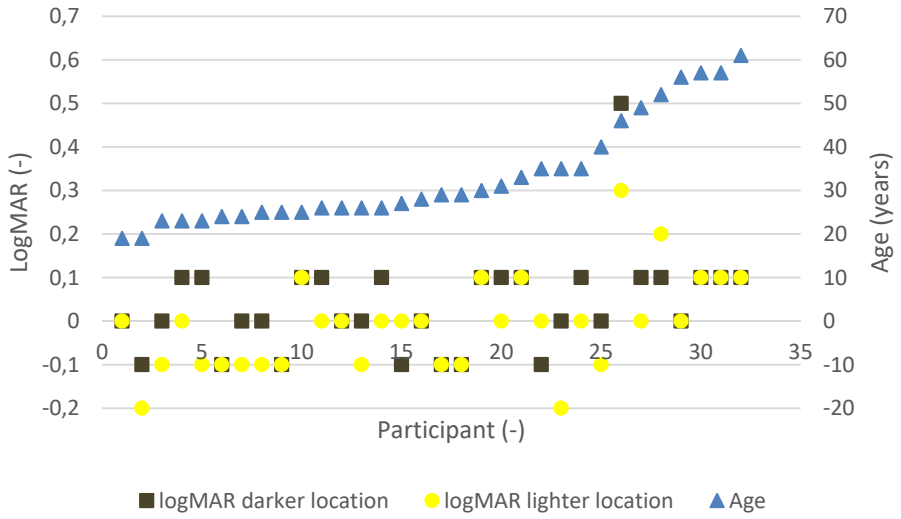

Figure 25 VA light and dark condition ordered per age of participant.

Discussion and Conclusion

The results indicate that although large differences in light conditions have been observed in different medication rooms, the majority of the nurses perceive the lighting as good. This also holds true when the illuminances are lower than the recommended levels according to the standard. That this might be a case of unawareness can be concluded from the results of the VA-test. For nearly half of all participants, the visual performance was significantly better on a relatively bright position in comparison to a relatively dark position in the medication room.

When considering the process of mediation care, dealing with sometimes very small letter sizes, appropriate lighting might therefore contribute to lower the error rate. In a follow-up test, the light parameters illuminance and correlated colour temperature will be varied in order to find the most suitable light condition for reading different prints on different types of medication packages.

Acknowledgement

The authors gratefully acknowledge the support of the hospitals and their staff for participating in this study. The authors also want to thank L. Mennen, student at the TU/e, for collecting the data for this study. This study is part of the SPARK impuls II project.

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