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INFLUENCE OF LIGHT LEVELS ON VISIBILITY FOR SAFETY AT AUTOMATED TELLER MACHINE FACILITIES

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Abstract

People need light to safely use an automated teller machine (ATM) at night. Standards and recommendations for the amount of lighting, as well as the locations to be lighted, at ATMs differ across organizations and jurisdictions. The objectives of the present study were to identify relevant visual tasks that the customer needs to perform for efficient and safe use of the ATM, and to investigate how different light levels impact performance of those tasks. The results indicate that minimum illuminances of 10 lx at and around the ATM are sufficient to achieve adequate visual performance for safety-related visual tasks such as those evaluated in the present study. The present findings suggest that a minimum illuminance of 10 lx can be sufficient for many visual tasks required for safe ATM use. Visibility analyses using the relative visual performance model can be useful in evaluating lighting in the ATM environment.

Keywords: Safety and Security, Visual Performance, Exterior Lighting

1 Introduction

Lighting is a critical and well recognized element in the perceived and actual safety of ATM facilities (Ross, 2013). In addition to contributing to personal safety, lighting is becoming increasingly important for video and camera-based activities. Recently published research has confirmed the usefulness of metrics of visual performance and glare for characterizing the safety-related performance of lighting in environments like those around ATMs, and for understanding how lighting can influence subjective perceptions of brightness and personal safety.

The development of ATM lighting requirements from the 1990s to the present time has been based mainly upon the recognition for the need for security lighting (DeYoung, 1995; Scott, 2001; Guerette and Clarke, 2003; Turner et al., 2004; Scott and Atlas, 2008). In parallel with initial design guidelines from the Illuminating Engineering Society (IES, 1997) the areas surrounding the ATM have been divided into specific regions with different lighting requirements. The immediately surrounding area within 1.5 to 3 m tends to receive higher illuminances of 100 lx, and illuminances at further distances, out to approximately 15 m, tend to be lower (20 lx). Such recommendations have been repeated and consolidated by both lighting and security professionals (Kaplan, 1995; IDA, 2000; OSRAM SYLVANIA, 2012) and represent current recommended practice (IES, 2003). DeYoung (1995) summarized regulations in force as of the mid-1990s in states across the U.S.

In addition to the specification of particular light levels near and around the ATM, lighting quality issues such as glare (IDA, 2000; Bullough et al., 2008), and light source spectrum as it influences colour identification and perceptions of personal safety and security (Rea et al., 2009) are also important to successful lighting at ATMs. Finally, the energy use and maintenance associated with lighting at ATMs, while not necessarily of primary concern for security, are important factors in the overall cost of operating these systems, and controls technologies that would permit lighting energy to be reduced without negatively impacting safety and security will likely grow in importance (Abubeker et al., 2013).
Recent research has confirmed the utility of metrics for assessing different aspects of lighting performance including discomfort glare (Mou et al., 2017), scene brightness perception (Rea et al., 2017), and visual performance (Rea and Ouellette, 1991; Bullough and Radetsky, 2014). Finally, while not within the scope of the present study, a number of authors have recognized that lighting for video and camera-based applications at the ATM (e.g., for security or for remote teller use) will present substantial challenges (e.g., Ray et al., 2015; Kayim et al., 2016; Zhang et al., 2017).

2 Methods

Three important safety-related visual tasks were identified and investigated in the present study: identifying the currency of bills retrieved from an ATM, orienting oneself safely through the area surrounding an ATM before and after using the facility, and identifying features of other people in the vicinity of the ATM. These tasks were simulated through human factors experiments in the photometry laboratory of the Lighting Research Center, a large, windowless, black-painted room. The participants in all three experiments were 12 adults with an average age of 49 years, ranging between 26 and 72 years.

2.1 Currency Identification

A set of printed notes designed to look like currency in three different denominations ($1, $2 and $5) were spread randomly on a table top (see Figure 1) lighted to an illuminance of 5, 10 or 20 lx. There were 12 copies of each denomination, and at any given time, all 12 of two of the denominations were placed on the table, but only one of the third denomination. For example, there might be 12 notes with a denomination of $1, 12 with a denomination of $2 and one with a denomination of $5. The location of the unique denomination was randomized during each trial.

![Figure 1 – Examples of Simulated Currency Notes Used in the Experiment](image)

During some trials, a glare source consisting of a halogen lamp adjusted to produce a vertical illuminance of 0.2 or 2 lx was energized. The glare source could be positioned so that it would be located 5° above the subject’s line of sight if the subject were looking straight ahead, or located 10° above the subject’s line of sight. Because of the table’s height, however, the subjects’ actual line of sight during each trial was downward toward the table. In other trials, neither glare source was energized.

Before each trial, the subjects were asked to turn away from the table while an experimenter set up the notes on the table. Subjects were told ahead of time which denomination they would be looking for. Once the notes and lighting conditions were set up for each trial (in randomized order), the subject was asked to turn toward the table, but not to look at the table until given a signal by the experimenter, who also initiated a stopwatch timer at this moment. When the experimenter signalled, the subject was instructed to locate the unique denomination as quickly as possible among the notes on the table and point to it while exclaiming, “there!” At this time the experimenter stopped the stopwatch and recorded the search time.

2.2 Spatial Orientation

On a 2-m by 3-m black carpet, dark green tape was used to outline a simple 3 x 5 maze (see Figure 2) with a grid size approximately 0.6 m square. The illuminance on the carpet was
adjusted to be 5, 10 or 20 lx. A glare source was used in some of the trials and the locations and light levels of it were the same as in the currency identification experiment.

In each trial a subject was asked to stand at one end of the carpet and, upon a signal from an experimenter, to navigate through the maze to the other end, one grid square at a time, by moving both feet into each square before proceeding to the next square. Subjects were instructed not to cross the imaginary line indicated by the tape. The experimenter set the lighting conditions (in randomized order) and measured the time taken to complete each trial with a stopwatch. The time for the subjects to place their second foot in the final square of the maze (opposite the square they started in) was used to determine the completion time.

![Figure 2 – Photograph of the Carpet Delineated with a Maze](image)

### 2.3 Face Identification

In the third experiment, 1:6 scale doll heads (Figure 3) were painted with either light (reflectance 0.7) or dark (reflectance 0.2) skin tone paint. Heads of each skin tone were also outfitted with black hair on the head or were bald, with a black moustache or no facial hair, and with a pair of earrings or none. Vertical illuminances on the face of the head when mounted for an experimental trial were either 5, 10 or 20 lx. The same glare sources used in the currency and spatial orientation experiments were used, with one source located 5° to the right of the head, and the other source located 10° above the head, and the illuminances from each glare source, when energized, were 0.2 or 2 lx at the eyes of the observer. Subjects serving as observers in this experiment stood 2.5 m from the scale model faces, simulating a viewing distance of 15 m from a full-scale face.

![Figure 3 – Scale Model Heads Used in the Face Identification Experiment](image)

In each trial, an experimenter set up the lighting conditions while the subject looked away, and once the face, randomized for skin tone, hair, moustache and earrings, was mounted in place, the subject was asked to look at the face and answer the following questions:

- Is the skin tone light or dark?
- Does the person have hair?
- Does the person have a moustache?
• Is the person wearing earrings?

Subjects were given as much time as needed to answer each question, and were instructed to guess one of the two answers if they were uncertain. In most trials, the subjects took only a few seconds to answer each question. The experimenter recorded whether the answers to each question were correct for each trial. The order of lighting conditions and of the facial features were randomized for each subject’s set of trials.

3 Results

3.1 Currency Identification

A within-subjects analysis of variance (ANOVA) was conducted on the search identification times in the currency identification experiment. The ANOVA revealed that there were no statistically significant (p>0.05) main effects of illuminance, nor the presence of glare, on the search identification times. This indicates that performance was not affected by the light level on the table (either 5, 10 or 20 lx; see vertical bars in Figure 4), nor by the presence, amount or location of the glare source. Because the glare source was located relatively far from the line of sight for this visual task, it was not surprising that the glare-related variables exhibited no statistically reliable main effects. Importantly, even though the illuminance trend on identification times was not statistically significant, the times are consistent with RVP-based response times predicted for the combinations of light level, contrast and size for the average age of the participants (circles in Figure 4).

![Figure 4](image_url)

**Figure 4 – Mean (+/- Standard Error of the Mean) Currency Identification Times (Vertical Bars) for Each Illuminance; Also Shown are RVP-Predicted Response Times for Each Condition (Circles)**

Half of the subjects were more than 50 years old (average of 61 years). In order to assess a possible role of age on the currency identification task, a statistical analysis was run on the identification times for the older subjects (vertical bars in Figure 5). There was a statistically significant (p<0.05) main effect of the light level, with the identification time at 5 lx being longer than the identification times for 10 and 20 lx, and age-adjusted RVP-based response times were correlated with the average identification times for these subjects as well (circles in Figure 5). Importantly, as predicted, the identification times only appeared to increase substantially for the older subjects at the lowest illuminance of 5 lx, and were similar to the overall times for the illuminances of 10 and 20 lx.
3.2 Spatial Orientation

All of the subjects in all trials completed each trial without making any errors. As in the currency experiment, a within-subjects ANOVA revealed no statistically significant (p>0.05) main effects of illuminance on the carpet, nor of the presence, amount or location of glare on the time taken to traverse the maze. Also similar to the currency experiment, the subjects’ line of sight was generally downward toward the floor while they were performing each trial, so the lack of significant glare effects is again, not surprising.

3.3 Face Identification

Within-subjects ANOVAs revealed that neither the illuminance on the scale model faces nor the presence, amount or location of glare had a statistically significant (p>0.05) main effect on identification of any of the facial features used in this experiment. Identification accuracy was 100% for skin tone and the presence of earrings; accuracy was slightly lower for hair and lowest for the moustache (see Figure 7), which was expected since the moustache has the smallest size (3.4 microsteradians) among the facial features evaluated. Also shown in Figure 7 are the average RVP-predicted response times for the moustache under each illuminance condition. Although one might not expect the number of errors to be correlated with response times, Rea (1981) found that these responses followed very similar functions of contrast or light level.
Subsequent analyses were performed to assess the possible influence of age on face feature identification, but no reliable differences were found between the younger and older subjects in this experiment. Overall, however, the results suggest that there is little if any difference in performance among illuminances of 5, 10 or 20 lx on the faces used in this experiment. The slightly larger number of errors in identifying the moustache at 5 lx is qualitatively consistent with the slightly longer response times that would be predicted for this stimulus using the RVP model.

4 Discussion and Conclusions

4.1 Summary of Findings

The findings from the human factors experiments and the accompanying RVP analyses described in the previous section of this paper are consistent in that they support the notion that visual performance on several important visual tasks performed by the ATM user is maintained by an illuminance (on the relevant plane for each task) of 10 lx, with negligible measurable benefit when the illuminance is increased to 20 lx. This suggests that an illuminance of 10 lx in the area immediately adjacent to the ATM (at 1 m above the ground) and along walkways (at grade), and a vertical illuminance of 10 lx in the vertical plane (at a height of 1.5 m) could serve as a basis for light level recommendations in and around ATM facilities. For illuminating open spaces away from designated walkways where the presence of a person may need to be detected, an illuminance of 5 lx would be sufficient based on detecting an entire person rather than a small portion of the face.

Restricting the ratio between illuminances at the ATM itself and those on walkways outdoors at night to no more than 30:1 (1.5 log units), will help minimize visual adaptation times as a user moves from the ATM to exterior locations. Adaptation to differences in light levels of less than 2 to 3 log units requires a duration of less than 1 second (Rea, 2000).

For some of the tasks used in the human factors experiments, the presence of glare tended to worsen performance. Disability glare is approximately inversely proportional to the square of the angular distance between the line of sight and the location of a potential glare source (Fry, 1954) so that glare is worst when the glare source is located near an object in the field of view. For this reason, it is important that the specifier of an ATM lighting installation selects luminaire mounting heights, locations and if needed, shielding, so that it is unlikely for an observer to view a bright light source close to the location of another person in the field of view. Luminaires such as wall packs, or floodlights mounted on short poles (less than 3 m in height) can be especially problematic for disability glare.

4.2 Notes on Field Measurements

In order to verify whether a particular ATM lighting installation meets the light level criteria outlined previously, it is important to define the appropriate measurement planes. For transactional related tasks, such as counting currency, illuminances within 3 m of the ATM

Figure 7 – Number of Errors (Vertical Bars, +/- Standard Error of the Mean) for the Presence of a Moustache at Each Illuminance; Also Shown are RVP-Predicted Response Times for Each Condition
should be measured horizontally at 1 m above the ground (to help users identify currency they are holding).

For safety related tasks, such as basic orientation and identification of persons at or around the ATM, illuminances within 3 m of the ATM should be measured horizontally at grade (to help users avoid tripping hazards or locate dropped items) and vertically at 1.5 m above the ground, facing out (to help users identify facial features of others exiting the ATM). Between 3 and 15 m from the ATM, illuminances on walkways should be measured at grade (to help users avoid tripping hazards or locate dropped items). Illuminances should also be measured at grade in areas away from designated walkways (to help users detect the presence of individuals in those areas). At a distance of 15 m from the ATM, illuminances should be measured in the vertical plane 1.5 m above the ground, facing in (to help users identify features of others approaching the ATM). Beyond 15 m, light levels and conditions should follow standard recommended practices, such as those published by the IES, for the type of location. For example, if an ATM is located adjacent to a parking lot, the area within 15 m of the ATM should meet the criteria identified above; beyond that distance, recommended practices for parking lots should be followed. Table 1 summarizes these measurement planes for each distance range.

<table>
<thead>
<tr>
<th>Distance from ATM</th>
<th>Measurement Plane – Transactional Tasks</th>
<th>Measurement Plane – Safety-Related Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 3 m</td>
<td>Horizontal, 1 m above ground</td>
<td>Horizontal, at grade</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vertical, 1.5 m above ground (facing out at 3 m)</td>
</tr>
<tr>
<td>3 – 15 m</td>
<td>N/A</td>
<td>Vertical, 1.5 m above ground (facing in at 15 m)</td>
</tr>
<tr>
<td>&gt; 15 m</td>
<td>N/A</td>
<td>*</td>
</tr>
</tbody>
</table>

*Follow recommended practices for location type beyond 15 m.*

For all measurement points, it is assumed that a user at or approaching an ATM has a direct, unobstructed view in a given direction. For example, if an ATM were located on the exterior wall of a building, measurements would not be taken within the interior of the building even for those locations that are less than 15 m from the ATM. The entire area surrounding the ATM being evaluated, with the exception of any region obstructed as described above, should be included in the measurement region that extends to 15 m.

It is recommended that the measurement locations within 15 m of the ATM be of sufficient density and orientation to ensure appropriate data collection for the associated tasks in those areas. In addition, to ensure that the lighting in the approach area around the ATM has sufficient coverage, it is recommended that measurement locations be no more than 8 m apart. The presence of obstructions or large changes in elevation (e.g., stairs) may warrant shorter distances between measurement locations. The minimum recommended spacing of 8 m provides sufficient proximity that the person making the measurements can estimate whether the light levels between two adjacent points appear to be substantially lower than the values recommended in this paper.

For assessment of glare, in most instances it will not be practical to utilize necessary instrumentation in the field to quantify the significance of glare at a particular location. Given this reality, an assessment of glare, if conducted, should at least be determined by a trained person to identify whether significant disabling glare is present and whether it impairs performance of a user’s safety related tasks.
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