Using Individual Light Rigs to Control the Perception of a Virtual Character's Personality

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Abstract. We investigate how lighting can be used to influence how the personality of virtual characters is perceived. We propose a character-centric lighting system composed of three dynamic lights that can be configured using an interactive editor. To study the effect of character-centric lighting on observers, we created four lighting configurations derived from the photography and film literature. A user study with 32 subjects shows that the lighting setups do influence the perception of the characters' personality. We found lighting effects with regard to the perception of dominance. Moreover, we found that the personality perception of female characters seems to change more easily than for male characters.

Keywords: lighting, perception of personality, virtual characters

1 Introduction

In order to be perceived as natural and engaging, virtual characters must convey affective and individual qualities such as personality, mood and emotional state. The expression of such attributes has traditionally been realized using bodily modalities: overall motion [1], gesture [2, 8, 11, 9], facial expression [3] or verbal content and prosody [11, 16]. However, a character's affective state and personality can also be expressed through environmental aspects like lighting, as is evident in paintings and movies. As a step towards a principled approach to exploiting the modality of lighting, we propose an interactive system for creating character-centric *lighting setups* (that we also call *light rigs*), and evaluate how this system influences the perception of a lit character's personality.

So far, little work has been done on studying how the environment could influence the perception of a virtual character's affective state and personality. Expressive environmental modalities that have been used include sound, camera position, on-surface textures, on-screen filters and lighting [6, 12, 5].

In painting and in the game industry, lighting is often used to emphasize a character's mood and emotion, guide visual interest and suggest a character's intentions. In these disciplines, successful lighting often violates the laws dictated by physically accurate illumination: for instance, a painter or a digital lighting artist might want to use an invisible spotlight which illuminates only one of many characters in order, for instance, to emphasize her status difference. If the lighting is successful, most viewers will recognize the artist's intention without being irritated by the lighting inconsistencies: only experts will see that an added, invisible light source has been used. Designing a system that supports the creation of such effects in an interactive environment implies three research questions:

- **Effect**: Do specific lighting configurations cause a particular perception effect on characters? For instance, does bright lighting makes a character to be perceived as more agreeable?
- **Control**: What system allows us rigging up each character in a 3D scene with its own lighting setup? Lighting should remain constant with respect to the individual character, independent of the character's movement.
- **Acceptance**: Although reaching a desired effect may violate the physical rules of light, the lit characters should still integrate in an acceptable way within the environment. When does unnatural lighting become too obvious and irritating?

In this paper, we address the first two research questions by proposing a prototype of an individual lighting system (light rig) where a set of dynamic lights anchored to a character are created and used as a genuine expressive modality. We also validate our model by assessing a set of lighting setups commonly used in film and photography in a user study that shows how our lighting setups influence the perception of the characters personality.

2 Related Work

Only few research projects have addressed the problem of controlling the perception of a character's affective state and personality through the environment. These projects used modalities such as camera angle, pictograms and lighting. In the following, we provide a brief description of existing work.

Cameras, image mapping and pictograms

Camera angle plays a crucial role in the building of the film language, and several projects have been dedicated to automated cinematography [4]. In psychology, studies have shown that camera angle has a significant influence on how juries assess a person's honesty in the context of criminal confessions [15]. The direct display of information about an agent's affect has been achieved using texture mapping on the character's mesh: for instance, Neviarouskaya et al. use heart-shaped pictogram textures to express the emotional state of SecondLife characters [12]. On-screen displays like text bubbles or floating billboards have been used to display speech, thoughts, or emotional state. Screen-space filters have also been used by de Melo et al. [5] to enhance rendering expressiveness in real time, for instance by manipulating picture light and contrast of the rendered output. In this work, we chose to focus solely on how lighting can be used to influence the perception of a virtual character's personality.

Lighting

Lighting has been used by de Melo et al. [6] as a genuine expressivity channel together with music and pictograms for expressing emotion and personality in a storytelling context. An empirical study showed that illumination had an influence on perceived emotion. However, this study did not focus on virtual humans but on dancing solids. In follow-up work, de Melo et al. [5] use a more elaborated model combining lighting and screen-space filtering. An evolutionary model infers from user feedback the mapping between its parameterization and emotion categories defined in the OCC model of emotions [14]. However, because the lighting parameterizations obtained with this model are the result of a semi-automated evolutionary process that does not account for aesthetic principles, they can hardly be transferred to other applications. In our approach, the creation of lighting setups is theory-driven: our lighting configurations are derived from the lighting techniques commonly used in photography, film and gaming industry [10]. El-Nasr [7] presented the Expressive Lighting Engine (ELE), a dynamic lighting system that can be interfaced with modern video games and that is capable of adjusting scene lighting in real time to achieve aesthetic and communicative functions, including evoking emotions, directing visual focus, and providing visibility and depth. In this work, we focus on the perceived personality of the lit characters. Application designers who are dealing with virtual characters can therefore use the results of our studies as guidelines.

3 Individual Lighting Rigs

In our implementation, we use three dynamic lights per character. Lights are defined as directional lights, parameterized using a single direction vector defined according to the character's local frame of reference. Lights also cast shadows: they are bound to a shadowcaster shader that influences all the lit objects having a shadow generator shader enabled.

The design process for lighting can hardly be formalized; it is a manual process that requires a tight visual feedback loop. In order to help the designer crafting a successful lighting setup, we implemented an interactive editor, shown in Fig. 2. The editor provides interactive controls for every parameter of all the lights involved in the setup. The parameters are orientation, intensity, color and shadow hardness. Although such a tool can potentially generate an infinite set of lighting setups, we focused our empirical investigation on a few specific ones that are described in the next section.

4 Our Approach Towards Lighting

In this study, we chose to evaluate the influence of four lighting setups defined by the position and intensity of their involved lights. These lighting configurations are taken from the film and photography literature [10] and are illustrated in Fig. 1.

A common general lighting technique in portrait photography, film and interactive drama is *three-point lighting*. In three-point lighting, there is the *key light*, the main source of light, the *fill light*, a low-intensity light filling the area on the character that otherwise would be too dark and the *back light*, separating the character from background by creating a light rim that crisply defines its edge. We used the following four specific three-point setups for our empirical investigation:

Broad lighting (a): This lighting illuminates the larger portion of the face of a character. In this lighting, the area of the face that is highlighted must be larger than the area in shadow. We consider this lighting the default lighting.

Rembrandt lighting (b): The general idea is to create a small upside-down triangle on the opposite side of the lit cheek on the subject's face. To create this pattern, it is necessary to move the main light source to the side and somewhat above eye level, casting a triangle of light on the subject's opposite cheek.

Butterfly lighting (c): This lighting is also known as "glamour lighting" using a high frontal main and fill light, almost in imitation of a strong summer sun.

The name butterfly comes from the distinctive butterfly-shaped shadow that appears beneath the nose and extends someway down the lips of the model.

From-Below lighting (d): In this lighting setup, a light is placed below the shoulder level of the subject. This lighting casts strong shadows, giving the scene a dramatic tone.

Fig. 1. Broadlighting(a), Rembrandt (b), butterfly (c), from below (d): the four lighting setups that we edited using our interactive authoring tool

5 User Study

To exploit individual lighting rigs effectively, one needs to know the precise effect that a particular lighting configuration, as described in Section 4, has in terms of personality perception. In a first user study, we aimed at identifying effects for a *single* agent.

5.1 Materials and Method

The experiment was conducted as an online questionnaire (in German) where selected participants were explicitly invited. The 36 participants were fluent German speakers, aged 25 to 68.

Ideally, the influence of the lighting rig system should be independent from the intrinsic characteristics of the lit characters: a gloomy lighting should evoke sadness for both a male and a female character. However, it has been shown that parameters like facial morphology [13] can significantly influence the perception of a character's personality. In order to assess how robust the lighting rig was against attributes like facial morphology or gender, we designed four declinations of a virtual agent by modulating two parameters, gender (male and female) and facial morphology (masculine and feminine). The resulting agents are shown in Fig. 2.

Fig. 2. (a) Screenshot of our interactive authoring tool, (b) the four characters used in the study: our results show that morphology does not influence the perception of a character's personality whereas gender does.

We used four different agents, all derived from two facial morphologies (A and B), rendered in two genders each (M and F): AM, AF, BM, BF. Each resulting character was lit with one of the four light setups described in Section 4: broad (BD), rembrandt (RT), from-below (FB) and butterfly (BF).

The test consisted of showing 16 screenshots of one of the four agents in one of the four light setups. We assessed personality perception by asking the subject to enter judgments along four dimensions D1 to D4. Each rating was done on a 7-point differential scale from -3 to +3. For the four dimensions we relied on research by Wiggins [17]. Every dimension had two opposing poles, specified as follows:

label	*left pole (-3)*	*right pole (+3)*
D1	cold, impolite	warm, polite
D2	arrogant, calculating	modest, guileless
D3	dominant, self-disciplined	timid, disorganized
D4	companionable, jovial	distant, shy

Table 1. the four dimensions used in the study and their corresponding adjectives.

The rating scheme is based on work by Oosterhof et al. and Wiggins. Oosterhof et al. [13] showed that two orthogonal dimensions, valence and dominance are sufficient to categorize and describe face evaluation and that these dimensions can be approximated by judgments of trustworthiness and dominance. Wiggins [17] proposed a more comprehensive taxonomy of trait-descriptive terms in English: eight adjectival scales were developed as markers of the principal vectors of the interpersonal domain. We reduced the dimensions to four by collapsing two neighboring/similar dimensions to one.

5.2 Results

We analyzed 32 of the 36 participants. We took out 4 participants whose answers were almost always neutral. Our formal rejection criterion was a standard deviation < 1 across all replies (where 0 was the neutral reply).

To avoid an abundance of tests we declared the "broad" lighting condition the default lighting and compared the other three against it, to see if a difference emerged in these three pairings (BD-RT, BD-FB, BD-BF). For every pair we computed four ANOVAs, one for each question dimension, with the three factors face, gender and lighting (we also report mean value M). For brevity, we only report significant findings.

First of all, we found an effect for factor face in all tests. This was expected, as different facial appearances are interpreted differently in terms of personality, so we do not report these results in detail.

Rembrandt (BD-RT): We found effects for light and gender in the the BD-RT comparison. RT lighting makes the agent appear significantly more dominant/self-disciplined (dimension D3; M = -0.80) compared to BD (M = -0.25; F(1,31)=10.30, p<.01), independent of face and gender. RT also makes the agent to be perceived as more companiable/jovial, i.e. less distant/shy, (dimension D4; M = -0.54) compared to BD (M = -0.09; F(1,31)=8.21, p<.01). We found an additional gender effect: the male agent is perceived as more arrogant (dimension D2; M = -0.64; F(1,31)=10.87, p<.01) than the female one (M = 0.01). He was also found more dominant (dimension D3; M = -0.80) than the female agent (M = -0.25; F(1,31)=10.39, p<.01).

Butterfly (BD-BF): We found the same two gender effects as in DB-RT, also for dimensions D2 and D3. The male agent was judged more arrogant (M = -0.56; F(1,31)=14.29, p<.01) than the female one (M = 0.07). He was also found more dominant (M= -0.59; F(1,31)=5.37, p<.05) compared to the female version (M = -0.11), all independent of light and face.

From-Below (BD-FB): Here, we found a light-gender interaction for dimensions D2 (F(1,31)=8.30, p<.01) and D3 (F(1,31)=5.55, p<.05), the latter is shown in Fig. 3. Under From-Below lighting, a female agent was perceived more modest (D2; M = -0.67) and more timid (D3: M = -0.75) compared to BD (D2: M = 0.14; D3: M = 0.00). In contrast, the male agent was hardly affected by the change of lighting from BD (D2: M = -0.52; D3: M = -0.50) to FB (D2: M = -0.42; D 3: M = -0.45). A post-hoc analysis, using a Fisher LSD test, confirmed that changing lighting setup makes a significant difference for the female agent (D2: p < 0.05; D3: p < 0.05) but not for the male agent (D2: p = 0.77; D3: p = 0.90).

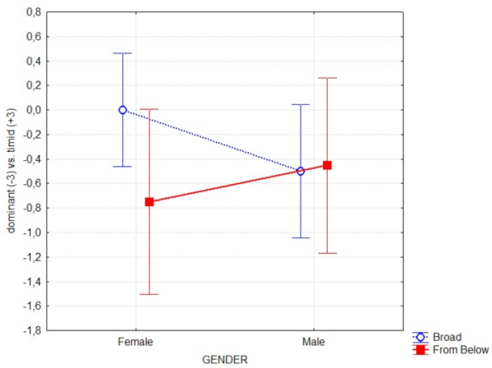

Fig. 3. The female agent is rated differently under BD vs. FB lighting, whereas the male agent is rated equally (dimension D3 for dominant vs. timid).

6 Discussion and Conclusion

The study showed that one lighting setup exhibited a significant effect for all characters, male and female: Rembrandt lighting (RT). Under RT lighting, agents are perceived as more *dominant and jovial* (D3 &D4). Only male characters were perceived as more arrogant under Butterfly lighting (BT), independent of facial morphology. In contrast, female characters lit with From-Below lighting (FB) were perceived as more modest and timid (D3), again, disregarding facial morphology.

More importantly, our results show that female characters are more susceptible to light changes in terms of personality perception. When comparing From-Below with the default lighting (Broad), we found that only the female agent was perceived differently, although both agents share facial morphologies. The fact that the effect of some lighting setups depends on the lit character's gender but not on its facial morphology may be explained by gender stereotypes almost universally observed: male subjects are commonly perceived as more dominant than female subjects. Even though we showed that lighting has indeed an effect on how the personality of virtual characters is perceived, none of the lighting configuration we assessed influenced the perception in the opposite direction of the commonly known stereotypes (e.g. male agent perceived as more modest and timid).

To sum up, we proposed a system for authoring character centric lighting rigs dedicated to modify the perception of a character's personality. This system is built upon a set of dynamic parameterizable lights anchored to an individual virtual character that can be modified with an interactive editor.

This system has been evaluated in a user study with 32 subjects. In this study, we assessed four lighting setups taken from the photography literature that we set up using our interactive editor. In order to rate the robustness of our model towards gender and morphology, we compared the effect of lighting on four different agents, derived from two facial models and two genders each.

We believe the system we proposed and the guidelines we derived from the empirical study could be used in interactive drama to make lighting a genuine expressive modality supporting the story. In future work, we plan to investigate how our system performs in dyadic configurations, for instance when agents are acting in a status game. We will also investigate how our system can be integrated into more complex environments. Most importantly, we have to empirically assess how much variety observers can tolerate while interacting with agents that are lit using different lighting setups, and at which point observers will be irritated by inconsistent lighting.

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