A Conceptual Framework studying the fidelity of Expressive Digital Doubles

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Abstract
Digital doubles are computer generated characters that have been created to represent digitally an existing person. Efforts to create, render and animate realistic faces of a recognizable person have made break-through in computer graphics and computer vision, blurring the line between reality and virtuality. Few studies explore how humans distinguish real faces from computer-generated faces of a real person. To our knowledge, there is no framework attempting to determine the factors on which human rely to assess the fidelity of a virtual face compared to the face of the original human. In this paper, we propose a conceptual framework for investigating the fidelity of expressive digital doubles.
Keywords: Digital Double, Fidelity, Facial Expressions, Virtual Humans.

1. Introduction

Creating photorealistic animated human faces are now possible thanks to recent advances in computer graphics [1] and 3D scan systems [2]. As a result, digital doubles are increasingly used in the entertainment industry. The movie industry relies on such technology in several famous productions such as "Tron: Legacy" and "The Curious Case of Benjamin Button". Realistic rendering of human faces is also used for real-time applications such as video games. Digital doubles contribute to the success of several interactive storytelling games such as "Heavy Rain" (Quantic Dream) or "LA Noire" (Rockstar) and popular sports simulation games.

Some experimental studies explore if human subjects are able to perceive differences between faces of virtual humans and pictures of faces of real humans [3,4]. Yet, we did not find any study aiming at identifying the main conceptual dimensions of fidelity of digital doubles.

In this paper we introduce a framework that enables to encompass the main concepts and dimensions involved in the study of fidelity of digital doubles. We focus on the appearance and expressions of the face since it is a main modality for expressing emotions, and there are multiple studies from several disciplines on which we can build upon.

In Section 2, we explore different definitions of fidelity provided by these various disciplines and research areas such as psychology, and virtual reality. We classify them as main dimensions and concepts related to fidelity.

2. Main dimensions of fidelity

We define our conceptual framework for the design and study of fidelity as the combination of (Figure 1): 1) Identity dimensions 2) the different entities involved in the perceptive evaluation of the fidelity, and 3) a set of variables that affect this process of evaluation.

Through this section we detail the choice of these dimensions.

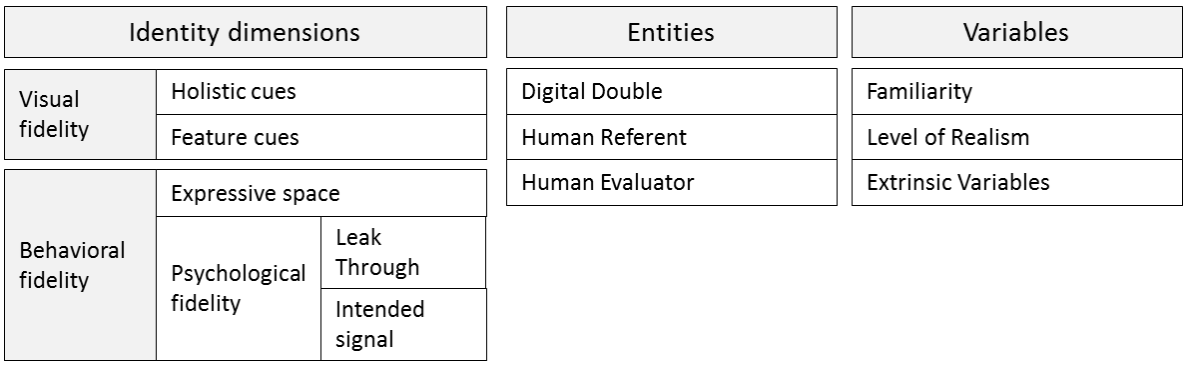

Figure 1. Conceptual framework for studying fidelity of digital doubles

2.1 Fidelity in virtual reality

Research in virtual reality uses fidelity as a means of validation. Fidelity in the context of simulations can be defined as the degree to which the virtual environment emulates the real world [5]. Fidelity is subdivided into several dimensions, such as physical, functional and psychological fidelity.

Physical fidelity encompasses a number of sub-dimensions concerning different modalities: visual, auditory, vestibular, olfactory, proprioceptive [6]. Visual fidelity is highly relevant to our research about face appearance and expressions. It refers to the degree to which visual features in the virtual environment conform to visual features in a real environment. Psychological fidelity is "the degree to which the simulation replicates the psychological factors (i.e. stress, fear) experienced in the real-world environment" [6]. Psychological fidelity is strongly related to the concepts of presence and feeling of immersion.

2.2 Fidelity in psychology

According to psychology, the fidelity of a virtual actor relates to recognizing its identity. An identity is defined from a psychological perspective by Goffman [7] as the mental model that one has of himself. Goffman distinguishes between *given information*, i.e. intended and managed in some way, and *given off information* which 'leaks through' without any intention or control.

Goffman argues that people present their identity to others through their actions and interactions. People infer the identity of others upon visual attributes such as one's appearance [7] and upon behaviors.

2.3 Human perception of human faces

2.3.1 Face perception as a holistic process

Research in cognitive psychology and neuroscience supports the notion that face perception in humans is a *holistic* and configurable process. Thus, Tanaka [8] argues that during face recognition, all facial features are processed at once. The holistic context seems to affect how individual features are processed. It has been observed that the evaluation of geometric relationships between each individual feature and the rest of the face is very important for face recognition [9].

The holistic process mainly includes the evaluation of two principal factors: shape, and pigmentation [10, 11]. Face images with negated contrast [9] or altered shape are very difficult to recognize. Several experiments observed that face recognition rates are higher using colored pictures than using grayscale images [11].

2.3.2 Fragmentary evaluation: the most important facial features to identify a person

In addition to the global evaluation of the face, humans also evaluate the different facial features independently. All these facial features do not play an equal part in the identification of a person's identity [9].

Experimental results [12] suggest that our perception focuses on specific parts of the face in a precise order: the eyes, the mouth and then the nose.

Sadro et al. [13] argue that eyebrows might be more important than the eyes for face recognition.

2.3.3 The role of face motions

Lander and Chuang [14] observed that the dynamics of facial expressions and its expressivity facilitate the recognition of familiar and famous people. Their results suggest that faces have distinctive motion patterns that are components of the face identity.

2.3.4 Extrinsic variables for face perception

Setting apart the variability of these intrinsic properties of the face considered in the previous section, face perception can also be affected by other phenomena related to environmental conditions and viewing conditions.

Several experiments report that face perception is sensitive to: the direction of illumination [15], the viewing angle and the pose of the model [16]. Tolerance to degradation by the resolution of the image or distance judgment was also studied.

Extrinsic variables thus play an important role in the judgment of identity.

2.3.5 Familiarity

An important aspect of facial perception is face *familiarity*. Sinha et al. [9] argue that human subjects are capable of identifying familiar faces even in very low quality images. According to Bruce [17], unfamiliar faces are much more difficult to identify.

2.3.6 Individual differences in face perception

With the central role of the face in social cognition, social categories such as race, age and even ingroup / outgroup distinctions have an effect on face perception and face memory. Ethnicity seems to have a strong influence on face recognition. People seem to have a higher sensitivity for faces of their own races [3]. There are also inter-individual differences in memorizing faces. Face recognition is correlated to our ability to encode, store, and retrieve memory representations of faces [18]. In addition, perceivers can be influenced by perceptual experiences and cognitive capabilities. For example Fan et al. [3] found that perception of virtual faces depends on previous experiences with virtual media.

2.4 Resemblance and Caricature

Identity can be conveyed with avatars that are not necessarily *realistic*. Avatars may also only possess a subset of another person's identity features. Vugt et al. [19] studied facial similarity by morphing a 3d representation of a person and a generic head. They found that people trust more faces that are similar to their own face. Caricatured versions of faces are also designed to convey identity of the human referent. According to Mauro and Kubovy [20], using caricatures leads to a better recognition performance than using real faces.

2.5 Entities involved in the judgment of fidelity

Both realism and fidelity need to be validated by perceptive studies. While realism can be evaluated with any virtual face using high quality capture and rendering, the concept of *fidelity* can only be evaluated if the subject knows the *referent's* face. We thus need to consider two important questions about a possible evaluation protocol: who is the *human referent* for the digital double (the real person)? Who is the *judging subject (human evaluator)*?

3. Conclusion

In this paper we presented a conceptual, framework dedicated to the study of the fidelity of digital doubles' faces. We proposed a definition of fidelity, identifying its main dimensions and the way they convey identity through visual cues and behavior cues. We noticed also that fidelity perception might be constrained during evaluation due to environmental conditions, the nature of the viewer, and the nature of watched stimuli.

We believe that this definition can contribute to several fields. Understanding important factors for the perception of fidelity may help computer-graphics artists creating more recognizable digital doubles. It might also help cognitive scientists and psychologists to better understand the perceptual and cognitive mechanisms that underlie face recognition by enabling a precise control of

the different concepts related to the fidelity of a digital double compared to the real person.

Acknowledgment

This research is developed within the ADN T-R project, a collaborative R&D project supported by the French public funding of the competitive clusters - FUI-11.

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