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A Pilot Study of Altering Depth Perception with Projection-Based Illusions

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Abstract

We present first approaches to manipulate perceived spatial relationships between the user and real-world objects by introducing perceptual illusions to a projection-based augmented reality (AR) environment. Therefore, we analyzed the effect of three monoscopic illusions, which are inspired by visual arts, i. e., (i) color temperature, (ii) luminance contrast and (iii) blur. The results provide positive indications that computer-generated projected illusions can influence the human depth perception in such an environment, even in the presence of additional conflicting depth cues.

CCS Concepts

•***Human-centered computing*** → ***Mixed / augmented reality;*** *Empirical studies in HCI;*

1. Introduction

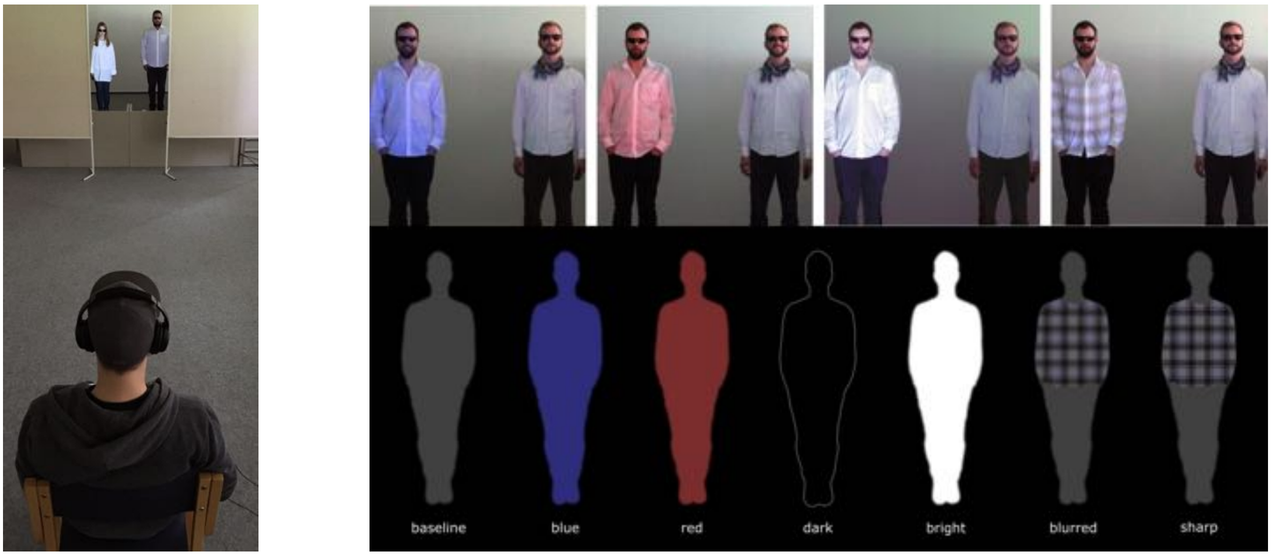
Depth perception plays an essential role in almost all activities of our daily life ranging from fundamental processes like eye-hand coordination to task-specific requirements, for example, when ascending stairs. Regarding this crucial rule of depth perception, the interesting question arises whether it is feasible to influence how people perceive spatial relationships of objects and therefore to change the way they interact with their environment. By manipulating how people perceive depth, one could support humans by compensating systematic depth underestimation or overestimation known from several everyday activities such as driving or parking a car, or performing complex assembling or fabrication tasks. Furthermore, one might support people who suffer from a poor depth perception caused by an eye disease or other vision problems. Another interesting application of providing a situation-dependent modification of depth cues is to enlarge a room of claustrophobic proportions.

Inspiration for techniques that affect the human depth perception can be found in traditional arts and filmmaking. For instance, different color temperatures and luminance values are used to create apparent depth in 2D paintings [BG06]. In order to apply such techniques to a real 3D environment, the emerging paradigm of *spatial augmented reality (SAR)*, sometimes also referred to as *3D projection mapping* or *projection-based AR*, appears to be a suitable solution. In SAR environments, the virtual content is projected directly onto real-world objects and, therefore, the objects' appearance can be changed in a variety of ways. While most previous projects used SAR to augment physical objects with additional information, the focus of this poster is to investigate how depth is perceived in such environments, and whether perceived spatial relationships between real-world objects and the user can be manipulated by projecting onto these objects. For this purpose, we made a selection of three depth cues, which were rated as most practical in a SAR environment: (i) color temperature, (ii) luminance contrast and (iii) blur.

2. Experiment

We conducted a pre-study in order to test different projected illusions in a SAR environment with a high degree of abstraction [SBS16]. Since the results indicated that projected illusions can influence the perceived distance of objects, we decided to conduct a follow-up experiment within more realistic and plausible environments. The main intention of this experiment is to investigate whether (and to what extent) these results can be replicated in such an environment or if the applied illusions are dominated by additional depth cues that are provided by a real scene such as the familiar size of objects, texture gradients or shading. We invited 12 male and 8 female participants, aged 20 to 58 ($M = 30.8$). In the experimental setup, a projector was used to augment two target persons with six different illusions, which are illustrated in Figure 1. They were presented to the participants pairwise, with a direct comparison of the two color temperature values (blue vs. red), as well as the luminance contrast values (dark vs. bright), and the blur effects (blurred vs. sharp). In addition, each effect was compared to a baseline condition, in which a gray color was projected onto one of the target persons, simulating a low illumination of the scene.

During the experiment, the participants were required to perform a 2-AFCT by judging which of two target persons appears closer to them [Fer08]. In order to obtain an absolute measure for the mis-



(a) **(b)**

Figure 1: *Illustration of (a) the experimental setup, and (b) the projected illusions. (b) also shows some of the conditions from the user's perspective, i. e., left-to-right: blue, red, bright, and blurred illusions always displayed against the baseline condition.*

judgment of depth caused by a particular illusion, we altered the relative distance between both target persons following an adaptive staircase design [Cor62]. One target person remained at a fixed position while the second person moved forward and backward depending on the participant's decision in the 2-AFCT. By this iterative refinement, the interleaved staircase design converges to a distance difference for which the participant perceives both target persons at the same egocentric distance. The mean difference was determined by the average of the last ten estimates [Cor62]. Overall, participants performed the 2-AFCT 30 times for each of the 9 tested pairs of illusions.

3. Results

We analyzed the data with a repeated-measures ANOVA and multiple pairwise comparisons with Bonferroni correction at the 5% significance level. We found a significant main effect of the projected illusion on judged distance differences, $F(2.94, 55.86) = 3.716$, $p = .017$, $\eta_p^2 = .164$. In particular, an increase of the luminance contrast made the object appear closer to the observer ($p = .007$). Manipulations of color temperature also caused significant effects in the perceived depth, however, they strongly depended on the observer.

4. Conclusion

The results of the experiment suggest that perceived depth of objects can be affected by projected illusions, even in a complex environment with diverse distance cues. In order to account for individual differences between observers, even a short calibration routine with test stimuli would be sufficient, without the need for measuring specific values as the stereo acuity or the location of the pupillary center. In the future, such individualizations might be of particular interest for AR devices that allow a private augmented view of the real environment, such as smart glasses or contact lenses. However, in order to transfer the proposed perceptual illusions to other AR devices, general depth misperceptions, which usually appear in such environments, have to be considered [SJK*07, KSF10].

Finally, even if the currently achievable effects are too small for most real-world applications, we can still draw lessons from the experimental results for the design of AR interfaces. For example, when using colored overlays to highlight specific objects, we should be aware of the varying perceptual effect this modification induces for different observers. With the advances in ubiquitous computing, such user-centered considerations will be an essential part of future AR research.

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