# BrightLights: Gamifying Data Capture for Situational Visual Impairments

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## ABSTRACT
With the growing popularity of mobile devices, Situational Visual Impairments (SVIs) can cause accessibility challenges. When addressing SVIs, interface and content designers are lacking guidelines based on empirically-determined SVI contrast sensitivities. To address this, we developed BrightLights – a game that collects screen-content-contrast data in-the-wild that will enable new SVI-pertinent contrast ratio recommendations. In our evaluation with 15 participants, we found significantly worse performance with low screen brightness versus medium or high screen brightness, showing that BrightLights is sensitive to at least one factor that contributes to SVI (screen brightness). Once validated for in-the-wild deployment, BrightLights data will finally help designers address SVIs through their designs.

### Author Keywords
Situational impairment; accessibility; mobile devices; games.

## INTRODUCTION AND BACKGROUND
Mobile devices enhance convenience and are now ubiquitous beyond personal use, e.g., tablets are used in schools [5], iPads are replacing pilot reference manuals [20], and neurologists can access information from anywhere [3]. These diverse use contexts increase the potential for *situational impairments*, a phenomenon recognised in HCI over many years [10, 16, 21].

In this study, we focus on mobile device Situational Visual Impairments (SVIs), e.g., difficulty using a smartphone on a sunny day. Mobile devices are susceptible to degraded image quality as ambient light increases [7] and exposure to glare can reduce our perceived contrast sensitivity [12]. SVIs can cause further accessibility problems for people with an existing visual impairment. We still have a lot to learn regarding mobile device situational impairments [14], and in particular for severely constraining situations [15], but we do know that there are several contributing factors to SVIs [18] (e.g., content design), yet mobile designers are under-supported in dealing with SVIs and requested improved guidelines, education, and digital design tools [19].



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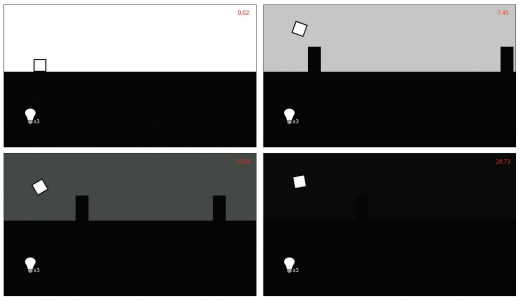

**Figure 1. A demonstration of the BrightLights gameplay. The player jumps obstacles as the background shifts from white to black over time.**

Mobile designers are currently advised in mobile OS design guidelines [1, 2, 9] to use the Web Content Accessibility Guidelines (WCAG) 2.0 [4] for sufficient text and icon contrast, however, those guidelines were judge as sufficient on a large desktop display [11], which may be unsuitable for mobile. Unfortunately, WCAG 2.1 did not update its screen contrast criteria [8]. SVI-specific contrast guidelines are needed.

Before we can introduce new design guidelines, we need to collect ecologically valid data on a large scale due to the complexity of mobile device SVIs. A previous large-scale online study found increasing ambient brightness and decreasing screen brightness can reduce people's colour differentiation abilities [13], however, the majority of participants did not use a mobile phone or tablet and the data suggested that the participants took part under reasonable viewing conditions. While motivating people to engage with research is a challenge, user enjoyment can be increased by adding game elements [6].

We introduce BrightLights, an endless-runner game that challenges a player to overcome obstacles. As the player progresses, the background fades from white to black reducing the contrast between background and obstacles, increasing the game difficulty. During play-through, data about the user's performance is collected and stored. Initial findings demonstrate significantly worse performance for the low screen-brightness condition in comparison to medium and high screen-brightness conditions, which suggests that BrightLights is a suitable instrument for collecting SVI-related contrast sensitivity data.

## SYSTEM OVERVIEW

BrightLights was developed through a series of user-centered design iterations. In BrightLights, the player is represented by a white square on the left side. Black blocks (obstacles) appear from the right with random spacing between them, and the player taps on the screen to jump over each obstacle. The background fades from white to black (see Figure 1), reducing the contrast and increasing difficulty. If the player hits an obstacle, the square changes to the current background brightness further increasing difficultly, but the obstacle is removed and the game continues. The background and the player square are reset to white by pressing the 'light bulb' button. There are three light bulbs available. Players are encouraged to press the light bulb when it becomes too difficult to distinguish between the background and obstacles. The game ends on the third collision after all the light bulbs are used and the game data is logged for future analysis.

## EVALUATION

### Participants and Procedure

Fifteen participants (9 male, 5 female, 1 preferred not to say) with a mean age of 21.5 years-old (21-25 years-old) took part. Participants read an information sheet and completed a consent form as per our REB approval. No participant played endless runner games more than occasionally so were given a training session (max 5 minutes) with a popular endless runner [17].

We counterbalanced the three levels of the independent variable (***screen brightness***). These were determined by setting the brightness slider to low (3cd/m$^2$), medium (202cd/m$^2$) and high (407cd/m$^2$) on a OnePlus 3T phone, with a 5.5" screen. The mean ambient lighting level of the room where the study took place was calculated at 26.73lx (range: 12-45lx).

The primary dependent variable was the time at which the light bulb was pressed rather than number of collisions in order to avoid the skill of participants becoming a confounding variable. We also recorded the background brightness, which directly correlates with time. Other independent measures were recorded via demographic questionnaires.

### Results

A one-way repeated-measures ANOVA was conducted to identify how screen brightness affected performance when contrast diminished. The participants had three attempts at each level of brightness and an average time was used for analysis (Figure 2 shows an overview of participant performance). P1 and P6 had incomplete data due to ending their runs early by failing to reset the brightness in time and therefore could not be included in the analysis due to listwise deletion. Mauchly's test indicated that the assumption of sphericity was not violated ($p = .24$). The results show that time to button press was significantly reduced when screen brightness was lower, $F(2, 24) = 21.62$, $p < .001$. Bonferroni-corrected pairwise comparisons revealed a significant difference between the low and medium and the low and high screen brightness conditions ($p < .001$), however, there was no significant difference between the medium and high screen brightness conditions.

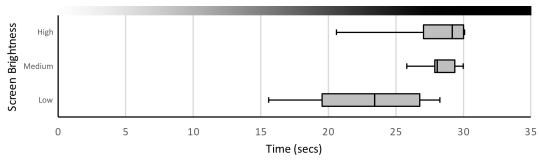


**Figure 2. Box plots for the average time (in seconds) when the bulb is pressed during the low, medium, and high screen brightness trials.**

## DISCUSSION AND FUTURE WORK

BrightLights is the first system to gamify the gathering of contrast ratio data. Our data suggests that BrightLights is indeed sensitive to at least one factor that contributes to SVIs (dark screen). However, further refinement and a full evaluation are required before we can confidently use it in a large-scale study.

During the evaluation, we manually measured the ambient light level and set the screen brightness. To forego the need for a researcher being present, we plan for BrightLights to utilise the mobile device's light sensor and identify the screen brightness level. In doing so, we will strengthen the independence of the game in successfully gathering data in-the-wild.

There are potential issues with building the data collection into a game because participants are likely to perform differently. We plan to run a thorough evaluation comparing the data from BrightLights used in-the-wild against data from a controlled lab study (e.g., using the DENOTE method [22]). We can conduct a rigorous analysis of the data to understand the interacting variables (i.e., ambient brightness, screen brightness, and content contrast) in a lab vs in-the-wild setting.

When we are certain that the accuracy of BrightLights is equal to (or better than) a controlled study we will deploy the game for large-scale data collection. The resulting data will allow us to extend current contrast guidelines to SVIs, thus enabling designers to reduce the impact and severity of SVIs.

There is also potential for us to use BrightLights to measure and model other visual impairments, such as low vision and colour vision deficiency (CVD). Colour pairs that are difficult to distinguish for people with CVD could be applied to the background and the obstacles. We could also include the option to change colour pairs for different types of CVD.

## CONCLUSION

Situational visual impairments (SVIs) become a greater concern with the increased use and reliance on mobile devices. It is necessary to understand SVIs so that effective support can be provided. We introduced an endless runner game called BrightLights, which decreases the background brightness as the player progresses to increase the difficulty in avoiding obstacles. Data is recorded during gameplay and can be used to model the way in which content design affects the onset of SVIs. Our initial evaluation showed that participants performed significantly worse under low screen-brightness conditions compared to medium and high screen-brightness conditions. However, before we can use BrightLights in a large-scale study, we need to further refine the game and run a more comprehensive evaluation in a controlled environment to determine if gamifying the collection of this data is reliable.

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