Journal of the Association for Information Systems (2018) **19**(10), 953-981
**doi:** 10.17705/1jais.00515

**RESEARCH PAPER**

ISSN 1536-9323

# Actors, Avatars and Agents: Potentials and Implications of Natural Face Technology for the Creation of Realistic Visual Presence

**Mike Seymour[1], Kai Riemer[2], Judy Kay[3]**
[1]University of Sydney, Australia, mike.seymour@sydney.edu.au
[2]University of Sydney, Australia, kai.riemer@sydney.edu.au
[3]University of Sydney, Australia, judy.kay@sydney.edu.au

**Abstract**

We are on the cusp of creating realistic, interactive, fully rendered human faces on computers that transcend the "uncanny valley," widely known for capturing the phenomenon of "eeriness" in faces that are almost, but not fully realistic. Because humans are hardwired to respond to faces in uniquely positive ways, artificial realistic faces hold great promise for advancing human interaction with machines. For example, realistic avatars will enable presentation of human actors in virtual collaboration settings with new levels of realism; artificial natural faces will allow the embodiment of cognitive agents, such as Amazon's Alexa or Apple's Siri, putting us on a path to create "artificial human" entities in the near future. In this conceptual paper, we introduce natural face technology (NFT) and its potential for creating realistic visual presence (RVP), a sensation of presence in interaction with a digital actor, as if present with another human. We contribute a forward-looking research agenda to information systems (IS) research, comprising terminology, early conceptual work, concrete ideas for research projects, and a broad range of research questions for engaging with this emerging, transformative technology as it becomes available for application. By doing so, we respond to calls for "blue ocean research" that explores unchartered territory and makes a novel technology accessible to IS early in its application. We outline promising areas of application and foreshadow philosophical, ethical, and conceptual questions for IS research pertaining to the more speculative phenomena of "living with artificial humans."

**Keywords:** Realistic Faces, Avatars, Cognitive Agents, Uncanny Valley, User Interfaces, Virtual Reality, Virtual Presence.

Joey George was the accepting senior editor. This research article was submitted on June 8, 2017 and went through one revision.

## 1 Introduction

A range of recent technical advances in fields such as gaming, entertainment, and computer graphics, have put us on the cusp of creating realistic, interactive, fully 3D-rendered human faces on computers. Because humans are hardwired to respond to human faces in unique and positive ways (Meng, Cherian, Singal, & Sinha, 2012), artificial human faces hold great promise for advancing human-computer interaction and increasing affinity between humans and their machines (Sproull, Subramai, Kiesler, Walker, & Waters, 1996). Against this backdrop, natural face technology (NFT) refers to computer-based entities that are presented with believable human faces. For example, realistic avatars might be utilized to re-present human actors in virtual collaboration environments, allowing people to act and connect with each other with a new level of realism. Realistic human faces might equally be used to embody newly emerging conversational agents, such as Amazon's Alexa or Apple's Siri, putting us on a path to create entities that resemble "artificial humans" in the not so distant future. Such visual cognitive agents have the potential to reshape advisory, consulting, and training services in contexts such as business, education, or health care.

In this paper we argue that the information systems (IS) field should engage early with emerging natural face technologies. Too often, we see IS research having to play catch-up with industry applications of novel technologies. While the development of the enabling technologies falls outside of the scope of IS, we argue that the discipline will have an interest in studying and influencing their effective and ethical applications in real-life contexts as they become available. We thus set out to lay the foundations for a research program into the application of natural face technology (NFT), comprising terminology, conceptual work, ideas for early research work, as well as a catalogue of research questions on different levels of analysis.

Concretely, we argue that while realistic, interactive faces are becoming available, we do not yet understand how users will respond to artificial faces with different degrees of realism, or which factors might contribute positively to the creation of natural and believable interactions with synthetic, humanlike actors, a phenomenon which we term realistic visual presence (RVP). Furthermore, as cognitive agents with natural faces make their way into real-life contexts, questions will arise regarding both the ability and desirability of such agents for building relationships with users over time, their impact on our professional and social identities, and what these entities will become once they are part of our collective world.

We argue that NFT, as a transformative technology, has the potential to bring about a new computing paradigm—one that will allow interaction with (or via) machines in more natural and unobtrusive ways than current computing interfaces offer, and one that will potentially raise far-reaching existential questions, as it might blur the boundaries between what counts as machine and what counts as human. While this brings with it a range of ethical and philosophical questions, it also comes with the opportunity to disclose new worlds of possibility (Spinosa, Flores, & Dreyus, 1997) in redefining the role of computing in society.

Hence, with this conceptual paper we respond to calls for "blue ocean research"—research that seeks to "move into intellectual territory that is unexploited" (Straub, 2009). Our viewpoint is forward-looking, in that we envision applications and implications of NFT and an IS research agenda that usefully accompanies the process through which these technologies make their way into practice. We thus note that many of the ideas presented in this paper are, by necessity, speculative and imaginative.

We will contribute a tentative research agenda to IS, which comprises concrete ideas for early IS research and a broad range of research questions on different levels of inquiry. We further contribute terminology and early conceptual work for grasping the nature and application of NFT in areas such as immersive collaboration via realistic avatars or conversational computing with cognitive agents. We also foreshadow certain conceptual implications for IS research pertaining to the more speculative phenomena of "living with artificial humans." For example, we will ask critically whether the taken-for-granted concepts of IT artifact and IT user will still be appropriate for framing situations that resemble natural language conversations between human and nonhuman actors—a phenomenon quite different to the "using" of inanimate IT tools for certain tasks.

We begin by defining key terms and providing background on the technical aspects of NFT, the importance of faces more generally, and typical areas of application for NFT (in Section 2). On this basis, we then outline the sketches of an IS research program (in Section 3), which we spell out in more detail in the subsequent sections. In Section 4 we outline, in some detail, a research approach for investigating the relationship between face realism and interactivity in creating user affinity with avatars, and argue that interaction with digital avatars presents a new kind of phenomenon that is distinctly different from the mere judging of realistic, prerendered faces, as is captured in the widely known uncanny valley theory. In Section 5 we then widen our gaze and discuss implications of visual cognitive agents and their imminent roll-out into practical contexts, with a view toward imagining what it takes for these entities to not only interact with users, but to build relationships with them over time. We then consolidate our research agenda in the form of a table with research questions and IS research approaches, and envision concrete scenarios for applications of NFT. We conclude the paper in Section 7.

## 2 Background: The Emergence and Application of Natural Face Technology

Progress toward natural and believable interaction with fully synthetic or human actors in digital, virtual environments hinges, among other things, on creating appropriate visual (re)presentations of agents and avatars. In this section, we provide a brief outline of the conceptual, technical, and theoretical background of natural face technology as the basis for achieving what we term realistic visual presence with digital actors. We note that RVP is not merely an outcome of, or reaction to, a realistic face presentation. We suggest that the study of mere visual characteristics of such face renderings is a problem better suited to information technology (IT) or computer-human interaction (CHI) research, which is concerned, for example, with the exploration of skin rendering algorithms or light simulation (Debevec et al., 2000).

Rather, we are concerned here with the effects and implications of human interaction with such visual entities. We note that recent work in IS has already highlighted the importance of engaging with new visual technologies, e.g., as a rich source of data (Andrade, Urquhart, & Arthanari, 2015). We intend to contribute to this emerging stream of research by studying how visual technologies reshape user interactions. We begin by defining key terms, and note that, as there is some diversity in use of some of these terms, we provide definitions for clarification and use in the context of our topic. We then provide some technical background on natural face technology before introducing existing research on the acceptance of such technology in the subsequent sections.

## 2.1 Definitions and Key Concepts

This research is concerned with *natural face technology* and *realistic visual presence*. We define NFT as a set of technologies for the creation of fully 3D, real-time rendered faces with a high degree of human realism, and RVP as a quality of the interaction between a human actor and a visually believable humanlike digital actor. This interaction can be a user interface experience, an interaction with an entity on a computer screen, or can take place in a fully immersive virtual environment, such as a virtual world. RVP is a quality of interaction with nonhuman actors, such as a synthetic, cognitive agent—or with another human actor, present as an avatar on screen or in a virtual environment.

We define an *agent* as a fully computer-based entity that exhibits, at least to some degree, autonomous behavior. Agents can carry out specified, recurring tasks in a self-directed way (e.g., in a multiple agent simulation system in virtual environment software, i.e., MASSIVE software), or interact with human actors in various ways, including natural language understanding and/or dialogue. To separate different levels of agents we further define *cognitive agents* as agents that appear to understand language and respond equally with the appearance and understanding of a human actor, and *simple agents* as those that execute merely scripted behaviors, such as "nonplayer characters" in video games. Examples of cognitive agents are personal digital assistants, such as Amazon's Alexa, Apple's Siri, or Google Home, which engage in natural language interactions with human actors. We refer to cognitive agents that are visualized as a synthetic, real-time rendered entity (e.g., with a realistic human face) as *visual cognitive agents*.

*Avatars* refer to visual re-presentations of human actors. An avatar can be thought of as a digital puppet, a character that is instructed by and acts on behalf of a human actor for whom the avatar acts as a digital "stand-in." A *realistic avatar* denotes a specific kind of avatar that can faithfully replicate the actual features of a human actor, in particular, their facial features and expressions. Much as with agents, we draw a line between interactive avatars and noninteractive, recorded, or prerendered depictions of human actors; for example, a digital double (digi-double) of an actor in a motion picture.

We theorize that RVP is a function of the believability of both the visual appearance of an actor (agent or avatar) and their perceived behavior as experienced by the human "user." We note that the term "user" might not be appropriate when describing an actor in interaction with the kinds of entities we are interested in here, but will set aside this discussion until later. Visual appearance refers to the digital rendering of humanlike features of the actor, most notably a realistic human face. Behavior of the agent refers to how the agent's actions are perceived by the human actor during interaction. Our interest in the remainder of the paper specifically concerns visual cognitive agents (VCA) and realistic avatars (RA).

**Table 1. Key Definitions**

| | |
|---|---|
| **Natural face technology (NFT)** | NFT refers to a complex combination of technologies and techniques for the creation of fully 3D, real-time rendered human faces with a high degree of realism that are based on computer graphic imagery and ideally indistinguishable from real human faces. |
| **Realistic visual presence (RVP)** | RVP is a quality of the interaction of a human actor with a visually believable computer-based actor, either an agent or an avatar-represented human actor. RVP refers to the sensation of presence, as if present in direct interaction with another human actor. |
| **Actor** | Any entity that acts. Refers to both nonhuman actors, such as agents, and human actors, e.g., when represented as an avatar in a virtual environment. |
| **Agent** | A fully computer-based entity that exhibits autonomous behavior, at least to some degree. |
| **Cognitive agent** | An agent with the understanding of a human actor. Cognitive agents are found in conversational computing and advanced HCI design. |
| **Visual cognitive agent (VCA)** | A cognitive agent visually presented as an interactive, real-time rendered human-like entity, on a screen or in a virtual environment. |
| **Avatar** | Visual representation of a human actor, which acts as a mediated stand-in or surrogate for the human actor in a virtual environment. Such visual representations can take varying degrees of realism. |
| **Realistic avatar (RA)** | An avatar with the realistic, interactive facial—and sometimes bodily—representation of the human actor puppeteering it. |
| **Virtual environment** | A fully immersive computerized environment or world, sometimes referred to as a virtual reality (VR) and accessed using a head-mounted display. |
| **Augmented reality** | An overlay on the physical world with an additional layer of visual information so that it appears as if the information is connected logically or physically with features of the physical world. |
| **Digital double or digi-double** | A noninteractive rendering of a human actor, for example in a film or computer game. Digi-doubles can be thought of as noninteractive avatars and thus do not fall under the RVP definition |
| **Nonplayer characters (NPC)** | Secondary background characters in a computer game that are programmed on simple loop and not designed to interact; they thus have limited behavioral options. An NPCs can be thought of as a greatly simplified agent. |

We assert that we are only now on the cusp of creating the kinds of experiences in which RVP might reliably manifest. This is due to recent advances in natural face technology which put us in a position to create the kinds of visual (re)presentations of agents and avatars that we expect will bring about RVP. Accordingly, we argue that existing studies have only been able to investigate the believability of either highly realistically rendered human-faces in noninteractive media such as film (Butler & Joschko, 2009), or human interactions with cognitive agents with only approximate face interfaces, but not a combination of both (Melo & Gratch, 2011).

## 2.2 On the Significance of Faces

Humans are hardwired to interpret human faces (Meng et al., 2012). From birth, children respond to and learn from their parents' faces (Sagar, Seymour, & Henderson, 2016). These interpretations are fundamental for the successful growth and functioning of humans (Sagar et al., 2014). As such, the brain has developed the ability to read faces far more specifically and with greater fidelity than any other object we see (Meng et al., 2012). Evolution has left us with both the ability to see a face in a few pen strokes of a cartoon or in a puffy cloud (pareidolia), but also to identify and reject artificial faces that are only approximately realistic (Meng et al., 2012). Not only can we detect these inferior renditions easily, but we react to them far less favorably than we do to much simpler caricatures.

Humans have dedicated neurological pathways for facial recognition but also processing and communicating back to other people. The "decision" to react to a face with a smile comes to the facial nucleus from a network of structures that include the amygdala and multiple interconnected cortical and subcortical motor areas (Gothard, 2014). These structures constantly both process faces and drive a person's own facial expressions without deliberate thought.

A simple experiment known as the Thatcher illusion using a still image can illustrate how the brain (of both humans and some primates) processes faces in very specialized ways (Adachi, Chou, & Hampton, 2009). Figure 1 shows an inverted face, which seems slightly odd but not greatly alarming to most viewers. When the same image (Figure 2 below) is rotated 180 degrees, the result seems "grossly off-putting." This effect holds true even when, as shown here, the image is only roughly composited and little effort has been made to blend the images seamlessly or match shading and correct position.

**Figure 1. An Example of the Brain's Separate and Specialist Facial Processing. Compare This Image to Figure 2 Below.**

The Thatcher illusion demonstrates not only the way in which faces are processed in the brain differently from other objects but how, when the face is wrong, it is not "idly inaccurate," it is actually "off-putting" and disturbing. The second face in the example does more than fail to meet our standards of accurate or acceptable, it is in some way repulsive and we exhibit negative affinity to the face. This desire to move on or look away is rooted in an evolved response and cannot be attributed as a learnt response, since these misplaced facial characteristics are unlikely to have ever been seen before (Adachi et al., 2009).

It is now commonly accepted that reading human facial expressions is so central to human communication and survival that we have developed dedicated neurological skills for reading faces (Meng et al., 2012). This is also why very small changes in expression can lead to interpreting very different signals from those around us. As we will discuss further, we propose that this sharp change of response is due to different parts of the brain processing different aspects of the image of the face, but at the same time seeking to recognize identity. There are numerous examples of functional magnetic resonance imaging (fMRI) and electroencephalogram (EEG) studies (Han, Jiang, Humphreys, Zhou, & Cai, 2005) showing that facial recognition is associated with very specific patterns in the brain (Meng et al., 2012).

**Figure 2. The Same Image As Figure 1, Rotated 180 Degrees**

We conclude that a critical component of recognizing “humanness” is the face. Of all the experiences we have in life, face-to-face interactions fill many of our most meaningful moments. The complex interplay of facial expressions, eye gaze, head movements, and vocalizations in quickly evolving “social interaction loops” (Sagar et al., 2016) has enormous influence on how a situation will unfold. From birth, these interactions are a fundamental element of learning and lay the foundation for successful social and emotional functioning through life.

Consequently, we argue that exploring the simulation of human faces as a form of computer-human interface holds great promise for advancing HCI, as it greatly increases the available communication richness between humans and machines in an intuitive and accessible way. We argue that interfaces and user interaction based on natural face technology might enable potentially new forms of interactions with machines. Conversely, application of such technology might also be a vehicle with which to explore our own nature and our relationship with machines in our collective lives. For example, exploring the underlying processes that drive the face during social interaction may enable researchers to explore behavioral and learning models involving naturalistic face-to-face interaction (Sagar et al., 2016), with potentially significant advances for the creation of effective computer-assisted learning. In the following, by way of example, we present areas for the application of natural face technology.

## 2.3 Applications of Natural Face Technologies

Technically, there are significant challenges still to overcome in order to create a realistic, interactive human face in a computer. At the same time the following two examples illustrate the advances that have been made recently, which demonstrates that realistic visual presence will become reality in the very near future. We offer as two exemplary areas of application of natural face technology (1) immersive collaboration—a form of collaborative interaction with realistic avatars in a virtual environment, and (2) conversational computing—the creation of cognitive agents with realistic face presentation in application areas such as education, service, or health advice. We offer these examples to demonstrate the technical advances that have been made, the challenges that designers of these technologies still face, the relevance of natural face presentation in both cases, as well as initial research issues that emerge from potential applications of each technology.

### 2.3.1 Digital Mike: Immersive Collaboration with Realistic Avatars

Achieving a realistic human face in a noninteractive environment is only just being addressed at the high end of feature film effects (Klehm et al., 2015). Excellent work has been done in producing high-quality facial rendering and animation (Seymour, 2013), but most of these faces cannot be rendered in real time.

While the emerging area of immersive collaboration has previously explored real-time avatars as a means to “realize high presence communication” (Ogi, Yamada, Tamagawa, Kano, & Hirose, 2001), in virtual contexts, these avatars were based on quite limited visual camera projection techniques that relied on 2.5 dimensional video superimposed on a virtual world, and not on fully 3D computer-rendered graphics with all the scope they provide for the movement of the avatar in the virtual environment. At the time, this was due to technical limitations; the authors point out that “it is difficult to represent natural facial expressions using the polygon model" and "it is difficult to represent instantaneous facial expression by deforming the original image of the face" (Ogi et al., 2001, p. 45)

Only recently have technologies developed in the gaming and entertainment industries allowed the creation of real-time realistic faces based on true computer graphic imagery (CGI). Gaming technology has facilitated advancements in real-time facial rendering in stand-alone PC systems, but they still require high-end graphics cards and powerful processing. Steady advances in computational power and algorithmic innovation means that there is a reasonable expectation that such work will be widely available on accessible computing platforms, including mobile devices, soon. This has made it timely to build a framework that supports effective design and use of avatars that are interactive and at a suitable level of realism. Figure 3 shows an example of a recent experimental prototype in CGI, using real-time game-engine rendering that is capable of interactivity, rendering at 90 frames per second, in stereo, via an experimental build of Epic Games' Unreal Engine (UE4).

Such realistic avatars are highly complex technically, as they require advanced and specialized scanning and facial animation rigging, a form of computer controls that can puppet a neutral face to any required expression or combination of expressions. Additionally, the resulting system must be able to almost instantly read and decode the facial expressions of the human actor. So-called expression decomposition and digital expression reconstruction is done via a human-expression coding scheme called the facial action coding system: action units (FACS-AUs) (Ekman, 1992), which enables the translation of human face expressions into actions carried out by the avatar. This process is difficult to achieve, not just because of the complexity of the human face, but due to the degree to which all aspects of the performance need to be matched with a high degree of fidelity to achieve real-time synchronization between facial movement, speech, and action. As the Thatcher illusion has shown, humans have a highly evolved empathy for faces and are thus very sensitive to any errors. Specifically, even miniscule changes in eyelid movement, mouth or lip expressions, eye wetness, or head tilt can be interpreted as an unintended change in expression, which can result in negative reactions in the human interacting with the avatar.

Such a system needs to accurately read the expressions of the human actor via multiple stereo cameras, interpret those images using advanced deep-learning aided computer vision algorithms, and then drive a complex facial rig or animation apparatus. This animation rig reproduces a set of instructions to match the expression on the face of the computer model. Using motion sensors (motion capture) of the human actor's posture, it further combines this facial expression with a head position and orientation and then outputs an animated head from a particular viewpoint or virtual camera, all in real-time. The final images of the CGI face are rendered from this camera view, in stereo, at a resolution of 2160 x 1200 pixels. All of this is done at 90 times per second (or 9 to 11 milliseconds).

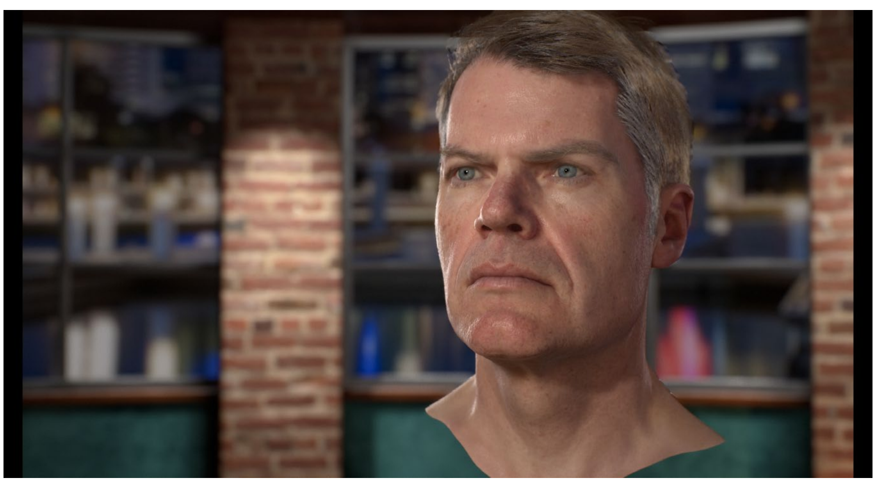

**Figure 3. Realistic avatar, fully synthetic, CGI rendered in Epic Games' UE4**

The process for creating digital face representations modeled after the actual face of a human actor is, at present, highly time-consuming, and requires the combination of a range of sometimes experimental techniques. Yet, once the model and the rig that drives it are successfully created and calibrated to an input device worn on the head of a human actor who puppeteers the avatar (Figure 5), the actual puppeteering operation and visual rendering of the avatar is achieved in real time, or nearly instantaneously, without observable lag to the observer. Figure 4 shows a comparison of a real photograph of the human actor (on the left) and of their realistic, fully computer generated (CGI) avatar (on the right), which would normally be viewed in VR.

Immersive collaboration with realistic avatars, as discussed here, builds on the notion of embodiment and presence (telepresence) in virtual worlds (Schultze, 2010). It feeds on the idea that "even though part or all of the individual's current experience is generated by and/or filtered through human-made technology, part or all of the individual's perception fails to accurately acknowledge the role of the technology in the experience" (Riva, 2009). In other words, immersive collaboration aims to bring about an interactive experience among two or more human actors in a virtual space with a degree of realism that allows the technology to recede into the background so that the actors can get on with their collaborative business. We argue that realistic avatars have the potential to contribute to such realistic technology-mediated collaborative experiences.

**Figure 4. Human Actor (Left) Realistic, Fully Synthetic, Rendered Avatar (Right).**

We envision applications of immersive collaboration ranging from remote working to realistic, immersive meeting and conferencing applications and interpersonal negotiation situations, which would benefit from communication that provides not only verbal but also visual expressive facial communication without being restricted to a strict traditional camera (webcam) perspective. For example, current webcam-style teleconferencing that uses a lens mounted above the screen makes it impossible to provide direct eye contact between the conference participants.

**Figure 5. A Head-Mounted Face Input Digital Puppet System (Including Lights)**

As immersive collaboration technologies with realistic avatars become available, several interesting research issues arise pertaining to the perception, acceptance, and efficacy of natural face technology itself, as well as the experience of immersion in a virtual environment mediated by realistic avatars. IS researchers, we argue, will be interested in investigating if and how such immersive collaboration leads to realistic visual presence (RVP), and what the role is of (1) the degree of realism of the real-time rendered faces of realistic avatars, (2) the quality of the interaction enabled by realistic avatars, and (3) the immersion in a virtual context more broadly. We will return to these questions in the following sections of the paper.

### 2.3.2 NADIA: Conversational Computing with a Cognitive Agent

Conversational computing, the interaction with a computer agent via natural speech, is cited as a major advance in human-computer interaction that provides "a natural means of interaction" to "transform computing," because "being able to talk to computers abolishes the need for the abstraction of a 'user interface' at all" ("Now we're talking," 2017). While this is not to suggest that traditional computer user interfaces will be fully replaced, controlling computers and other computing devices via speech has gained momentum, with commercially available technologies such as Apple's Siri or Amazon's Alexa that have made their way into smartphones (e.g., the iPhone) or dedicated devices (e.g., Amazon's Echo). MIT studies as early as 1996 indicate that personified interfaces help users engage in computing tasks. The same studies also indicated that "people's impression of a face in a task are different from one of the face in isolation." The research used very simple cartoon faces but it did state that "perceived intelligence is not determined by the Agent's appearance but by its competence" (Koda & Maes, 1996).

Against this backdrop, the next development step will be to create highly accurate visually represented cognitive agents that are based on similar synthetic face rendering technology as introduced above. We note that in creating such entities, designers have more degrees of freedom in creating the visual presentation when compared to the creation of realistic avatars that need to match a particular human face. At the same time, the creation of visual cognitive agents is complicated by the need to drive believable behavior of the agent with artificial intelligence (AI) technology. Once successful, such agents should resemble fully synthetic humanlike entities, in both visual appearance and behavior, entities that up until now have only been seen in science fiction.

One example of such a visual cognitive agent is Nadia, which was developed in New Zealand by researchers at Soul Machines and the University of Auckland as an advisory interface for the National Disability Program/Insurance Scheme (NDIS), funded by the Australian federal government (Seymour, 2017). Nadia was intended to be made available online as part of the virtual assistant platform of the NDIS for users with various disabilities. The intention was that Nadia would answer questions, provide advice, and engage in a normal language conversation with clients of the NDIS. Visually, Nadia is fully synthetically created. Her facial expressions are created by autonomous expressive embodied models of behavior driven by neural-system models based on affective and cognitive neuroscience theories. She is not instructed by a human actor. The agent can express emotions via facial expressions, and is able to emotionally respond to the discerned emotional states of the user (Seymour, 2017).

Behaviorally, Nadia is a conversational bot, as she is not fully scripted with a set of predetermined responses, but can situationally react to the flow of a conversation. While her responses are drawn from a knowledge database carefully curated by the NDIS, each spoken phrase is individually created for the discussion at hand instead of using prerecorded lines. Her voice is generated semi-synthetically from the voice of actress Cate Blanchett. Nadia sounds natural, as her answers are generated from partial samples derived from more than 20 hours of Blanchett's recorded voice. Nadia can "say" whatever is needed, even if the range of her responses is tightly defined.

As a cognitive agent, Nadia can be thought of as a visual version of Amazon's Alexa with a specific domain of knowledge. Nadia extends the notion of the cognitive agent by adding a human face; we thus characterize Nadia as a visual cognitive agent (VCA). Nadia is driven by its own "brain" or artificial intelligence (AI) schema, with an ontology provided by IBM's Watson technology. It is worth mentioning that the underlying agent technology was designed to be knowledge domain–agnostic. As a result, it is possible to instantiate agents similar to Nadia, connected to a variety of different back-end conversational knowledge engines (Seymour, 2017). In fact, another cognitive agent created by Soul Machine, labeled Jamie and using the same technology, will provide banking advice as an ANZ banking agent (Paredes, 2018).

We envision conversational computing with VCAs to raise interesting practical and conceptual, as well as philosophical questions, opening a new field of research for IS. For example, will interaction with what will appear like fully synthetic human characters bring about an instant affinity that enables more natural human-machine interaction, or will it be irritating and off-putting at first? We envision that interaction with VCAs will be both alien and strangely familiar at the same time. Moreover, will the quality of advice received from a VCA be perceived as superior to the same advice when presented by a traditional user interface? Will users develop relationships with and attachments to VCAs over time? And what are the implications for our relationships with machines more broadly? In the following we will outline a research program to investigate such questions in IS.

**Table 2. Characteristics of Nadia, the NDIS Visual Cognitive Agent**

| The Nadia Visual Cognitive Agent |
| --- |
| • Has the ability to say anything, her responses are not prerecorded |
| • Is visualized with a highly detailed human face, able to express complex emotions quickly |
| • Reads the emotions of the user and reacts accordingly (via an input web camera and voice stress analysis) |
| • Provides answers by interfacing with a secondary AI engine—for example, IBM's Watson |
| • Is built with design input from the disabled community functionally and attitudinally |
| • Improves in answer relevance and accuracy over time (i.e., learns from use) |

**Figure 6. Three Visual Cognitive Agents by Soul Machines: Rachel, Nadia, and Roman. Each Is Driven By Forms of AI and Engages in Natural Language Conversation.**

## 3 Toward a Program for Researching Natural Face Technology

We have outlined the technical and conceptual foundations for achieving realistic visual presence (RVP) with computers, which has not been done before, and have discussed the importance of natural face technology for doing so. We argue that once real-time rendered realistic human faces become available for application in such contexts as immersive collaboration or conversational computing, we will be able to achieve RVP, defined as the sensation of interacting directly with another human actor, even though interaction takes place via an avatar or with a fully synthetic agent.

We argue that natural face technology, as a new-to-the-world technology is transformative in that it has the potential to enable a new computing paradigm, one that will allow interaction with (or via) machines in potentially more natural and unobtrusive ways than current computing interfaces offer, to the extent that the distinctions between human-to-human and human-to-machine interaction become decidedly blurred. Given its novelty there is naturally a dearth of existing research applicable and transferrable to this technology that would allow theorizing and predicting (1) how users will react when presented with realistic and interactive fully synthetic faces in machines, (2) what the implications of such technology for application in various contexts might be, and importantly, (3) how this technology might challenge established thinking and ontological categories, such as those of the IT user and IT artifact. Specifically, the question arises, will it still be appropriate, and true to the phenomenon, to frame a conversation with an agent such as Nadia as a user "using" a machine—will this capture what is going on in such a situation?

We believe that IS has a duty to engage with new technologies and their implications as early as possible. Too often, we see IS research trailing and playing catch-up with industry applications of novel technologies. While we acknowledge that the technical creation of natural face technology may fall outside of the scope of IS, we argue that IS—with its focus on the user, the application context, and the (broader) implications of technology—will play a crucial role in understanding the nature of this new technology, in finding ways to employ such technology successfully, and ethically, and in reflecting on the implications the technology poses both for society and for how we think about and theorize technology itself.

Consequently, in the remainder of the paper we will outline and discuss the early sketches of a research program for investigating realistic visual presence with natural face technology. We distinguish three levels of research, which we envision the IS field will progressively engage with as natural face technology becomes available and broadly applied in practical contexts (see Figure 7 for an overview):

- **Microlevel studies:** Experimental research to investigate responses to, perception and efficacy of (interactions with) real-time face renderings of different degrees of realism, and the extent to which RVP is experienced by human subjects in varying (experimental) situations.
- **Mesolevel studies:** Research into the roll-out of immersive collaboration, or conversational computing, into practical contexts; rich data collection into user interactions and realistic visual presence in natural environments.
- **Macrolevel studies:** Reflection on the nature and implications of natural face technology for society and the IS field itself; the extent to which such technologies challenge accepted conceptual categories and our familiar conceptions of human-machine relationships.

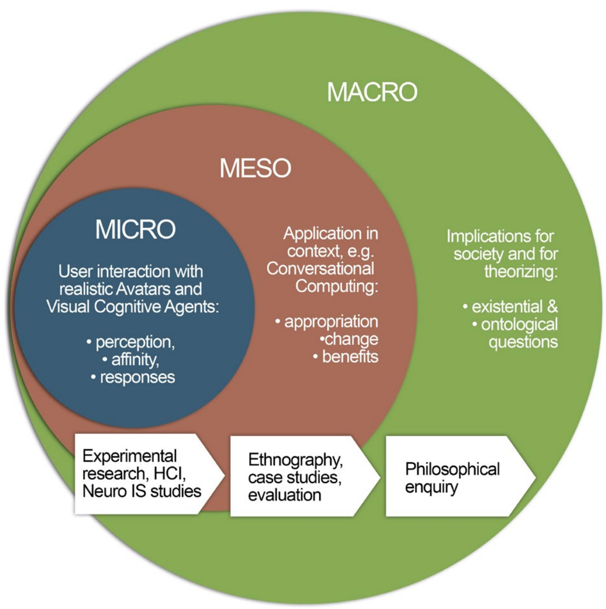


**Figure 7. Research Program Outline For Investigating Natural Face Technology.**

The remainder of the paper will be devoted to outlining in more detail future research into natural face technologies and the creation of real visual presence. Concretely, we present two sections—one outlining experimental research into natural face technology at the microlevel using realistic avatar technology as an example, and a second section that discusses future research into the application and broader implications of conversational computing with visual cognitive agents.

We note that given the novelty of the technology and research topic, our ideas will, by necessity, become more speculative as we progress: while we present concrete ideas for experimental testing of natural face technology for creating RVP in immersive collaboration scenarios (in Section 4), our ideas for research into practical applications of visual cognitive agents (in Section 5) are more high-level at this stage, given the degree of uncertainty around possible implications of such technologies when rolled out into everyday use contexts. Nevertheless, we will introduce a range of research issues and list research questions and discuss conceptual and philosophical issues as a foundation for future IS research.

# 4 User Affinity with Natural Face Technology: The Role of Interactivity

How will users react to real-time rendered natural faces? What contributes to affinity in users when interacting with natural face interfaces? To what extent does familiarity with rendered faces in the users contribute to affinity with the agent or avatar?

These and similar questions will be at the heart of initial experimental research into user interactions with natural face technologies. In this section, we first outline the dominant theory capturing human perception of face technology: the uncanny valley theory. We will question critically the applicability of this theory for contexts in which users interact with natural face avatars and highlight the role of interactivity in creating affinity with face technology in the user. By way of example, we outline in some detail a research project for investigating the relationship between face realism and interactivity in creating user affinity with avatars. We end the section by arguing that interaction with digital avatars or agents brings about a new kind of phenomenon, distinctly different from the mere judgement of realistic prerendered faces. We argue that the experience of meaningful interaction with a realistic avatar (or cognitive agent) is what we referred to earlier as realistic visual presence.

## 4.1 Uncanny Valley Theory

Realistic (but perhaps not photo-real) face renderings are not new; they have been around in the gaming and film industry for quite a while now. The dominant way to theorize human perception and acceptance of photo-realistic face technology involves the so-called "uncanny valley" (Kawaguchi, 2011). This theory, now over 40 years old, predicts that acceptance of an artificial face increases steadily as realism in its presentation increases, before dropping off sharply and becoming negative. It then rises strongly again as realism approaches perfect reproduction (see Figure 8 below). The resulting "valley" metaphorically captures the effect that faces can look almost real, but feel quite "wrong" in subtle, yet important ways. In other words, as realism increases to an almost realistic but still inaccurate state, the outcome in reaction to such faces worsens before it becomes better in a nonlinear fashion. Masahiro Mori's 1970 paper (Mori, Kageki, & MacDorman, 2012) termed this limitation "bukimi no tani," commonly translated as "uncanny valley."

As visualized in Figure 8a, Mori's theory maps a function of increasing realism against an axis of affinity. As the realism of a human representation increases, the affinity increases, but only to a point. Once realism exceeds a certain point, there is a sharp drop in acceptance or affinity. Figure 8b offers three views of the same face—all artificial and not photographic—as examples of this point along the uncanny curve, ranging from cartoon, to an uncanny NCP version and then a high-resolution 3D model. According to this theory, the state of most affinity is explicitly formulated to be that of a completely believable or real person, where the difference is impossible to detect. But it also postulates a high level of affinity with only moderate realism, just before the valley drops off, such as one might experience with a cartoon version of a face.

However, it has been noted that there is no clear measure or metric for the notion of "affinity": it is not a dependent variable against which one can test with some independent variable (Mori et al., 2012). Importantly, the word itself is a translation from the original Japanese word Shinwakan ( 親 和 感 ), and thus is open to interpretation. While affinity is the currently accepted translation, other English translations have also been used, such as; familiarity, rapport, and comfort level to describe the theory's reactionary vertical axis (Ho & MacDorman, 2010). Several previous studies have judged "affinity" by perceived familiarity. These studies asked participants to rate avatars on a nine-point scale in terms of how strange or familiar they judged it to be from 1 (very strange) to 9 (very familiar) (MacDorman, 2006; Tinwell, Grimshaw, Nabi, & Williams, 2011a).

At the same time, determining what triggers the negative response in viewers captured in the notion of the "uncanny valley" is not a matter of a simple equation. There appears to be no single cause that makes a digital face seem uncanny (Tinwell, 2009). Researchers have speculated that this "eerie sensation" when viewing a close approximation of human reality "is probably a form of instinct that protects us from proximal, rather than distal, sources of danger. Proximal sources of danger include corpses, members of different species, and other entities we can closely approach" (Mori et al., 2012).

MacDorman, Srinivas, & Patel (2013) state that "anecdotal evidence indicates the Uncanny Valley suppresses empathy," citing many such studies. They outline a series of experiments to investigate if higher realism enhances one's ability to take the perspective of a character. They suggest this might be so, because of increased activation of so-called mirror neurons (MacDorman et al., 2013). Mirror neurons were first discovered in the ventral premotor region F5 of the macaque monkey (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992). The part of the brain that contains mirror neurons shows fMRI activity both when an action is done and observed. Dinstein et al. (2007) stated this is because "the stimulus feature encoded in mirror neurons is repeated irrespective of whether the action is observed or executed". In other words, the same brain activity occurs when an individual is performing the action and also when they are observing someone else performing the same action.

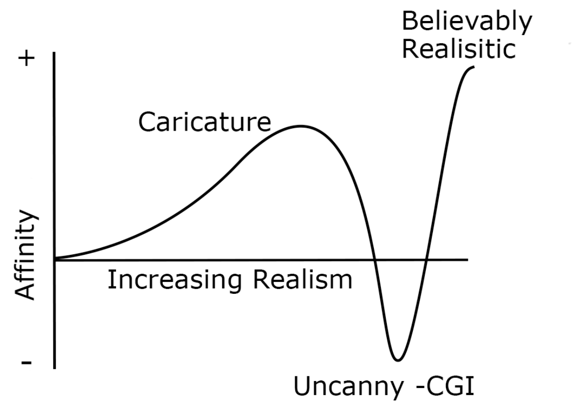


**Figure 8a. The Uncanny Valley Updated to Reflect Its Application To CGI.**

**Figure 8b. The Uncanny Valley CGI Examples of A Caricature, A Low Affinity CGI NPC, and A Highly Believably Photo-Real CGI Model**

While the original theory was formulated in the context of robotics and prosthetics, its efficacy has been demonstrated for computer graphics images (CGI) of faces as well (Klehm et al., 2015; Rachel McDonnell, Breidt, & Bülthoff, 2012; Pollick, 2010). Yet, while the theory has been successfully applied in such contexts as computer animation, gaming and digital representations of human faces (Tinwell, Grimshaw, Nabi, & Williams, 2011b), it is important to note that most applications of the theory have focused on prerendered stills and preanimated film clips (Macdorman & Entezari, 2015; McDonnell & Breidt, 2010). In general, the focus of the theory has been on the appearance of the digital or robotic artifact as judged by an observer (MacDorman, Green, Ho, & Koch, 2009; Pollick, 2010; Tinwell, Abdel, & Charlton, 2013). Furthermore, later studies have shown that movement in faces made the uncanny effect even worse, and thus "changes the shape of the uncanny valley graph by amplifying the peaks and valleys" (Mori et al., 2012 p. 99).

When extrapolating these findings, we would expect that the "uncanny effect" would become even more pronounced for the technologies discussed in this paper—immersive collaboration with realistic avatars (RA) and conversational computing with visual cognitive agents (VCA), in which faces are not only animated but also in direct interaction with the user. Interestingly however, anecdotal evidence from observations of such interactive situations suggests that the opposite happens: The uncanny valley appears to be mitigated in interactive situations, not aggravated. Hence, we have reason to believe that the change from merely standing back and judging the appearance of a natural face to being in direct interaction with a realistic avatar or visual cognitive agent leads to a phenomenon of a different kind, not merely to a variation of the known effect captured in the uncanny valley theory.

## 4.2 Moving Beyond the Uncanny Valley: Anecdotal Evidence from Demonstrations of BabyX

We proceed by offering as anecdotal evidence our firsthand observations of a series of demonstrations of a visual cognitive agent technology in which, as we aim to show, direct interaction with a VCA created a phenomenon that is different in important ways to the one covered by the uncanny valley theory. The author team witnessed demonstrations of BabyX on three separate occasions. On each occasion BabyX was presented by its creator Mark Sagar in front of a conference audience. These demonstrations took place at (1) the industry conference DISRUPT.SYDNEY in Sydney, Australia, in 2014[1]; (2) at the International Conference on Information Systems (ICIS) in Auckland in 2015 as part of a keynote presentation; and most recently at the ACM SIGGRAPH Realtime LIVE 2015 conference in front of computer graphics specialists.

BabyX is a visual cognitive agent which presents as a young child. BabyX was a precursor to Nadia and developed by the same team. BabyX is based on a self-learning neural brain model. "She" works using biologically based computational behavioral models driving her virtual babylike character. BabyX uses a psychobiological modeling framework called "Brain Language" (BL) to create an autonomous agent with a realistic face. BabyX's autonomous expressive behavior is driven by various neural-system models based on affective and cognitive neuroscience theories. As a result, she resembles an "unscripted agent," in that her responses are constructed in the moment, using the latest theories in childhood neuroscience (Sagar et al., 2016).

[1] A recording of this presentation is available here: https://www.youtube.com/watch?v=pFjlGiqGrJc

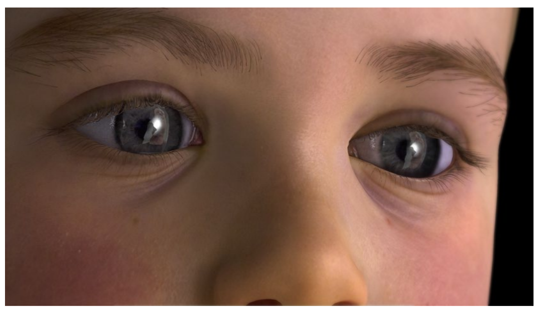

**Figure 9. Close-Up of Baby X (Source: Soul Machines)**

During each demonstration, Mark Sagar would begin by talking about BabyX as a technology and its neurological and psychological underpinnings. At some point, he would put the "face layer" on BabyX and begin interacting with "her." On each occasion, we observed a strong noticeable change in the mood and reactions from the audience, as Mark began eliciting from BabyX emotional face responses (e.g., smiling when he smiled, or distress when his face would disappear from her visual field) or verbal repetitions of words he would teach her. The reactions from the audience were audible and visceral, there was laughter, gasps, and joyful expressions in reaction to her emotive responses.

It was clear that something had changed in the room the moment Mark elicited responses from BabyX and interacted with her, which he did in an unscripted, quite natural way. While there is no suggestion that the audience rationally thought the baby on screen was in any way "real," they nevertheless instantly and emotionally react to her as if she was. This became particularly clear when Mark offered to demonstrate the "pain response" of the neurological net underpinning BabyX, applying a stimulus as if someone was about to "hurt" the baby. Significantly, even though these were academic presentations in front of professional audiences, and pain response is a perfectly valid part of any brain model, the audience's reaction demonstrated that Mark's suggestion of "cruelty" toward BabyX was seen as inappropriate. Interestingly, this situation was followed by an emotional display of relief in the form of laughter when Mark refrained from applying the stimulus. As laughter is infectious, Mark also laughed, which was witnessed by BabyX, who in turn became more joyous based on reading genuine happiness sensory input from Mark's face. On each occasion BabyX spurred many discussions after the presentations; audience members appeared taken aback by the collective emotional responses to BabyX even though they understood quite well that what they witnessed was merely a simulation in software code.

These observations offer the following insights: We note first that the dynamic in the room changed when BabyX's face appeared on the screen. This is not surprising in light of the general significance of human faces, as outlined earlier. Second, we note that BabyX's face was by no means a 100% realistic rendering and that it might well have elicited a typical uncanny valley response under different circumstances, e.g., when judged for appearance alone. In the observed settings, however, we witnessed direct interactions between the demonstrator and the BabyX agent. This leads us to reason that third, what happened in each of the presentations is not that the audience merely saw and reacted to an animated, moving face, but that they observed an interaction between two actors, one human and one nonhuman, which resulted in a different phenomenon altogether. Finally, we observed that as engagement between these actors unfolded the audience went from mere observers to engaged participants in a social situation. Rather than standing apart as mere spectators, they were involved emotionally and emphatically in the unfolding situation on stage. Interestingly, we have observed that people who merely watch a recorded video of such BabyX demonstrations do not exhibit the same degree of response as those who were in the room at the time.

These observations lead us to argue that it is the direct engagement, or interaction, with the VCA that changes the nature of the phenomenon, as compared with a mere presentation of the VCA or the judgement of appearances of prerendered faces, still or moving. In turn, this suggests that the uncanny valley theory, despite its long-standing success in predicting responses to recorded realistic rendered faces might not be directly applicable to situations that include interactivity and direct engagement as outlined above, or that the theory should be modified and retested with interactivity as an additional construct. In what follows we briefly present, by way of example, a research design for testing the impact of interactivity in creating user affinity with natural face technology. We conclude this section with a discussion of the nature of interaction as a new phenomenon beyond the uncanny valley, a phenomenon that opens up a space for new theorizing in IS of user interaction with VCAs and RAs.

### 4.3 A Research Design for Testing the Impact of Interactivity on User Affinity with Natural Face Technology

The dominance of the uncanny valley in computer science and in CHI is understandable, but it may not serve as a ground for IS research to stand on as we begin to investigate and theorize natural face technology in actual applications. We note again that the original theory predicts that the uncanny effect will be amplified by movement, but that it either does not make any assumptions about the role of interactivity, or that interaction has implicitly been subsumed under the movement category. Against this backdrop, we argue that our observations above warrant the investigation of interactivity as a separate construct. To do justice to our observations, we hypothesize that interactivity operates on an independent, orthogonal dimension to "appearance," and that the user processes the experience differently. Hence, in the following we present an experimental research design as an example of initial research into the application of natural face technology.

We present here the design and foundation work for a study to test the influence of appearance and of interaction as two separate effects on the acceptance of nonhuman actors that are presented by faces with varying degrees of photo-realism. In the following we use a setup based on avatar technology. In doing so, we are interested to test if and to what extent a digital character's lack of realism in appearance is mitigated by human interaction, as was suggested by our observations above. We thus ask the questions: if a realistic avatar is not only moving but interacting, is the interaction characterized by more affinity? In more general terms, does interactivity change the phenomenon?

While the original uncanny valley theory juxtaposes affinity (in the user) and realism (of the appearance of the rendered face), we propose interactivity as an additional construct, which results in a 3D mapping of interaction vs. realism vs. affinity (see Figure 10). By treating realism and interactivity as two separate dimensions we assert that there are situations where a face may be considered unacceptable on the basis of appearance alone, but could be quite acceptable when combined with interactivity, even though the face might still be judged as artificial (i.e., something less than imperceptibly real). Interactivity is thus theorized to have a mitigating effect for appearance.

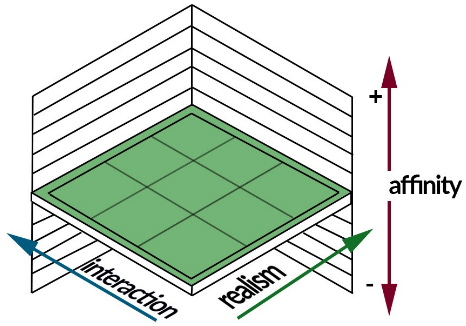


**Figure 10. Mapping of Constructs.**

The experimental setup will thus have to account for different degrees of realism in avatar appearance, and different situations involving varying degrees of interactivity. We propose to account for realism by utilizing 3D-rendered faces with different degrees of realism (such as shown in Figure 8b above). We note that the efficacy of prior studies comparing different degrees of facial realism was often limited by not using examples based on the same face. We thus argue that a variation utilizing the same face at different levels of realism should be used.

**Table 3. Range of Test Variables**

| Levels of realism | (1) Still image | (2) Prerecorded video | (3) Interacting on screen | (4) Immersive interaction |
|---|---|---|---|---|
|  | • Simplest imagery<br>• No movement | • Simplest imagery<br>• Filmed movement | • Simplest imagery<br>• Interact with avatar viewed on a monitor | • Simplest imagery<br>• Interactive<br>• Viewed in VR |
|  | • Moderate imagery<br>• No movement | • Moderate imagery<br>• Filmed movement | • Moderate imagery<br>• Interact with avatar viewed on a monitor | • Moderate imagery<br>• Interactive<br>• Viewed in VR |
|  | • complex imagery<br>• No movement | • complex imagery<br>• filmed movement | • complex imagery<br>• interact with avatar viewed on a monitor | • complex imagery<br>• fully interactive in VR |

Moreover, users will be exposed to different situations of varying degrees of interactivity. We suggest the different avatars need to be experienced as (1) a still, (2) a prerecorded video clip, (3) an interactive avatar on screen, and (4) as an interactive avatar in an immersive VR environment. In order to create true interactivity, the two interactive avatar versions will require advanced digital real-time face tracking and rendering, because interactive avatars require the ability to exhibit immediate emotional matching between the person driving the avatar and their avatar when reacting to the user subject. Table 3 provides an example of the various test cases covered in such an experimental setup.

For the actual experimental setup, we envision user subjects being presented with still images and videos on a screen, on which they will also interact with the avatar in a video conferencing style communication situation. For the situation with the highest degree of interactivity, participants will be seated wearing a VR head set and be exposed to an interaction situation comparable to the immersive collaboration scenario described in section 2.

In both interactive scenarios, a person "behind the curtain" will drive the avatar's interaction with the participants. This "Wizard of Oz" style interaction will allow the researcher driving the facial interface to be hidden from view, but able to see and hear the participant via their webcam, while projecting onto the avatar their own facial expressions. Figure 5 shows the head-mounted display that registers the researcher's reactions and drives the on-screen avatar; Figure 11 shows the experimental setup using a screen. The research will involve a small sample trial to validate the data collection process and analysis before proceeding. The eventual sample size of the main subject group is expected to be greater than 30. We note that the technical details of the face tracking and advanced rendering are outside this scope of this paper, but that both are achievable technically today with the latest available technology.

We further envision participants engaging in a specific task, such as planning an overseas holiday with the aid of an assistant available via avatar. The chosen task should not invoke strong recall of previous emotions (which may be hard to separate from emotions and responses due to the avatar), and should neither be unpleasant nor too routine.

For the procedural setup of the experiment, participants would explore and experience face presentations that are successively modified in terms of both interactivity and realism, and the experiment would measure positive or negative degrees of affinity. Participants would be surveyed after exposure with a concise Likert questionnaire. An Attrakdiff UX eSurvey–style model[2] could be utilized for evaluation regarding how much affinity the participants feel toward the avatars in terms of usability and appearance. The process would be a within-subjects design using a Latin square. In order to gauge if there is basic emotional attachment to the avatar, part of the experiment would need to involve exploring a baseline empathy present without the introduction of a facial avatar representation, building on the work of Clifford Nass and others (Lee & Nass, 2003; Nass & Yen, 2010; Reeves & Nass, 1996). Furthermore, a limitation of the proposed research is the limited exposure to one base subject only in terms of facial features and gender.

[2]http://www.uid.com/en/services/user-research/ux-evaluation.html

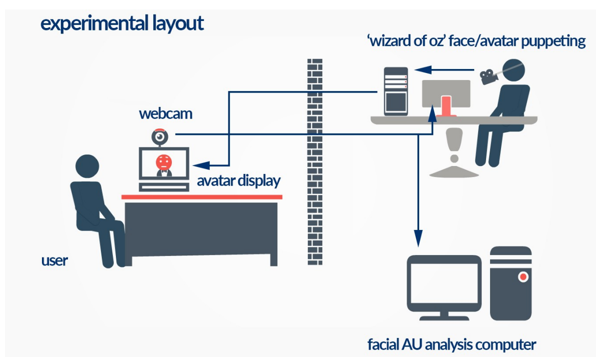


**Figure 11. The Experimental Layout Illustrating The "Wizard of Oz" Researcher Behind a Wall Controlling the Avatar.**

It is worth mentioning that this research plan meets the criteria of a design science approach, as it incorporates principles and practices associated with IS design science research. It meets the three objectives stated by Pfeffers et al.: it is consistent with prior literature and theory, it provides a process model for doing the research, and it provides a mental model for presenting and evaluating design science research (Pfeffers, Tuunanen, Rothenberger, & Chatterjee, 2007). We note that this is merely one possible approach to researching the specific (microlevel) issues of this new phenomenon.

## 4.4 Interaction with Digital, Nonhuman Actors—A New Phenomenon?

We propose that the simple two-dimensional relationship between affinity and realism in the uncanny valley theory does not encapsulate the complexity of a situation where interactivity is introduced, and we expect the above experimental setup to be able to confirm this assumption. We propose as a metaphor for the role of interactivity the "flooding" of the uncanny valley, as this implies that we are no longer merely crossing the uncanny valley on a quest to improving realism in appearance, but exploring a phenomenon of a different kind, one that is not encompassed by the original theory. While one could argue that interaction is just an extension of realism, this would imply that they are part of the same axis. We propose here that there is an additional dimension and that this new dimension invokes different cognitive processes than just aesthetics or appearance; it affects sensemaking and is likely to involve different neurological processing. Conceptually and philosophically, we argue it brings about a different mode of engagement.

Neurologically, we would expect to see a change in brain activation when moving from mere face recognition and judging of face realism to observing or engaging with a realistic avatar. We have reason to believe that mirror neurons, which have been credited with enabling empathetic mirroring responses (Keysers & Gazzola, 2008; Kilner & Lemon, 2013; Rizzolatti & Craighero, 2004), are responsible for instilling empathy in the observer when the avatar entity is no longer static and judged for appearance but is now interacting, and therefore being taken as a "person" rather than an image. This mirroring response, we suggest, will be responsible for the "flooding" of the uncanny valley. We propose that extensions to the data collection procedures in the above experiment might be used to investigate differences in neurological processing associated with judging appearances versus engaging in interaction.

Philosophically, we argue that interaction with realistic avatars (or visual cognitive agents) presents an entirely different phenomenon from the judgement of facial appearance. During interactions, we do not normally scrutinize or judge another person's face, nor do we merely recognize a face when we encounter someone in the street—in both of these situations, we encounter or engage with the whole person. During such encounters, we make no conscious distinction between the person, their identity, or their face. While we recognize a person by their face, it is not the face we recognize, but the person as such.

Similarly, when we interact with someone or observe someone else interact with another person—or with a believable humanlike entity for that matter—we do not merely look "at" the other, but find ourselves in a situation "with" the other. This mode of engagement is what (Heidegger, 1962) captures in his notion of "being-with-one-another" a form of situational engagement in which one finds oneself engaged with another person in a concernful and practical manner, oriented toward whatever one's joint business is. In other words, when interacting with another person, one's attention and orientation are typically focused on the topic of the conversation or whatever joint business the interaction involves, and not on the other person as such.

This distinguishes sharply from a mode of engagement whereby one would look at and judge another person as the explicit object of attention—this mode of engaging would capture the judgingof facial appearances but not one's normal encounters with another person. Similarly, when observing other people interacting, we would normally focus on the interaction (e.g., on the flow of conversation), rather than on the specific features of the individual actors.

We thus suggest that there is an important changeover in our mode of engagement that is at the heart of the above experiment—our mode of engagement changes when moving from paying attention to and judging a face (still or video) to interacting with an avatar or agent. We further suggest that it is such being-with-the-agent (or avatar) in interaction that is captured in our notion of realistic visual presence (RVP), a sensation of being with a nonhuman actor as if it were a human actor.

Finally, we note that the role of realistic faces, while still important, will be backgrounded in such interactions, in the sense that when the interaction progresses naturally the face as such will not be noticed if it is believable and realistic. Only if the face is off-putting, or otherwise stands out as conspicuous (e.g., due to a flaw in rendering or time-lag), will a breakdown occur that interrupts the flow of interaction. In such a breakdown situation, our engagement would change from being-with-one-another to an explicit scrutinizing of the face as the object of attention (Dreyfus, 1991). If the face were then judged unfavorably in terms of the uncanny valley response, we might expect the interaction to be compromised with a lasting negative response by the subject, given that the "illusion" of "being with" would then be broken. Equally, we would expect that interacting with avatars with low levels of realism in the above experiment would not result in the kind of interaction that results in RVP, as human subjects would not naturally take the entity to be a believable person.

We conclude that as realistic avatars and visual cognitive agents become available, a new field of research for IS will emerge: the study of human interactions with such nonhuman actors, which will raise a range of potential research questions. We provide an overview and consolidated list of potential research questions in the discussion section below.

# 5 Visual Cognitive Agents in the Field: From Interaction to Relationship

In this section, we widen our perspective to discuss research implications of visual cognitive agents and their imminent roll-out into practical contexts. As we previously outlined, VCAs, while sharing a natural face interface with realistic avatars, come with an additional behavioral dimension that adds significant complexity to their design and ability to bring about creating realistic visual presence in interaction with a user. Hence, fully realistic visual cognitive agents will not only have a humanlike appearance but will also be able to display believable behavioral competence in that they appear to understand language and respond in a way that makes sense to the user. Once VCAs (such as Nadia) are released "into the wild," they will have to prove themselves not only through interactions, but also over time, by building relationships with their users. In the following we will discuss in more detail: (1) the behavioral dimension of VCAs, (2) the requirements of VCAs to engage in relationships with users over time, and finally (3) philosophical questions that arise from living with these emerging new forms of "artificial humans."

## 5.1 Behavioral Competence in Visual Cognitive Agents

We begin by noting that the behavioral dimension of VCAs is not independent from their visual presentation, since much of the behavioral competence of a VCA is carried by emotional expressions of the face. In general, we distinguish two main behavioral components:

1. **Domain competence:** An agent must demonstrate competence in its domain of expertise. For example, Nadia is underpinned by a knowledge database that was carefully curated by the NDIS, so that "she" is capable of providing useful and relevant advice in an interactive way.
2. **Social competence:** In addition to providing factually correct information about the domain area, VCAs will also have to be able to behave and interact in socially acceptable and appropriate ways, both in terms of holding a conversation and in displaying emotions and social cues via facial expressions.

It is the second component that we envision will open a new, productive space for future research, as researchers and designers in IS and adjacent spaces will progressively have to learn about the intricacies of how to "teach" these "artificial humans" socially acceptable manners and demeanor. We suggest that the humanlike appearance of VCAs will come with expectations regarding their capabilities to engage in realistic, natural interactions. While a user might naturally take to interacting with a VCA as if they were a person, the challenge of generating in the agent the kinds of believable responses that bring about the sensation of realistic visual presence is not trivial. While it is beyond the scope of this paper to delve into the technical details of how to imbue software agents with the ability to read and respond to the emotional states of users, be it through elaborate user modeling or self-learning AI (Sagar et al., 2016), it is worth pointing out that there is a long-standing research field in computer science built around these issues:

Affective computing is concerned with bidirectional relationships between humans and computers (Picard, 2003)—in particular, the reading and modeling of a user's emotional state and reflecting this state in a user interface. While emotions are sometimes, and in certain contexts, portrayed in a negative light, this research stream explicitly recognizes the importance of emotions for task success and human-machine interaction generally (Picard, 2010). We argue that when it comes to creating natural, conversational interactions between a user and a visual cognitive agent, it is important that the agent not only respond appropriately at the level of content (what is said), but also at the level of social cues and emotions (how something is said). Relevant in this context is the concept of mirroring behavior—the unconscious mimicry of postures, mannerisms, and also facial expressions, such that one's behavior passively and unintentionally changes to match that of another

(Chartrand & Bargh, 1999). Much effort will thus need to go into creating neuroadaptivity in the agent entity—the ability of the artificial neural system to "recognize the physiological state of the user and [to] adapt, based on that information, in real-time" (Riedl, Davis, & Hevner, 2014) to express the kinds of subtle, usually unnoticed expressions and facial responses necessary for an interaction to feel natural, and thus for realistic visual presence to occur.

Conversely, we would expect that when the expression and demeanor of an agent engaged in an interaction feels "off-putting," this might lead to similar situations of "breakdown" that interrupt the flow of interaction, as discussed above with cases of inaccuracies in face renderings more generally. While this might cause reactions in the user as mild as momentary irritation, in extreme cases, such breakdowns might result in repulsion and a feeling of deception. We argue that as these technologies become available and make their way into real-life use situations, it is worthwhile to consider and investigate the existence of a kind of behavioral "uncanny valley" effect that is caused not by visual repulsion but by the off-putting behavior of the agent, either conversational or pertaining to the facial display of emotions.

## 5.2 Building Relationships with Visual Cognitive Agents

With traditional software systems, there is an implicit expectation that the user interface and behavior of a system is the same every time one uses the system (any changes via update or upgrade are usually known in advance). However, this expectation could change when the user interface is an artificial person. Would we not expect an agent, such as Nadia, to remember us, learn about us and over time adjust her behavior between interactions in ways that we would expect from a real person? In other words, the question arises, if, and under what circumstances, a VCA should accommodate building relationships with users over time, rather than merely engaging in a series of isolated, transactional interactions as if they were starting over each time. For this to be possible, we envision a VCA requiring three separate, yet interrelated levels of sophistication:

1. **Recognition:** the VCA must be able to recognize each individual user, e.g., via face recognition. For example, Nadia is capable of recognizing and greeting by name each user individually.
2. **Recall:** the VCA needs to remember past interactions and build a historical record of past encounters with each user. We would expect the agent to remember and recall the content and outcome of past interactions, akin to a combination of access to a factual client file and the personal memory of each encounter and conversation.
3. **Adaptation:** the highest level of sophistication will be the ability to adjust social demeanor and comportment toward the user in subtle ways over time, in order to create the appearance of increasing familiarity that is characteristic of an emerging interpersonal relationship.

We suggest that the first two levels of sophistication are reasonably straightforward to implement technically, while the third level will be exponentially more difficult to achieve. Social, interpersonal relationships develop gradually and over time (Kramer & Tyler, 1996); they are highly complex arrangements that comprise a multitude of dimensions, such as rapport, familiarity, trustworthiness, and a shared understanding and predictability in the other's behavior, to name a few (Krackhardt, 1992). At present, we do not know how to build in an agent the kind of behaviors that are based on an accumulating history with an individual user and that would resemble believable behavior familiarity typically experienced in an emerging interpersonal relationship.

We envision that only research in situ, via rich methods of inquiry, such as shadowing, ethnography, or similar rich data collection methods, will shed light on whether such relationship building is necessary or valuable, and if so, what its contribution to the experience of RVP and the efficacy of a particular service provided by the VCA might be. We suggest that while appearance and believability in interaction might be necessary for the initial user acceptance of VCA technology, the relationship component might turn out to be crucial for the long-term success of VCAs in the field.

## 5.3 Broader Philosophical, Ethical, and Conceptual Questions

As we contemplate the implications of visual cognitive agents becoming widely available in everyday contexts, we argue that we will have to engage with questions about the effects such agents will have for our own self-understanding. We suggest that the creation of artificial human entities will raise quite profound ethical and existential questions. While we cannot possibly foresee and discuss such questions comprehensively, we would nevertheless like to raise a few. To do so, we suggest it is necessary to adopt a different philosophical stance than we have implicitly taken so far in this paper.

Thus far, we have, quite naturally, taken avatars, agents, and users to be entities defined by properties. Such an entity-oriented worldview is commonly known as substantialism, whereby what it means to *be* is essentially a matter of physical existence, to be a substance, mental or physical. Or as King (2001) puts it: “when Greek-Western philosophy speaks of *to be*, it thinks of the *is* of a thing” (emphasis added). Under this view, the world consists of independently existent substances with properties (Bunge 1977; Weber 1997); even humans are conceived in that way, as minds with mental attributes such as goals, beliefs, and attitudes about the world (Weber 2012, 2).

We note that such a view is widely taken for granted in (Western) everyday life and scientific thinking (Spinosa et al., 1997), and this view is useful for designing avatars and agents as material entities imbued with certain face and artificial mind properties.

However, it is less useful for asking existential questions about what agents might become once they are part of a user’s world and how they might change our own self-understanding in the process. Consequently, we envision future philosophical inquiry to engage with this topic from within a relational ontological view, one that makes a distinction between entities (the things we refer to) and their being (what they are by way of involvement in the world) (Riemer & Johnston, 2014), taking into account that entities acquire their being relationally through active, practical involvement with each other in the world. Such a worldview makes it possible to inquire phenomenologically about the being of the entity— i.e., what is this entity? What place does it have in the world?

As such, we will be able to ask questions about the being of a VCA, such as Nadia, when relationally involved with particular users, whereby the VCA might become different things to different people, such as a useful advisor, a trusted companion, or a mere nuisance, depending on “her” involvement in a particular user world. Equally, we suggest that interaction with such artificial humans might also change or challenge us in quite existential ways, in that previously stable professional and personal identities become renegotiated. For example, we might have to ask, does it matter how we treat our agents? Will this reflect badly on us? What does it say about us if we choose one kind of agent as a personal assistant over another? Will there be new social conventions or norms that organize our collective lives with visual cognitive agents once they become ever-present on our mobile devices? And what happens if we go to a friend’s house who maintains a relationship with the same agent, will he/she recognize us, and should they? Will there be a sociality of agents? Moreover, will it be appropriate to “own” these agents in conventional ways? Will a corporation that provides a VCA be allowed to change his/her appearance at will, or even decommission agents when they have already become integral parts of peoples’ lives in quite existential ways? Will users rebel? Will there be a new ethics covering the “lives” of VCAs? Similarly, will advanced VCAs be recognized as a legal entity with certain rights and liabilities when carrying out certain tasks autonomously?

Finally, we argue that the nature of interacting and building relationships with artificial human entities, such as VCAs, puts into question the usefulness of IS foundational constructs such as the “IT artifact” and “IT user” for adequately capturing this phenomenon. We question their usefulness because they are unlikely to capture what it is like to interact and converse with an entity capable of displaying intelligent and emotional responses via a human face. We ask, is it appropriate to speak of being a “user” of a such an entity? Does the artifact-user dyad appropriately capture the experience of interacting and living with a VCA? We argue that the discipline might want to explore alternative (e.g., existential, relational) philosophical perspectives as a grounding for researching the role of VCAs in the world.

We note that the foundational nature of IT artifact and IT user has already recently been challenged in IS by proponents of alternative philosophical positions, such as sociomateriality (Orlikowski, 2007). These scholars argue that in a world infused with technology, it is increasingly difficult to clearly separate entities such as the IT artifact or IT user empirically (Orlikowski & Scott, 2008), and that “users” often do not experience IT as separate from them, but rather as an integral part of their lives and identity (Riemer & Johnston, 2014). We emphasize that while we equally question the appropriateness of the IT artifact and user, it is not because the artifact disappears from view (e.g., as part of a sociomaterial assemblage), but because the entity in question resembles an artificial person interacted with as a dedicated “other,” rather than being experienced as a piece of IT being “used.”

# 6 Discussion

We began with an introduction to natural face technology (NFT) and demonstrated the significance and importance of human faces and their potential for rethinking computer interfaces and our interactions with machines. We have used as examples the application of NFT in immersive collaboration with realistic avatars (RA) and conversational computing with visual cognitive agents (VCA). The main aim of this paper was to outline for the IS discipline a provisional research agenda that would allow engaging with this emerging technology at an early stage. To this end, we took as a starting point the dominant uncanny valley theory which theorizes user responses to artificial face renderings. Using anecdotal evidence from real-life interactions with VCAs, we argued that interactivity brings about a new kind of phenomenon different from merely judging the appearance of prerendered faces. We theorized that it is the "being with" an agent or avatar experienced in interaction that brings about realistic visual presence (RVP)—the sensation of being present with a digital actor as if it was a human actor. We proceeded to argue that once such NFTs are released into the wild, our gaze will have to widen to account for multiple interactions with such entities over time, which raises questions about the ability of VCAs to engage in believable relationship building. Finally, this led to a discussion of emerging philosophical, ethical, and conceptual questions concerned with the implications of VCAs "in the wild." In the following we consolidate our insights into a provisional research agenda, and briefly discuss practical applications and areas of ethical concern from the application of NFT.

## 6.1 A provisional IS research agenda

We present here as a main contribution a provisional research agenda for studying the design, acceptance, use, and application of natural face technologies. Table 4 presents a consolidated list of the various research questions we raised and discussed over the course of our argument, covering micro-, meso-, and macrolevels of inquiry as presented in Figure 7 initially. We note that as NFTs progressively become more widely available and make their way into practical applications, a range of research opportunities will emerge. We outline, by way of example, yet by no means comprehensively, a number of different research areas, each of which will contribute important insights into the emerging phenomena associated with NFT.

We envision research to be experimental initially, exposing test users to various early incarnations of NFT. In Section 4.3 we outlined an example research design for testing the impact of different levels of realism and interactivity on user affinity with realistic avatars. Furthermore, we see opportunity for NeuroIS research (Dimoka, Pavlou, & Davis, 2011; Riedl et al., 2014) that looks into the neurocorrelates of various constructs involved in bringing about RVP through interaction with realistic avatars or visual cognitive agents. Equally, we envision that NFT will provide a productive space for design sciences research (Hevner, March, Park, & Ram, 2004)—for both research that develops and tests design theories (Gregor & Jones, 2007) for the creation of effective NFT, as well as design research that provides new insights and theorizing into how humans interact with and behave toward these new artifacts (Kuechler & Vaishnavi, 2008). Finally, as we have discussed at length in the previous section, we suggest that the application of NFT-based artifacts such as VCAs raise interesting new philosophical, ethical, and conceptual questions for IS and for adjacent fields more broadly.

**Table 4. Consolidated List of Indicative Research Question.**

| Time | Indicative List of Research Questions | Type of Research/Inquiry |
|---|---|---|
| **Microlevel:** Focus on NFT artifact-user dyad | • Which factors contribute to affinity with and acceptance of various natural face technologies, such as realistic avatars and visual cognitive agents?<br>• Specifically, does interactivity positively affect affinity?<br>• If yes, is there a threshold for realism in appearance in situations with interactivity?<br>• More generally, does interactivity change the phenomenon?<br>• What is the role of emotional expressions in VCAs for user acceptance?<br>• What is the role of mirroring behavior in VCAs for user acceptance?<br>• What factors (e.g., rendering problems, conspicuous behavior) cause breakdowns in interaction with NFT artifacts? | Experimental research into user perception, acceptance of NFT, testing the uncanny valley theory, and creation of RVP |
| | • Which parts of the brain are involved in face recognition?<br>• Which brain regions are involved in judging NFT appearance vs interacting with NFT artifacts? I.e., does interactivity change the phenomenon?<br>• Which role do mirror neurons play for effective interaction with NFT artifacts and the creation of RVP? | NeuroIS research into interaction with NFT |
| | • What are suitable kernel theories for creating effective NFT artifacts to facilitate RVP?<br>• What are design principles for creating NFT artifacts that facilitate RVP?<br>• How can NFT artifacts best be evaluated to derive useful design principles for designing NFT artifacts with high RVP efficacy? | Design science research into creation of RVP with NFT, developing design theories for NFT |
| **Mesolevel:** Focus on NFT use in context | • What is the level of history required in VCAs to facilitate RVP consistently over time (e.g., recognition, recall, adaptation)?<br>• Which factors are relevant for social adaptation of VCA behavior over time? Display of trustworthiness? Predictability?<br>• What is the optimal level of recall and memory in creating VCA relationships with users?<br>• Is too much recall unnerving? Do VCAs have to be forgetful to be more humanlike?<br>• More generally, is it possible to create a believable relationship experience with VCAs?<br>• What are the benefits from deployment of VCAs in various contexts? | Rich data collection to study user appropriation of VCAs in context, over time |
| **Macrolevel:** Broader implications of NFT application | • What will particular VCAs become when appropriated into a user's world?<br>• How does working and living with VCAs change us?<br>• What does it say about us if we choose one kind of agent as a personal assistant over another?<br>• Will there be new social conventions or norms that organize our collective lives with VCAs?<br>• Will agents be tethered to their "users" in one-on-one relationships or will they have a "social life"? | Philosophical questions arising from working and living with VCAs |
| | • Will there be a new ethics covering the "lives" of VCAs?<br>• Will it be appropriate to "own" a VCA?<br>• Will it be appropriate for a corporation to change or decommission a VCA that is part of peoples' lives already?<br>• Who is liable for the actions of VCAs? Their creator, owner?<br>• Will advanced VCAs be recognized as a legal entity with rights and liabilities? | Ethical and legal questions arising from working and living with VCAs |
| | • Is it appropriate to speak of being a "user" of a VCA?<br>• Hence, does the artifact-user dyad still appropriately capture the experience of interacting and living with a VCA?<br>• What are alternative (e.g., existential) perspectives to ground IS research on VCAs? | Conceptual implications for research and theorizing in IS |

## 6.2 Practical Implications of Natural Face Technologies

Natural face technologies offer many areas of practical application. Here we offer a selection of possible scenarios, from training, education, health advice, and therapy. Most generally, we suggest that NFT allows for creating new kinds of user interfaces that reduce the need for keyboard interaction, extending existing voice-based solutions, such as Alexa and Siri. In doing so, NFT allows for a richer interpretation of the virtual assistant metaphor, providing for verbal as well as facial communication.

Looking beyond user interface solutions to educational contexts we see applications for VCAs as coach, mentor, or teacher, as well as study companion (Chan, 1989). For example, would a 7-year-old girl learn mathematics better from another 7-year-old on the screen? Would she be more engaged if that girl were actually a digital version of herself? Would there be benefits in the positive visualization of herself succeeding and already being able to do difficult math problems? Would she just pay more attention to herself than an adult teacher?

Similarly, we see applications for realistic avatars in VR-based training scenarios. While VR already provides a trainee pilot with the ability to rehearse cockpit procedures in a virtual cockpit, realistic avatars will make it possible to create fully immersive collaborative settings that provide for realistic interaction between pilot and copilot (or instructor). With immersion an instructor could do more than merely observe and comment, as an avatar they could actively play a role in the simulation, adding realism of the human element that may be critical in such a simulation.

Moreover, when combined with recent developments in translation technology, one can imagine scenarios in which realistic avatars would be used to generate multilocation or multilanguage lecture, presentation, or conference setups in which a speaker is present in a number of contexts as an RA with the ability to translate speech into different languages in real time and also to interact and take questions from participants in each context.

In health and therapy, NFT might enable new forms of agent-based mental health services. While using VCAs for providing patient consultations or therapy might sound counterintuitive, existing work has already proven the benefits of using computer-based advisors to help returning servicemen and women rejoin civilian life, or support certain mental health patients in preparing for job interviews. Certain groups seem to respond better to computer agents than human consultants (Kleinsmith, Rivera-Gutierrez, Finney, Cendan, & Lok, 2015). Similarly, a team at the University of Southern California has built a virtual patient that allows both untrained medical and psychology students to practice conversations with patients (Rizzo et al., 2015, 2016). Each of these early agent applications might benefit from more realistic and subtle interactions provided by emerging VCA technology.

## 6.3 Potential Ethical and Moral Issues

With any new technology come certain ethical implications. The ability to create and puppet human realistic faces brings with it the potential for misuse and manipulation. Technically it will soon be possible to recreate the faces of celebrities or other persons in the public sphere from available visual materials. While we can already see the manipulation of still photographs, or even prerecorded videos, imagine the impact that an imposter with a realistic avatar of a country leader might have in the aftermath of a terror attack, where an online or televised broadcast with real-time immediacy could misdirect crowds to create panic or steer them toward another impending incident. It would be hard to discern such deception in the confusion of the immediate aftermath if the broadcast appeared to be a live response, expressed with the illusion of sincerity, emotion, and duty of care.

In the long term, the wider application of VCAs or avatars raises a multitude of use-related issues. For example, will we see cases of parental surrogacy where a parent abdicates reading a bedtime story, since a replica parent can be left to do so with infinite patience and no intolerance to repetitive children's stories?

And while the use of VCA in therapy is promising, who will be liable when businesses roll out VCAs as commercial self-help services and the VCA fails to react and provide empathy, support and intervention, leading to someone self-harming? Will not the illusion of human support imply a level of moral care and "human decency" which, however, may go unfulfilled due to the actual limitations of the technology?

Moreover, there are risks of vanity appearance in avatars. Given the vast use of "selfies" and programs such as Snapchat today, which already provide face-tracking digital makeup, will there be avatars that enable digitally replacing a normal face with a perfect, neater, perhaps younger version? Would it not be concerning if someone with a disability felt socially pressured to use a "normal" version of themselves to comply with emerging norms of digital perfection? And would not the use of younger versions of one's self result in long-term self-worth issues? Already there appear to be the beginnings of a certain gender bias in the creation of cognitive agents, given that Siri, Alexa, Nadia, and even BabyX are all female. Will we see the proliferation of conscious or unconscious gender or racial biases in the NFT space?

These are but a few ethical issues that we foresee arising once NFT becomes available at scale. While no technology is immune to misuse, we believe that as scholars involved in the creation and early application of such technologies, we have a duty of care to be aware of, raise awareness about, and influence the ethical applications of NFT.

## 7 Conclusion

In this paper, we introduced natural face technology and the phenomenon of realistic visual presence. We have argued that NFT, as a new-to-the-world technology is transformative, in that it has the potential to enable a new computing paradigm. We see IS as able to play a crucial role in understanding and shaping the nature and application of this new technology in effective and ethical ways. By outlining a tentative research agenda early in the development of this technology, we respond to calls for "blue ocean research" that ventures into unchartered technological and social territory.

Our contribution to IS research is twofold. First, we introduce NFT as a new technology and help shape terminology and early conceptual work for IS as the basis for future inquiries into this emerging research space. Second, we provide a tentative research agenda, which comprises concrete ideas for early experimental research, and a broad range of research questions on different levels of inquiry. We also foreshadow certain philosophical and conceptual implications for IS research pertaining to the more speculative phenomena of "living with artificial humans."

Our work is significant, because natural face technologies are currently being developed by a number of commercial entities in the gaming, entertainment, and technology sectors, as well as by a range of IT-focused academic groups and institutions globally. There is good reason to believe that a wider roll-out of these technologies is imminent. The IS field is thus presented with the opportunity to engage with this technology early and to play an active role in influencing its application in practice. We offer our insights and conceptualizations as an initial building block for creating a sound foundation for future research into natural face technology.

We look forward to a wide range of research that is diverse in content, perspectives, methods, and stakeholders affected. We envision research on visual cognitive agents to bring together existing behavioral and design science, with NeuroIS scholars and cognitive learning theorists helping to develop new theories and insights. Such research is likely to also involve intra- and interdisciplinary topics outside of the standard IS scope, as many of these human qualities, when simulated, touch on a wide range of practical, theoretical, philosophical, and ethical issues. We envision that such research, early in the process of technological diffusion, will be relevant to subject matter experts, such as user experience designers, educators, marketers, and others who wish to effectively create and understand new, emotionally engaging forms of human-machine interaction.

## References


Adachi, I., Chou, D. P., & Hampton, R. R. (2009). Thatcher effect in monkeys demonstrates conservation of face perception across primates. *Current Biology*, *19*(15), 1270–1273.

Andrade, A., Urquhart, C., & Arthanari, T. (2015). Seeing for understanding: Unlocking the potential of visual research in information systems. *Journal of the Association for Information Systems*, *16*(8), 646–673.

Butler, M., & Joschko, L. (2009). Final fantasy or the incredibles. *Animation studies* [1998] (pp. 55–63). Retrieved from http://journal. animationstudies.org/matthew-butler-lucie-joschko-final-fantasy-or-the-incredibles/

Chan, T.-W. (1989). *Learning companion systems* (Doctoral dissertation). University of Illinois at Urbana-Champaign, Urbana, IL.

Chartrand, T., & Bargh, J. (1999). The chameleon effect. *Journal of Personality and Social Psychology*, *76*(6), 893–910.

Debevec, P., Hawkins, T., Tchou, C., Duiker, H., Sagar, M., & Sarokin, W. (2000). Acquiring the reflectance field of a human face. *Proceedings of ACM Siggraph 2000* (pp. 145–156). ACM.

di Pellegrino, G., Fadiga, L., Fogassi, L., Gallese, V., & Rizzolatti, G. (1992). Understanding motor events: A neurophysiological study. *Experimental Brain Research*, *91*(1), 176–180.

Dimoka, A., Pavlou, P., & Davis, F. D. (2011). Neuro IS: The potential of cognitive neuroscience for information systems research. *Information Systems Research*, *22*(4), 687–702.

Dinstein I., Hasson U., Rubin N., & Heeger D. J. (2007) Brain areas selective for both observed and executed movements *Journal of Neurophysiology, 98*(3) 1415–1427

Dreyfus, H. (1991). *Being-in-the-World: A commentary on Heidegger's "Being and Time," Division 1. Sein*. Cambridge: Massachusetts Institute of Technology Press.

Ekman, P. (1992). Facial expressions of emotion: An old controversy and new findings. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *335*(1273), 63–69.

Gothard, K. M. (2014). The amygdalo-motor pathways and the control of facial expressions. *Frontiers in Neuroscience*, *8*(8), 1–7.

Gregor, S., & Jones, D. (2007). The Anatomy of a design science theory. *Journal of the Association for Information Systems*, *8*(5), 312–335.

Han, S., Jiang, Y., Humphreys, G. W., Zhou, T., & Cai, P. (2005). Distinct neural substrates for the perception of real and virtual visual worlds. *NeuroImage*, *24*(3), 928–935.

Heidegger, M. (1962). *Being and time*. Trans. J. Macquarie & E. Robinson. New York, NY: Harper

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS Quarterly*, *28*(1), 75–105.

Ho, C.-C., & MacDorman, K. F. (2010). Revisiting the uncanny valley theory: Developing and validating an alternative to the Godspeed indices. *Computers in Human Behavior*, *26*(6), 1508–1518.

Kawaguchi, J. (2011, March 10). Robocon founder Dr. Masahiro Mori. *Japan Times*. Retrieved from https://www.japantimes.co.jp/life/2011/03/10/people/robocon-founder-dr-masahiro-mori/#.W7awFWhKhhE

Keysers C., Gazzola V. (2008) Unifying social cognition. In J. A. Pineda (Ed.), *Mirror neuron systems* (pp. 1-35). London: Humana.

Kilner, J. M., & Lemon, R. N. (2013). What we know currently about mirror neurons. *Current Biology*, *23*(23), R1057–R1062.

Klehm, O., Rousselle, F., Papas, M., Bradley, D., Hery, C., Bickel, B., . . . Beeler, T. (2015). Recent advances in facial appearance capture. *Computer Graphics Forum*, *34*(2), 709–733.

Kleinsmith, A., Rivera-Gutierrez, D., Finney, G., Cendan, J., & Lok, B. (2015). Understanding empathy training with virtual patients. *Computers in Human Behavior*, *52*, 151–158.

Koda, T., & Maes, P. (1996). Agents with faces: The effect of personification. *Proceedings of the 5th IEEE International Workshop on Robot and Human Communication* (pp. 189–194). IEEE.

Krackhardt, D. (1992).The Strength of Strong Ties: The Importance of Philos in Organizations. In N. Nohria & D. Eccles (Eds.), *Networks and organizations: Structure, form, and action* (pp. 216–239). Boston, MA: Harvard Business School Press.

Kramer, R., & Tyler, T. (1996). *Trust in organizations: Frontiers of theory and research*. Thousand Oaks, California: SAGE.

Kuechler, B., & Vaishnavi, V. (2008). Theory development in design science research: Anatomy of a research project. *European Journal of Information Systems, 17*(5) 489–504.

HereLee, K. M., & Nass, C. (2003). Designing social presence of social actors in human computer interaction. *Proceedings of the Conference on Human Factors in Computing Systems* (pp. 289–296). ACM.

MacDorman, K. F. (2006, July). Subjective ratings of robot video clips for human likeness, familiarity, and eeriness: An exploration of the uncanny valley. *Proceedings of ICCS/CogSci-2006 Long Symposium: Toward Social Mechanisms of Android Science* (pp. 26–29). ICCS.

MacDorman, K. F., & Entezari, S. O. (2015). Individual differences predict sensitivity to the uncanny valley. *Interaction Studies*, *16*(2), 1–47.

MacDorman, K. F., Green, R. D., Ho, C.-C., & Koch, C. T. (2009). Too real for comfort? Uncanny responses to computer generated faces. *Computers in Human Behavior*, *25*(3), 695–710.

MacDorman, K. F., Srinivas, P., & Patel, H. (2013). The uncanny valley does not interfere with level 1 visual perspective taking. *Computers in Human Behavior*, *29*(4), 1671–1685.

McDonnell, R., & Breidt, M. (2010). Face Reality : Investigating the uncanny valley for virtual faces. In *ACM SIGGRAPH ASIA 2010 Sketches.* Retrieved from http://www.kyb.mpg.de/fileadmin/user_upload/files/publications/attachments/SiggraphAsia2010-McDonnell_6820%5b0%5d.pdf

McDonnell, R., Breidt, M., & Bülthoff, H. H. (2012). Render me real? *ACM Transactions on Graphics*, *31*(4), 1–11.

Melo, C. M. De, & Gratch, J. (2011). Beyond believability : Quantifying the differences between real and virtual humans, *Proceedings of International Conference on Intelligent Virtual Agents*, (pp. 109–118). Springer.

Meng, M., Cherian, T., Singal, G., & Sinha, P. (2012). Lateralization of face processing in the human brain. *Proceedings of the Royal Society B: Biological sciences*, *279*(1735), 2052–2061.

Mori, M., Kageki, N., & MacDorman, K. F. (2012, June). The uncanny valley. *IEEE Robotics & Automation Magazine*, 98–100.

Nass, C., & Yen, C. (2010). *The man who lied to his laptop: what we can learn about ourselves from our machines*. New York, NY: Penguin.

Now we're talking: How voice technology is transforming computing. (2017, January 7). *The Economist*. Retrieved from https://www.economist.com/leaders/2017/01/07/how-voice-technology-is-transforming-computing

Ogi, T., Yamada, T., Tamagawa, K., Kano, M., & Hirose, M. (2001). Immersive telecommunication using stereo video avatar. *Proceedings IEEE Virtual Reality* (pp. 45–51). IEEE.

Orlikowski, W. J. (2007). Sociomaterial practices: Exploring technology at work. *Organization Studies*, *28*(9), 1435–1448.

Orlikowski, W. J., & Scott, S. V. (2008). Sociomateriality: Challenging the separation of technology, work and organization. *The Academy of Management Annals*, *2*(1), 433–474.

Paredes, D (2018, October). The insider's guide to the making of a digital assistant. *CIO.* Retrieved from https://www.cio.co.nz/article/647897/theres-never-enough-time-the-insiders-guide-to-the-making-of-a-digital-assistant/

Pfeffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of Management Information Systems*, *24*(3), 45–77.

Picard, R. W. (2003). Affective computing: Challenges. *International Journal of Human-Computer Studies*, *59*(1–2), 55–64.

Picard, R. W. (2010). Emotion research by the people, for the people. *Emotion Review*, *2*(3), 250–254.

Pollick, F. E. (2010). In search of the uncanny valley. *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering*, *40*, 69–78.

Reeves, B., & Nass, C. (1996). *The media equation: How people treat computers, television, and new media*. Stanford, CA: Center for the Study of Language and Information.

Riedl, R., Davis, F. D., & Hevner, A. R. (2014). Towards a NeuroIS research methodology : Intensifying the discussion on methods. *Journal of the Association for Information Systems*, *15*(10), 1–35.

Riemer, K., & Johnston, R. B. (2014). Rethinking the place of the artefact in IS using Heidegger's analysis of equipment. *European Journal of Information Systems*, *23*, 273–288.

Riva, G. (2009). Is presence a technology issue? Some insights from cognitive sciences. *Virtual Reality, 13*, 159–169.

Rizzo, A., Cukor, J., Gerardi, M., Alley, S., Reist, C., Roy, M., … Difede, J. (2015). Virtual reality exposure for PTSD due to military combat and terrorist attacks. *Journal of Contemporary Psychotherapy*. *45*(4), 255–264.

Rizzo, A., Scherer, S., Devault, D., . . . Artstein, R. (2016). Detection and computational analysis of psychological signals using a virtual human interviewing agent. *Journal of Pain Management Special issue: Using virtual reality technologies to support, 9*(3), 311–321.

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience, 27(1)*, 169–192.

Sagar, M., Bullivant, D., Efimov, O., Jawed, M., Kalarot, R., Robertson, P., & Wu, T. (2014). Embodying models of expressive behaviour and learning with a biomimetic virtual infant. *4th International Conference on Development and Learning and on Epigenetic Robotics* 62–67. IEEE.

Sagar, M., Seymour, M., & Henderson, A. (2016). Creating connection with autonomous facial animation. *Communications of the ACM*, *59*(12), 82–91.

Schultze, U. (2010). Embodiment and presence in virtual worlds: A review. *Journal of Information Technology*, *25*(4), 434–449.

Seymour, M. (2013, November 25). The art of digital faces at ICT: From digital Emily to digital Ira. *fxguide.* Retrieved from https://www.fxguide.com/featured/the-art-of-digital-faces-at-ict-from-digital-emily-to-digital-ira/

Seymour, M. (2017, April 6). Conversational agents with Cate Blanchett: the expanding world of “film tech” to agents. *fxguide.* Retrieved from https://www.fxguide.com/featured/conversation-agents-with-cate-blanchett-the-expanding-world-of-film-face-tech-to-agents/

Spinosa, C., Flores, F., & Dreyus, H. L. (1997). *Disclosing New Worlds*. Boston: Massachusetts Institute of Technology Press.

Sproull, L., Subramai, M., Kiesler, S., Walker, J. H., & Waters, K. (1996). When the interface is a face. *Human-Computer Interaction*, *11*(2), 97–124.

Straub, D. W. (2009). Editor’s comments. *MIS Quarterly*, *33*(3), iii–x.

Tinwell, A. (2009). Uncanny as usability obstacle. *Proceedings of 3td International Conference, Online Communities and Social Computing* (pp. 622–631). Springer. Retrieved from http://link.springer.com /chapter/10.1007/978-3-642-02774-1_67

Tinwell, A., Abdel, D., & Charlton, J. P. (2013). Computers in human behavior perception of psychopathy and the uncanny valley in virtual characters. *Computers in Human Behavior*, *29*(4), 1617–1625.

Tinwell, A., Grimshaw, M., Nabi, D. A., & Williams, A. (2011a). Facial expression of emotion and perception of the uncanny valley in virtual characters. *Computers in Human Behavior*, *27*, 741–749.

## About the Authors

**Mike Seymour** is a researcher and lecturer in the Discipline of Business Information Systems at the University of Sydney Business School. He has previously had extensive industry experience in the film and television industries in the area of visual effects. He is an AFI winner and Emmy nominated in Visual Effects. Mike has extensive experience with industry-engaged research. He is cofounder of the VFX Industry web site fxguide. Mike leads the Motus Lab at the University of Sydney exploring advanced human computer interaction (HCI) solutions and applications. He is a member of the Digital Disruption Research Group (DDRG). Mike's expertise and research interests cover the areas of HCI, digital humans, machine learning, virtual production and the societal implications of digital humans.

**Kai Riemer** is a professor of information technology and organisation in the Discipline of Business Information Systems at the University of Sydney Business School. He has held previous positions with Münster University, The University of Melbourne and University College Dublin. Kai has extensive experience with industry-funded research and leads a Linkage project initiative on the management of disruptive technologies, sponsored by the Australian Research Council. He is the founder and leader of the Digital Disruption Research Group (DDRG) and convener of DISRUPT.SYDNEY$^{TM}$. Kai's expertise and research interests cover the areas of social networking, technology appropriation, enterprise 2.0, virtual work, digital disruption and the philosophy of technology. His research follows practice theoretical and nonorthodox approaches and has appeared in journals such as *MISQ Quarterly, European Journal of Information Systems, Journal of Information Technology, International Journal of Electronic Commerce,* and *Communications of the Association for Information Systems*. Kai is a board member of the *Journal of Information Technology*, *Electronic Markets*, and the *Business and Information Systems Engineering Journal*.

**Judy Kay** is a professor of computer science at the University of Sydney where she leads the multidisciplinary Human Centred Technology Research Cluster. Her research aims to create new technologies for human computer interaction (HCI), notably the infrastructures and tools needed for personalization, particularly to support lifelong, life-wide learning. This goal has driven the design of user-modeling systems so that people can control their personal data and its use in intelligent systems. She has also explored various ways of harvesting data from diverse sensors so that people can see useful forms of information about themselves to support reflection, self-monitoring and planning. Her research has been commercialized and deployed and she has extensive publications in leading venues for research in user modeling, AIED, human-computer interaction, and ubiquitous computing. She is editor in chief of the *International Journal of Artificial Intelligence in Education* and editor of *Interactive Mobile Wearable and Ubiquitous Technology*.