

THE EYES HAVE IT

The impact of eye gazing by a virtual person on energy consumption behavior

Ruud Mattheij

236113

HAIT Master Thesis series nr. 11-003

THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS IN COMMUNICATION AND INFORMATION SCIENCES,
MASTER TRACK HUMAN ASPECTS OF INFORMATION TECHNOLOGY,
AT THE FACULTY OF HUMANITIES
OF TILBURG UNIVERSITY

Thesis committee:
Prof. dr. E.O. Postma
Dr. Ir. P.H.M. Spronck

Tilburg University
Faculty of Humanities
Department of Communication and Information Sciences
Tilburg center for Cognition and Communication (TiCC)
Tilburg, The Netherlands
June 2011

PREFACE

"The most important thing in communication is hearing what isn't said."

Peter F. Drucker

Finishing this thesis marks the end of two years of education at Tilburg University. I decided to study the Human Aspects of Information Technology Master's program in order to learn new ways to bridge the gap between humans and computers. The subject of this thesis is the use of technology in order to persuade people to exhibit energy-saving behavior. The research is truly interdisciplinary as it combines elements of three closely-related fields of research: artificial intelligence, communication sciences, and psychology. Two experiments are performed. In the first experiment, a virtual person eye gazes at a human person moving in front of a screen. The gazing represents a social signal that may be perceived by the person and induce a feeling of "being watched". In the second experiment, the effectiveness of the social signal to affect energy-consumption behavior is evaluated in a realistic experimental setting; the Smart Home located near the Evoluon in Eindhoven.

I wish to express my gratitude to the following people for their aid and guidance during my thesis. First, I would like to thank prof. dr. Eric Postma. Eric, thank you for your support, your positive approach and your (by now) famous one-liners; "And Ruud, is there still hope? Well remember, there is always hope" always made my day. Second, I would like to thank dr. ir. Pieter Spronck for his thorough review of my thesis.

I would also like to thank my colleagues of the EOS project group: prof. dr. Cees Midden, dr. Jaap Ham, Peter Ruijten MSc. and Maaïke Roubroeks MSc. of the Human-Technologic Interaction department of Eindhoven University of Technology. Likewise, I would like to thank dr. ir. Ad van Berlo, Peter Brils and Richard Pasmans of Smart Homes in Eindhoven for their assistance and for allowing me to use their Smart Home for my experiments. Peter, I hope that the surplus hair gel serves you well...

I would also like to express my gratitude to Roland van Straten and Tycho Menting of Betronic for providing us with the water-flow sensors that enabled us to do our experiments. Bart Joosten, I hope that I can help you just as well in the next four years as you helped me during my writing phase. Maarten van Gompel is acknowledged for helping me out during the experiments.

Last, but certainly not least, I would like to thank my family and my girlfriend for their support during the stressful moments. Sjef, Irene, Paul, Jeanne & Susan: thank you.

Ruud, June 2011

SUMMARY

During the last decades, many attempts have been made to address the limits of the natural energy resources. These attempts were accompanied by scientific studies investigating ways to change the attitude of individuals towards energy consumption. As reducing energy consumption starts at the household, these studies often focused on presenting household members with factual information about energy consumption. Although this led to an increased awareness about the scarcity of resources, it did not lead to an actual change in behavior.

Behavioral scientists found that presenting individuals with *personalized* feedback about their own energy consumption is more effective than presenting individuals with general feedback. The effectiveness of personalized feedback is enhanced if two conditions are met: (1) the feedback should be non-obtrusive and (2) the feedback should be humanlike.

This thesis investigates the effect of personalized feedback that satisfies these two conditions: virtually generated humanlike nonverbal signals on the energy consumption behavior of household members. The following two research questions are addressed: (1) *Is it possible to develop a system that automatically gazes at a participant moving in front of the screen?*, and (2) *To what extent is it possible to influence the energy consumption of participants by exposing them to human-like nonverbal cues?*

To answer these questions, we developed and evaluated the Virtual Eye Controller (VEC) system. The system describes a feedback-cycle between a person's energy consuming behavior and the personal feedback the person receives as a result of that behavior. The VEC system is implemented as a virtual, humanlike person that gazes at people in front of a computer screen using a face detector that detects and tracks a person's eyes. The VEC system also generates a negative emotional expression of the virtual person in response to excess energy consumption.

Two experiments have been performed. In the first experiment, the face detector is evaluated and in the second experiment the VEC system's ability to influence the energy consumption behavior of participants is determined.

The results of the evaluation of the face detector revealed it to be robust against lighting variations and able to follow participants in a large region in front of the screen. The results of the evaluation of the VEC system revealed that nonverbal cues generated seem to decrease the energy consumption behavior of participants. From these results, we answer our two research questions by concluding that (1) it is possible to develop a system that automatically gazes at persons, and (2) that it may be possible to influence the energy-consumption behavior by social signals, although further research is required.

CONTENTS

- Preface..... 2
- SUMMARY 3
- Introduction..... 6
 - 1.1 Background..... 6
 - 1.2 Research questions..... 8
 - 1.3 Research approach 8
 - 1.4 Thesis outline..... 8
- The VEC system 10
 - 2.1 Overview of the VEC system 10
 - 2.1.1 The sensory component 11
 - 2.1.2 The presentation component..... 11
 - 2.2 Implementation of the VEC system..... 12
 - 2.2.1 The face detector 12
 - 2.2.2 The energy-consumption sensors 14
 - 2.2.3 The virtual person..... 15
- Experimental set-up 17
 - 3.1 Experimental set-up of the face detector evaluation 17
 - 3.2 Experimental set-up of the VEC system evaluation 18
 - 3.2.1 Participants..... 19
 - 3.2.2 Apparatus, stimulus and experimental environment 19
 - 3.2.3 Procedure 20
 - 3.2.4 Design 21
- Results 22
 - 4.1 Results of the face detector evaluation 22
 - 4.2 Results of the VEC system evaluation 23
- Discussion 26

5.1 The effectiveness of social signals.....	26
5.1.1 Validity of the experiment.....	26
5.1.2 Conscious versus unconscious operation of social signals.....	27
5.2 Points of improvement.....	27
5.2.1 Improvement of the VEC system.....	27
5.2.2 Improvement of the empirical investigation.....	28
Conclusions.....	29
References.....	30
Appendix A	33

Chapter 1

INTRODUCTION

"The energy crisis has not yet overwhelmed us, but it will if we do not act quickly. Our decision about energy will test the character of the American people and the ability of the President and the Congress to govern this nation. This difficult effort will be the 'moral equivalent of war', except that we will be uniting our efforts to build and not to destroy"

Jimmy Carter

1.1 Background

Carter's speech (1982) was one of the many attempts in the last few decades to address the limits of the natural energy resources (see, e.g., King & Schneider, 1993; Gore, 2006). These attempts were accompanied by scientific studies investigating ways to change the attitude of individuals towards energy consumption.

As reducing energy consumption starts at the household, these early studies presented household members with facts and figures about energy consumption. The implicit assumption was that this made them aware of the need to voluntarily change their energy-consumption behavior. The results of more recent studies indicated this assumption to be false: presenting general information leads to an increased awareness of the individual household members about the scarcity of resources, but it does not lead to an actual change in behavior (see, e.g., Abrahamse, Steg, Vlek & Rothengatter, 2005).

The importance of personalized feedback to change energy consumption behavior

Inspired by earlier findings (Midden, Meter, Weenig & Zieverink, 1983), recent studies adopt a more promising approach to change the energy consumption behavior of household members by providing them with personalized feedback (see, e.g. Vossen, Ham & Midden, 2009). Presenting individuals with personalized feedback about their own energy consumption is more effective than presenting individuals with general information (Midden, Meter, Weenig & Zieverink, 1983). The effectiveness of personalized feedback is enhanced if two conditions are met: (1) the feedback should be non-obtrusive and (2) the feedback should be humanlike. In what follows, we describe these conditions in more detail.

Two conditions to enhance personalized feedback to change energy consumption behavior

The condition of non-obtrusiveness is due to Brehm (1966). If personal feedback is experienced to be obtrusive, it may be regarded as an intrusion to the individual's autonomy. In case of personalized feedback on energy consumption, this may give rise to an increase in energy consumption, rather than a decrease. For instance, if members of a household are confronted obtrusively with feedback about, for instance, the fact that they are leaving the light on for a too long period, the resulting frustration may give rise to the behavior of not switching the light off to "show who is in charge". This effect is known as "psychological reactance" (Brehm, 1966). The condition of non-obtrusiveness can be met when providing individual feedback in a more subtle manner (Ham, Midden & Beute, 2009; Roubroeks, Midden & Ham, 2009). For example: Backlund et al. (2006) provided non-obtrusive individual feedback to their participants by using heat-sensitive tiles that were painted with a thermo-chromic ink. The tiles react to heat and fade away to reflect splashes and intensities of hot-water use; the longer the shower, the less decoration will be visible on the tiles. The disappearing patterns on the tiles therefore provide a subtle indication of the duration and amount of water consumption during a shower.

The condition of humanlike feedback follows from a recent study by André et al. (2011). This study showed that social virtual agents aiming to persuade people should appear credible, trustworthy, confident and non-threatening towards people in order to establish and maintain persuasive interaction. These results extend an earlier study by Bateson, Nettle & Roberts (2006) that showed that images of human-like eyes positively affect the cooperation of experimental subjects. In this study, Bateson et al. (2006) examined the effect of an image of a pair of eyes on contributions to an honesty box used to collect money for drinks in a university coffee room. The results showed that people had paid three times as much for their drinks when eyes were displayed rather than a control image. The evidence provides an indication of the importance of the cues of being watched on human cooperative behavior.

The condition of humanlike feedback can be met by employing a real human or a virtual personality or avatar. For practical reasons, the latter option is to be preferred.

Our approach and related work

To meet the two conditions to enhance the effectiveness of personalized feedback, we propose a personalized feedback system called the Virtual Eye Controller (VEC) system, featuring an eye-gazing and emotionally responsive virtual personality. The system meets the condition of non-obtrusiveness by communicating through non-verbal expressions (eye gazing and facial expression), only. It meets the condition of human-like feedback by using a virtual person with a humanoid appearance.

The development of the VEC system was inspired by the persuasive effect of eyes (Bateson et al., 2006). Our aim is to study to what extent the VEC system is capable of persuading the members of a household to lower their energy consumption. To be able to perform such a study, the VEC system controls the gaze direction of a virtual person so that it follows persons with its gaze. The VEC system also controls the virtual person's facial expressions to respond to their energy consumption.

Our VEC system is related to studies in which face-tracking systems are used to establish an interaction with humans (Wren, Azarbajani, Darrell & Pentland, 1997; Darrell, Gordon, Woodfill & Harville, 1998; Valenti & Gevers, 2008).

Wren et al. (1997) developed a system for tracking and interpreting people. This system runs on a standard computer and is able to track people in many different physical locations. It uses a statistical model of color and shape to obtain a two dimensional representation of a person's head

and hands. This system differs from our approach, as it needs to study the better part of a person's body in order to establish the representation. Our system, however, is able to pinpoint a person's location by solely detecting the location of the person's face region.

Darrell et al. (1998) describe a virtual mirror interface that reacts to people using real-time face tracking. Their display combines stereo, color and grey-scale pattern matching modules into a single real-time system, thereby ensuring a robust performance. This system requires a relatively complex two camera set-up to ensure the stereo pattern matching, while our system is able to recognize faces by using a single camera.

Valenti et al. (2008) developed a face detection algorithm for accurate eye location. This system is robust against changes in illumination and the person's pose. As this system is able to effectively determine a person's face region while using a single camera, we used this system as the basis for the VEC system's implementation.

Lee & Park (2009) described a gaze estimation method based on a three dimensional analysis of the human eye. This method creates a virtual eyeball model that is based on the characteristics of the human eyeball. The position of the virtual eyeball is then calculated using a camera and three collimated infrared LEDs. This approach differs from our approach due to its relative complex setup with a camera and multiple LEDs, while our approach uses a single webcam.

1.2 Research questions

This study investigates the effect of virtually generated human-like nonverbal signals, such as eye-gazing and frowning, on the energy consumption behavior of household members, leading to the following two research questions:

- 1) Is it possible to develop a system that automatically gazes at a participant moving in front of the screen?
- 2) To what extent is it possible to influence the energy consumption of participants by exposing them to humanlike nonverbal cues?

In the following subsection we describe how the research questions are addressed.

1.3 Research approach

We address the research questions by evaluating the eye-gazing component of the VEC system (research question 1) and by evaluating the effectiveness of the VEC system on modifying energy-consumption behavior (research question 2). The evaluation of the eye-gazing component is performed under various lighting conditions to assess the robustness of tracking. The evaluation of the effectiveness of the VEC system is studied in a realistic domestic environment.

1.4 Thesis outline

The outline of the remainder of the thesis is as follows. Chapter 2 describes the model of the VEC system and its two components: (i) the sensory component, and (ii) the presentation component. Chapter 2 also describes our implementation of the VEC system. Following the implementation,

Chapter 3 describes the experimental methods employed to evaluate the eye-gazing component of the VEC system and the VEC system in the domestic context. The results of these evaluations are presented in Chapter 4, while Chapter 5 discusses the implications of the results. Finally, Chapter 6 presents the conclusions of the discussion on the robustness of the face detector and the VEC system's ability to modify behavior. Chapter 6 also presents the possibilities for future research.

Chapter 2

THE VEC SYSTEM

This chapter presents the Virtual Eye Controller (VEC) system that will be used in our empirical studies. The VEC system establishes a feedback-cycle by determining the location and energy consumption of a person and by generating nonverbal feedback (social signals) to that person. Section 2.1 gives an overview of the VEC system and its two components. Section 2.2 provides the implementation details of the components.

2.1 Overview of the VEC system

The VEC system consists of two main components: (I) the sensory component and (II) the presentation component. These components interact with a person to establish a feedback-cycle by sensing behavioral information (sensory component) and by generating nonverbal expressions (presentation component). The person senses the expressions generated by the presentation component of the VEC system and may respond (e.g., by lowering energy consumption), which is sensed by the sensory component of the VEC system. Figure 1 presents an overview of the VEC system. The two rectangular gray areas represent the sensory component (bottom) and the presentation component (right). The black disk represents the person. The arrows represent information flows between the person and the VEC system and between the two components of the VEC system.

The sensory component collects two types of information: the person's location and energy-consumption behavior. Both types of information provide input to the presentation component featuring a virtual person that generates two types of nonverbal behavior: eye-gazing and facial expression. The location information is used to establish and to maintain eye-gaze to the person and an excess of energy consumption leads to a negative facial expression of the virtual person. Below, we describe the sensory component and presentation component in more detail.

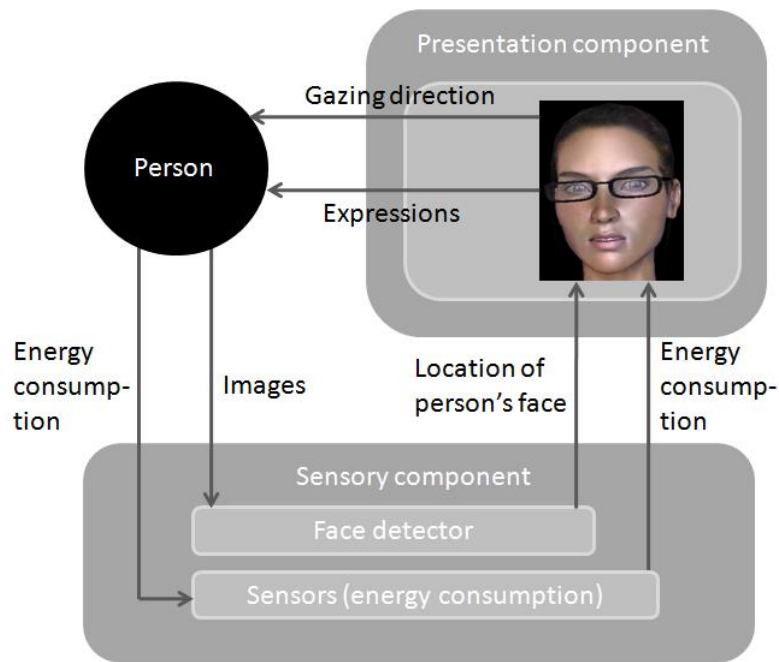


Figure 1: Schematic representation of the VEC system: the sensory component uses two sensors to measure a person’s energy consumption. The energy-consumption measurements are sent to the presentation component. In addition, the sensory component detects the location of the person’s eyes and sends this location to the presentation component. The presentation component then translates the energy-consumption measurements and location information into a facial expression and a gazing direction, respectively.

2.1.1 The sensory component

The sensory component of the VEC system consists of two subcomponents: a face detector and energy-consumption sensors.

The first subcomponent, the face detector determines the location of a person’s eyes in a stream of images or a video sequence by using a face detector, featuring an eye detector. More specifically, in order to create a realistic eye gazing, the face detector determines the locations of both eyes of a person, as this enables the virtual person to look the human person directly in the eyes. Determining the locations of the eyes occurs in two steps. In the first step, the image region containing the face is detected. In the second step, the locations of the eyes within the facial image region are detected. After detecting the locations of the eyes, the location of the midpoint of the line connecting both eye locations is computed. The sensory component sends this location to the presentation component.

The second subcomponent, the energy-consumption sensors, measure the amount of energy that is consumed by a person. More specifically, the VEC system used in our experiment includes two water-flow sensors. The energy-consumption information picked up by the sensors is sent to the presentation component.

2.1.2 The presentation component

The presentation component takes the coordinates outputted by the sensory module and renders a dynamic realistic humanlike face. To enhance realism, the face makes small movements, characteristic of real human faces. The presentation component uses the location information generated by the face detector to ensure that the face gazes in the appropriate direction. In addition, the presentation component translates the energy-consumption information provided by the energy-

consumption sensors into expressional feedback. If the energy consumption exceeds pre-defined thresholds, the presentation component renders the virtual person with increasingly negative expressions (i.e., sad and angry).

2.2 Implementation of the VEC system

We implemented the VEC system as a C# application that runs on a Windows platform. Section 2.2.1 describes the implementation of the face detector, and Sections 2.2.2 and 2.2.3 describe the sensors and the virtual person, respectively.

2.2.1 The face detector

The VEC system's sensory component detects and tracks a person's face region using a webcam and a face detector algorithm. In our implementation, we use a Logitech QuickCam Orbit AF. This webcam sends a stream of images to the face detector, which is used to determine the location of the person's face region. We implemented the face detector proposed by Valenti and Gevers (2008) using their EyeAPI eye detection application, that is publicly available¹. The EyeAPI application incorporates the Viola-Jones face detector (Viola & Jones, 2001) and the eye detector of Valenti and Gevers (2008). The EyeAPI application returns the coordinates of a person's eyes, as the person moves in front of the webcam. Figure 2 shows an example of the detection of the eyes in a face image using the EyeAPI application. The square box indicates the region detected by the Viola-Jones detector and the disks superimposed on the eyes are centered at the returned coordinates. Below, we discuss the Viola-Jones detector and the eye-detector in more detail.



Figure 2: An example of the detection of the eyes in a face image using the EyeAPI application (Valenti & Gevers, 2008).

The Viola-Jones detector

The Viola-Jones detector scans the input image for the potential presence of a face by means of a sliding window of a small size (i.e., 24×24 pixels). At each window position, the face detector extracts a large number of image features, a small fraction of which is relevant for the detection of faces (Viola & Jones, 2001; Mita, Kaneko, & Hori, 2005; Bergboer, 2007; Croon, 2008).

To select from the large number of image features those few that are relevant for the detection of faces, Viola and Jones employ the AdaBoost machine learning algorithm (Freund & Schapire, 1999).

¹ See: <http://staff.science.uva.nl/~rvalenti/>

AdaBoost creates a cascade of feature selectors. This cascade allows features irrelevant to the task of face detection to be quickly discarded. Given an image containing one or more faces, the Viola Jones face detector returns the coordinates of one or more image regions containing faces. In combination with the OpenCV library (Bradski & Kaehler, 2008), the Viola-Jones detector achieves real-time face detection speed.

The eye detector of Valenti and Gevers

Valenti and Gevers (2008) developed a method that localizes the eyes within the face regions returned by the Viola-Jones detector. Before giving a formal description of their eye detector, we explain the underlying ideas in a qualitative manner.

The key idea underlying their eye detector relies on the fact that eyes are radially symmetric brightness patterns. Given an image of a face, the eye detector computes the image's *isophote curvature* to determine the center of circular patterns. Isophotes are never intersecting curves connecting points of equal intensity in an image. The notion of isophote curvature refers to the curvature of curves connecting points (pixels) of equal intensity.

Figure 3a shows an example of an image. Applying an edge detector, such as Canny's edge detector, yields closed contours separating the black circular objects from the white background. Figure 3b illustrates the two closed contours which are colored in shades of black and white against the gray background. The shading of the contour represents the isophote curvature ranging from negative (black) to positive (white). The isophote curvature relates directly to the orientations of the vectors normal to the contour. Figure 3c shows these vectors, called the *displacement vectors*. The intersection point of all the displacement vectors corresponds to the center of the circle. Applied to images of faces, the isophote curvature of the eyes gives rise to reliable estimates of the center of the eyes.

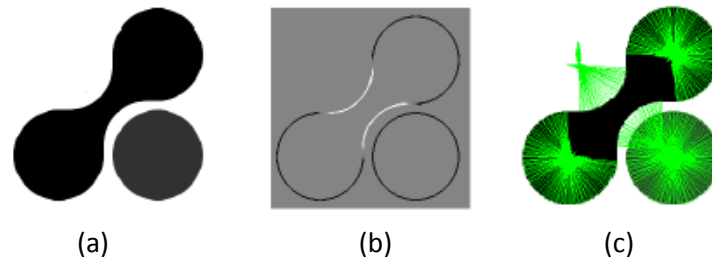


Figure 3: (a) An example of an image, (b) its isophote curvatures, and (c) the displacement vectors to the isophote centers (reproduced from Valenti and Gevers, 2008).

We now turn to a formal description of the eye localization method proposed by Valenti and Gevers (2008). The isophotes can be computed using *intrinsic geometry*, i.e. geometry with a locally defined coordinate system. In every point of the image, a local two-dimensional coordinate frame is defined in such a way that one axis points in the direction of the maximal change of the intensity, which corresponds to the direction of the gradient and the other points in the direction of points of equal intensity (isophotes). This coordinate frame $\{v, w\}$ is referred to as the gauge coordinates. Its frame vectors \hat{v} and \hat{w} are defined as:

$$\hat{w} = \frac{\{L_x, L_y\}}{\sqrt{L_x^2 + L_y^2}}; \hat{v} = \perp \hat{w}; \quad (1)$$

In this equation, L_x and L_y

represent the first order

derivatives of the luminance function $L(x, y)$ in the x and y dimension. A derivative in the w direction is the gradient itself, and the derivative in the v direction (perpendicular to the gradient) is 0 (no intensity change along the isophote).

The isophote curvature (κ) is defined by:

$$\kappa = -\frac{L_{vv}}{L_w}. \quad (2)$$

Where L_{vv} refers to the second-order derivative of the luminance function with respect to v . In Cartesian coordinates, the equation of the isophote curvature is rewritten as:

$$\kappa = -\frac{L_y^2 L_{xx} - 2L_x L_{xy} L_y + L_x^2 L_{yy}}{(L_x^2 + L_y^2)^{3/2}}. \quad (3)$$

Using the fact that the eyes are circular, the displacement vectors $D(x,y)$ can be computed from the isophote curvature:

$$\begin{aligned} D(x, y) &= \frac{\{L_x, L_y\}}{L_w} \left(-\frac{L_w}{L_{vv}} \right) = -\frac{\{L_x, L_y\}}{L_{vv}} \\ &= -\frac{\{L_x, L_y\}(L_x^2 + L_y^2)}{L_y^2 L_{xx} - 2L_x L_{xy} L_y + L_x^2 L_{yy}}. \end{aligned} \quad (4)$$

The intersection of all displacement vectors along the circular contour defines the center point.

Face and eye detector

The calculations of the combined face and eye detector (the EyeAPI) result in four coordinates, i.e., the horizontal and vertical coordinates of both eyes. The sensory component uses these coordinates to calculate the average vertical coordinate and an average horizontal coordinate of the eyes. These coordinates are then forwarded to the presentation component. This enables the virtual person of the presentation component to focus its gaze at a single location.

2.2.2 The energy-consumption sensors

The sensory component uses two sensors to measure the amount of energy that is consumed by participants: a “cold flow impulse” sensor that measures the cold water consumption and a “hot flow impulse sensor” that measures the hot water consumption. The flow sensors are connected to a so-called Arduino² board. The Arduino board sends the water consumption data to the sensory component through a virtual com port.

In our implementation, a timer starts to count as soon as one of both flow sensors detects a water flow, as this means that a person is consuming water (and therefore energy). If the person’s energy consumption exceeds the primary threshold Θ_1 , the presentation component requires the virtual person to look sad. If the person consumes even more water and thereby exceeds the secondary threshold Θ_2 ($\Theta_2 > \Theta_1$), the virtual person is required to look angry.

² The Arduino board is an open-source electronics prototyping platform; see <http://www.arduino.cc>.

Figure 4 shows an overview of the sensors used in our experiments and their connection to the presentation component. For completeness, the figure also shows the webcam and face detector and its connection to the presentation component.

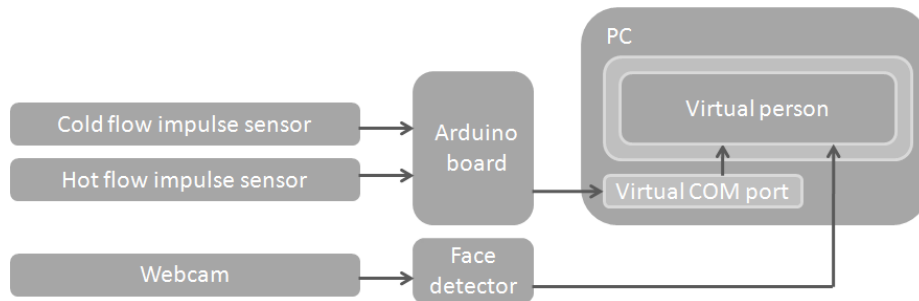


Figure 4: Schematic representation of the implementation of the sensory component: the sensor array uses flow sensors to measure both the hot and cold water flow. The sensor data are processed by an Arduino board and then transferred to the presentation module. The webcam and the face detector are used to locate a person’s face region.

2.2.3 The virtual person

The presentation component receives the energy-consumption data and the coordinates of a participant’s eyes from the face detector in the sensory component (see Figure 4). The presentation component uses these coordinates to determine the expression and the gazing direction of the virtual person

The presentation component uses a realistic three-dimensional female virtual person developed by Haptেক³ to provide nonverbal feedback to participants. Figure 5 shows the virtual person employed in our implementation.

The head and gaze direction of the virtual person are represented on a 3-state discrete scale. The discrete values inherent to the Haptেক software limits the precision of eye gazing, but in practice the resulting gazing errors are not noticeable.

The virtual person in our experimental setup uses three emotional-expression states. The neutral state is the default state. The virtual person is in the neutral state as long as participants’ energy consumption is smaller than the primary threshold Θ_1 . When participants use more water and exceed the primary threshold, the virtual person changes its emotional expression into “broken hearted”. If participants then continue to consume energy and exceed the secondary threshold, the virtual person changes its emotional expression into “angry”. Figure 5 shows the three expressions of the virtual person: (a) neutral, (b) broken hearted, and (c) angry.

³ See www.haptek.com

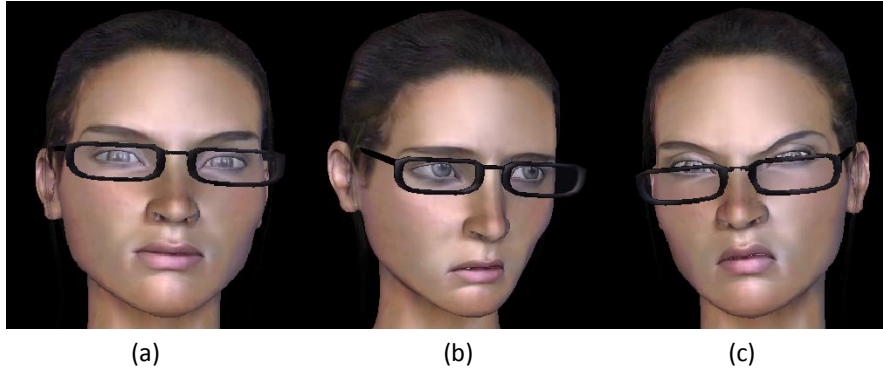


Figure 5: The virtual person used in our implementation includes several facial expressions: (a) a neutral expression, (b) a “broken hearted” expression and (c) an “angry” expression.

Chapter 3

EXPERIMENTAL SET-UP

The aim of our experiments is to assess whether the Virtual Eye Controller (VEC) system is able to influence the energy-consumption behavior of the participants in a realistic setting, a demonstration house called the Smart Home, located in Eindhoven, The Netherlands. The experimental evaluation of the VEC system is twofold. First, an evaluation of the face detector determines the performance of the face detector under variations in lighting conditions, viewing angle, and distance. Second, an evaluation of the entire VEC system in a household setting determines to what extent the system is capable of influencing the energy-consumption behavior of participants. Sections 3.1 and 3.2 describe the experimental set-up of the first and second experiment, respectively.

3.1 Experimental set-up of the face detector evaluation

To evaluate the performance of the face detector of the VEC system under variations in lighting conditions, viewing angle and distance to the experimenter, the experimental set-up was as follows. The experimenter was situated in front of a 15-inch laptop. The screen of the laptop was put in the upright (vertical) position. The top of the screen contained a webcam, built into the laptop. The eyes of the experimenter were positioned at the same level as the webcam. The initial distance between the experimenter and the screen was 60 cm. The initial horizontal angle (α_{hor}) and vertical angle (α_{vert}) of the experimenter with respect to the screen normal were 0 degrees. Figure 6 displays a schematic illustration of (a) a top view and (b) a lateral view of the experimental setting.

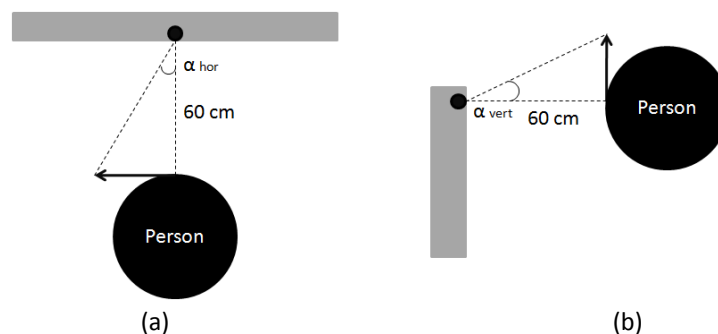


Figure 6: Schematic illustration of the experimental setting showing (a) a top view and (b) a lateral view. The black disk marked “person” represents the experimenter. The black dot in the grey rectangle represents the webcam in the laptop screen. (See text for further details.)

The evaluation of the face detector includes three variations in lighting conditions: artificial illumination, normal daylight and bright sunlight. As artificial illumination, we used the lights at the ceiling (a pair of fluorescent lights), positioned directly above the experimental set-up at a distance of approximately 2 meters; the window blinds were closed. As normal daylight, we used the light coming through the open windows. The room was approximately 5 meters long and 4.5 meters wide. It contained two windows, approximately 1.5 meters high and 3 meters wide. The distance from the windows to the laptop was approximately 3.5 meters. In this condition, all artificial light sources in the room were switched off. In the bright sunlight condition, the lighting was provided by direct sunlight. In this condition, the experiment was performed in the open air.

For all, the evaluation was performed by registering the ability of the face detector to eye gaze at the experimenter. The independent variables in this evaluation were the minimum and maximum distance from the screen (d^{\min} and d^{\max} , respectively) and the maximal horizontal and vertical viewing angles ($\alpha^{\text{vert}}_{\max}$ and $\alpha^{\text{hor}}_{\max}$, respectively), measured for the three types of illumination. All measurements were replicated 5 times.

The face detector uses a webcam integrated in a laptop. The laptop is a HP Pavilion 1160-ed. In order to measure the minimum- and maximum distance to the screen, a measuring tape was attached to the webcam.

To assess the performance, the experimenter moved in three orthogonal directions (left-right and up-down in a place parallel to the screen, and towards-from perpendicular to the screen), up to the point where the face detector lost eye contact. The experimenter started at a distance of 0 cm from the webcam and then increased the distance, while moving in perpendicular directions. The movements made by the experimenter were discrete steps of approximately 5 cm in all directions.

3.2 Experimental set-up of the VEC system evaluation

The aim of the VEC system evaluation was to determine whether the system is able to influence the energy consumption behavior of participants. This was evaluated in an experiment during which participants are requested to perform a task in front of the screen displaying the virtual person. The dependant variable of the task was the water consumption to clean the hands. The energy consumption was measured by sensing the volume of the water used by the participant. There were two conditions: the baseline condition and the experimental condition. In both conditions, the virtual person was visible. The critical difference was twofold: the eye gazing and the presence of a change in expression in response to above-threshold water consumption. In the baseline condition, the virtual person did not eye-gaze at the participant and the expression remained neutral irrespective of the amount of water consumed. In the experimental condition, the virtual person did eye-gaze at the participant and the expression changed from neutral to broken hearted and angry when the two associated thresholds were exceeded. Preceding the main experiment, a pilot experiment was performed. Table 1 summarizes the two conditions.

Condition	Virtual person visible	Gaze follower active	Expressions active
Baseline	Yes	No	No
Experimental	Yes	Yes	Yes

Table 1: Summary of the two conditions in the experiment (baseline and experimental) to determine whether the VEC system is able to influence a person’s energy-consumption behavior.

3.2.1 Participants

For the pilot experiment, we used 2 female participants. Both participants were approximately 1.80 meter tall and were visitors of the Smart Home in Eindhoven.

The main experiment involved 10 participants (6 men, average height: 1.80 meter and 4 women, average height: 1.68 meter). Each condition consisted of 5 participants. The baseline condition consisted of 2 men (average age: 22 years old, average height: 1.76 meter) and 3 women (average age: 31 years old, average height: 1.70 meter), while the experimental condition consisted of 4 men (average age: 34 years old, average height: 1.81 meter) and 1 woman (age: 22, height: 1.61 meter). The participants in the baseline condition and the experimental condition were visitors of the Smart Home and relatives and friends. Friends and relatives were equally divided over both conditions.

3.2.2 Apparatus, stimulus and experimental environment

The VEC system ran on a MSI touch screen computer (MSI AE2010, ATI Radeon 3200 graphics card) in combination with a Logitech QuickCam Orbit AF webcam, connected to the computer with an USB cable. The sensor array was also connected to the computer using an USB cable.

The virtual person is shown full-screen on the computer display, which is positioned on the right of the water tap. The display is within one meter of the water tap. The virtual person used is a female face with glasses (as shown in Figure 5 in the previous chapter).

The settings of the VEC system were optimized for participants to wash their hands. A pilot test was used to determine the water consumption thresholds for the virtual person's emotional responses. The primary threshold (Θ_1) determined the water consumption after which the virtual person started to look sad, while the secondary threshold (Θ_2) determined the water consumption after which the virtual person started to look angry. The pilot test showed us that fairly low thresholds should be maintained to enable the VEC system to respond to the participants' water consumption: for $\Theta_1 = 0.01$ liters and $\Theta_2 = 0.05$ liters.

The experimental environment was the kitchen part of the living room of the Smart Home, an experimental mobile home environment by the Smart Home Foundation⁴ on the terrain of the Evuon in Eindhoven, the Netherlands. Figure 6 is a photographic impression of the experimental environment.

During the experiment, the lights in the room were dimmed and the blinds were down. Two spotlights, located above the electronic water tap, were switched on. By default, the tap was switched off, set to its minimum temperature and water flow.

Each participant received a spoonful (approximately 40 ml) of strong hair gel purchased at the local supermarket (Albert Heijn). The gel was equally applied to both hands of the participants.

⁴ See: <http://www.smart-homes.nl/default.aspx?lang=en-US>



Figure 6: The experimental setup to evaluate the VEC system. The virtual person is shown on a display that is positioned on the right of the water tap.

3.2.3 Procedure

The experimental procedure consists of four stages. In the first stage, the participants complete a general questionnaire. In the second stage, the participants receive the hair gel. In the third stage, they wash their hands. In the fourth and final stage, the participants complete a second questionnaire about their perception of the virtual person. Figure 7 includes approximate distances between the locations of the four stages.

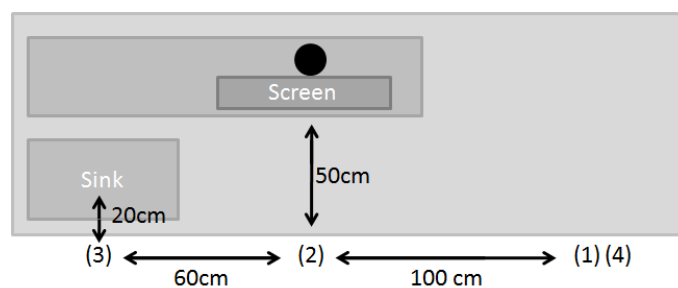


Figure 7: Schematic overview of the experimental setup and the positions of the participants during the four stages of the experiment (top view). The black disk represents the webcam; it is positioned above the screen displaying the virtual person. For each stage of the experiment, the position of the participants is represented by parenthesized digits indicating the stage. Stage (1): participants receive instructions and complete the first questionnaire. Stage (2): the hair gel is applied to the hands of the participants. Stage (3): participants wash their hands. Stage (4): participants complete the second questionnaire.

The details of the four stages were as follows. Each participant was led to the kitchen of the Smart Home and received a textual explanation that stated that this research is about studying new

methods to decrease water consumption. The literal text (in Dutch) is reproduced in Appendix A. After this explanation, each participant was asked to complete a short questionnaire (age, gender and height). All participants were then explained that they had to apply a premeasured spoonful of hair gel to their hands, after which they had to wash their hands at the sink in the kitchen. After finishing this task, all participants were asked to complete a second questionnaire. This questionnaire consisted of four questions (stated in Dutch): (1) “Did you see anything noteworthy about the virtual person?”, (2) “Did you have the feeling that the virtual person was gazing at you?”, (3) “Did you notice any emotional expressions at the virtual person?” and (4) “Did these expressions have any effect on you?”

3.2.4 Design

The independent variable in this experiment is the presence or absence of the nonverbal signals of the virtual person (eye gazing and emotional expression). The dependent variable is the total amount of water that was consumed by the participants. We aim to find a reduction in water consumption due to our experimental manipulation (presence of nonverbal signals).

Chapter 4

RESULTS

This chapter presents the results of the two experiments. Section 4.1 gives the results of the empirical evaluation of the face detector and Section 4.2 reports on the results of the empirical evaluation of the VEC system.

4.1 Results of the face detector evaluation

During the evaluation of the face detector, we determined the minimum and maximum distance from the screen (d^{\min} and d^{\max} , respectively) and the maximum horizontal and vertical viewing angles ($\alpha_{\max}^{\text{vert}}$ and $\alpha_{\max}^{\text{hor}}$, respectively) for three different illumination conditions. Table 2 shows the mean values for these measures, all based on 5 replications. The standard deviations are specified between brackets. The three rows represent the performances for the three illumination conditions.

Illumination	d^{\min} (cm)	d^{\max} (cm)	$\alpha_{\max}^{\text{vert}}$ (degrees)	$\alpha_{\max}^{\text{hor}}$ (degrees)
Daylight	21.9 (0.58)	75.6 (0.80)	28.4 (1.20)	24.6 (1.02)
Bright sun	26.9 (0.58)	81.4 (2.42)	29.4 (2.32)	23.4 (2.40)
Fluorescent	23.6 (0.58)	71.4 (2.42)	28.8 (2.32)	23.8 (2.40)

Table 2: the evaluation of the face detector indicated the minimum- and maximum distance at which face could be recognized, as well as the maximum vertical- and horizontal viewing angle.

The bar plot displayed in Figure 8 gives a graphical impression of the range of distances for which the face detector operates correctly under the three lighting conditions. The results show that the VEC system is quite robust to variations in illumination. Apparently, the face detector requires a slightly larger minimum distance in bright sunlight than in daylight or fluorescent light, although bright sunlight also increases the maximum distance over which faces can be detected. This is mainly due to the automatic-gain control of the webcam that compensates automatically for increases or decreases in overall illumination.

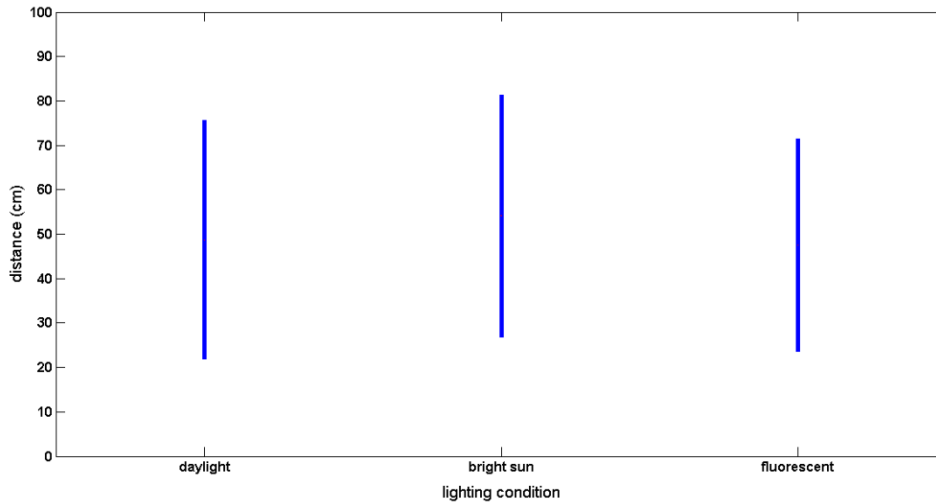


Figure 8: Graphical illustration of the ranges of distances for which the face detector is successful in eye-gazing for three different lighting conditions. The bottom and top of each bar correspond to the minimum and maximum distances for which the eye-gazing was successful, respectively.

The distances from the screen for which successful eye contact is established range from about 25 to 75 centimeters, which is appropriate for our experiment in the Smart Home. Figure 9 illustrates the maximum vertical and horizontal angular deviations for the three lighting conditions. The range of angles for which the face detector succeeds in eye-gazing the experimenter is appropriate for the experiment in the Smart Home.

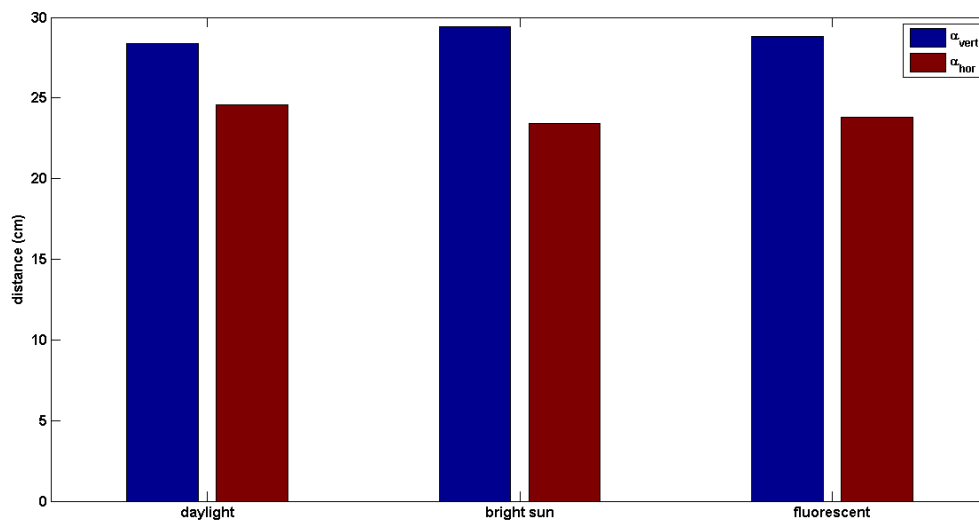


Figure 9: Illustration of the maximum vertical (blue) and horizontal (red) visual angles for which the face detector maintains eye-contact with the experimenter.

4.2 Results of the VEC system evaluation

The results presented below, indicate the extent to which the VEC system is able to influence the energy consumption of participants. We present the results in two parts. In the first part we give the quantitative results obtained from the water flow sensor for the two experimental conditions. In the second part, we report on the questionnaires completed by the participants.

Water consumption

Table 3 shows the water consumption of the individual participants in both conditions of the experiment. The main observation is that in the experimental condition the average water consumption in the experimental condition is lower than the average water consumption in the baseline condition (0.523 L versus 0.783 L). Of course, the statistical power of the difference of these averages is weak given the small number of participants in the conditions.

The standard deviation of the average consumption in the baseline condition is relatively large ($\sigma = 0.534$) as compared to the standard deviation of the average consumption in the experimental condition ($\sigma = 0.006$), except for the first measurement, which may be an outlier.

Baseline condition		Experimental condition	
Participant	Water consumption (L)	Participant	Water consumption (L)
1	0,277	6	2,502
2	0,233	7	0,026
3	1,434	8	0,022
4	1,181	9	0,030
5	0,788	10	0,037

Table 3: Water consumption (in liters) for the individual participants in the two conditions.

Questionnaires

The questionnaires offered a qualitative insight into the experienced persuasiveness of the virtual person. We briefly describe the responses in the baseline and experimental conditions.

Baseline condition: In the baseline condition, the majority of the participants (participant number 2, 3, 4 and 5) indicated that they noticed the movements of the virtual person. Participant 2 indicated that the virtual person was “looking thoughtfully”. Participant 4 stated that the virtual person “was moving her head and her glasses”. Three out of the five participants (participant number 1, 2 and 5) stated that they had “the feeling of being followed by the virtual person’s eyes.”, despite the fact that in the baseline condition, eye-gazing was turned off. All participants indicated that they had not noticed any expressions on the virtual person’s face. None of the participants felt that they were being influenced by the emotions expressed by the virtual person.

Experimental condition: In the experimental condition, three out of the five participants (participant number 6, 7 and 9) stated that they noticed nothing in particular about the virtual person. Participant 8 noticed that the virtual person followed the participants’ movements, while participant 10 stated that the avatar appeared to be uninterested in the participants’ actions. Participant 6 stated that he did not notice the presence of the virtual person at all. Except for participant 8, none of the participants reported to be aware of eye-gazing by the virtual person, despite the fact that eye-gazing was switched on in this condition. The majority of the participants did not report to be aware of the virtual person’s expressions, except for participant 8, who stated that the virtual person expressed attentiveness, suspicion and thoughtfulness. None of the participants felt to be influenced by the emotions that were expressed by the virtual person.

4.2 Discussion of the results

In this section, we discuss the distribution of the results of our evaluations and we identify the outliers of our results.

The results of the evaluation of the face detector

The results of the evaluation of the face detector indicate that the range in which the face detector is able to detect faces varies only slightly under different illumination conditions. We noticed that the standard deviation for the measurements in the normal daylight condition is relatively low compared to the standard deviation of the measurements in the direct bright sunlight-condition and the artificial illumination-condition. This might be caused because by a difference in the brightness of the light in the lighting condition: in the direct sunlight-condition and in the artificial illumination-condition, the light came directly from the light source (the sun and the ceiling lamps, respectively), while the light in the normal daylight-condition came indirectly from a light source outside the window. We therefore suggest that future research might investigate the effects direct and indirect illumination have on the effectiveness of the face detector.

The results of the evaluation of the VEC system

Although the average water consumption in the experimental condition is lower than the average water consumption in the baseline condition, the experimental condition includes a measurement result that is relatively high compared to the other measurement results. The participant responsible for this result (participant 6) was the only participant who indicated that he had not noticed the presence of the virtual person at all. Therefore, it might be possible that perceiving the presence of the virtual person causes a change in energy-consumption behavior. If we would consider participant 6 as an outlier, the average water consumption decreases drastically due to our experimental manipulation.

It is intriguing that most participants did not seem to be aware of the eye-gazing or responsiveness of the virtual person, as these manipulations seem to influence the participants' energy-consumption behavior, although most participants stated they did not perceive them consciously.

The standard deviation in the baseline condition is relative high compared to the standard deviation of the experimental condition. The virtual person in the baseline condition was not responding to the energy-consumption behavior of the participants, unlike the virtual person in the experimental condition. Given this lack of responsiveness of the virtual person, it might be possible that the participants in the baseline condition did not pay as much attention to the virtual person as the participants of the experimental condition did. Therefore, it might be possible that the participants in the baseline condition are less influenced by the virtual person compared to the persons in the experimental condition. This may therefore explain the larger standard deviation in the baseline setting.

Chapter 5

DISCUSSION

Our study with the VEC system suggests that social signals generated by a virtual person may affect energy-consumption behavior. Obviously, our experiment needs to be replicated with a larger number of participants to determine if this suggestion holds. In this chapter we discuss the implications of our findings and the extent to which they hold (5.1) and we identify points of improvement of our system and our empirical investigations (5.2).

5.1 The effectiveness of social signals

The results of the evaluation of the VEC system indicate that the average water consumption in the experimental condition is significantly lower than the average water consumption in the baseline condition. Therefore, the results suggest that the nonverbal cues generated by the VEC system affect energy consumption behavior. Below we briefly discuss the extent to which this suggestion may be valid. Our discussion focuses on two points: (1) the validity of the experiment, and (2) the conscious versus unconscious operation of social signals.

5.1.1 Validity of the experiment.

Our study aims at affecting the energy-consumption behavior of household members. Our evaluation of the VEC system, focused on the question to what extent the VEC system is able to influence the water consumption of participants washing their hands. We discuss two concerns with respect to the validity of our findings: the water temperature and the critical experimental manipulation.

The results of the evaluation suggest that the VEC system is capable of influencing the participants' water consumption. However, we did not take the water temperature into account in our evaluation. Therefore, we cannot deny the possibility that participants consumed a lower amount of water, but of a higher temperature. As a higher water temperature requires gas consumption, this might negate the effects on the energy-consumption behavior. Future extensions and replications of our experiment should take the water temperature into account.

The evaluation consisted of two conditions: the baseline condition and the experimental condition. In the baseline condition, the virtual person was visible with its default, idle behavior to participants; the virtual person did not follow participants with its gaze and it did not react to the water consumption of participants. In the experimental condition, the virtual person was also visible, but this time, the virtual person followed participants with its gaze and responded to their energy

consumption by changing its emotional expressions. Although the results suggest that the VEC system is able to influence the energy-consumption behavior of the participants, our experimental set-up precludes us from identifying the critical manipulation. It is not clear what caused the difference in behavior: the presence of the virtual person, the perception of eye-gazing, the perception of the expressions of the virtual person or a combination of these factors. Future versions of our experiment should adopt an experimental design that tests for each of these possibilities.

5.1.2 Conscious versus unconscious operation of social signals

The majority of the participants in both conditions stated that they had the feeling that they were being watched by the virtual person, even though the virtual person was only eye-gazing in the experimental condition. Apparently, the feeling of being watched can arise even when the virtual person was not watching participants at all. This finding agrees with Brehm (1966), who found that personal feedback that is experienced as being obtrusive may be regarded as an intrusion to the individual's autonomy and with the findings of Bateson, Nettle & Roberts (2006), that images of human-like eyes affect human behavior. Overall, our results suggest that if our experimental manipulation was effective, it operates on an unconscious level. After all, consciously both conditions appeared identical to most participants. If the eye gazing and expressions affect behavior unconsciously, the feedback provided by the VEC system can be considered as being non-obtrusive (Ham, Midden & Beute, 2009; Roubroeks, Midden & Ham, 2009). Future studies should address the conscious and unconscious operation of social signals in more detail.

5.2 Points of improvement

Below we briefly identify and discuss the improvement of our system and our empirical investigations.

5.2.1 Improvement of the VEC system

We identify three main improvements of the VEC system. Firstly, in our experiment, the virtual person responded using negative emotions only. The VEC system might be improved using a larger range of expressions for the virtual person to respond to energy consumption. For instance, positive expressions may be generated for rewarding participants who consume little energy.

Secondly, André et al. (2011) showed that social virtual agents aiming to persuade people should appear credible and non-threatening towards people in order to establish and maintain persuasive interaction. Future extensions of the VEC system may be equipped with the ability to communicate verbally with participants, as this might increase the credibility of the virtual person and the VEC system.

Finally, as we stated in Chapter 2, the discrete values inherent to the Haptik software limits the precision of eye gazing, but in practice the resulting gazing errors are not noticeable. However, we expect that an even more convincing eye gazing effect can be constructed by using more discrete steps for the virtual person's gazing direction.

5.2.2 Improvement of the empirical investigation

As stated in the previous Chapter, our experiment should be improved by increasing the number of participants. This would allow us to determine if social signals have an impact on energy-consumption behavior as suggested by our findings. In addition to the further improvements mentioned in this Chapter (incorporation of water temperature, improving the design, investigating the conscious versus unconscious processes), future empirical investigations may vary the type of virtual person and explore variations in location and size of the avatar (screen). Also, different manners of energy consumption may be explored (e.g., electricity and gas). Of particular interest is a more realistic experimental setting in which the virtual person is part of everyday life in a household.

Chapter 6

CONCLUSIONS

This thesis presented the VEC (Virtual Eye Controller) system and evaluated its performance. The first research question addressed in this thesis reads: *Is it possible to develop a system that automatically gazes at a participant moving in front of the screen?* This question is answered affirmatively by the results of the evaluation of the face detector. Given these results, we conclude that the face detector is robust against lighting variations and that the face detector (and therefore the VEC system) is able to follow participants in front of the screen. We therefore conclude that it is possible to develop a system that automatically gazes at persons.

The second research question addressed in this thesis reads: *To what extent is it possible to influence the energy consumption of participants by exposing them to human-like nonverbal cues?* The answer to this question is less clear. The evaluation of the VEC system determined to what extent the VEC system is able to influence the energy consumption of a few participants only. Given the small sample size employed in our experiment, we conclude that it may be possible to influence the energy-consumption behavior by social signals and that further research is required.

REFERENCES

1. Abrahamse, W., Steg, L., Vlek, C. & Rothengatter, T. (2005). A review of intervention studies aimed at Household energy conservation. *Journal of Environmental Psychology*, 25(3), 273-291
2. André, E., Bevacqua, E., Heylen, D., Niewiadomski, R., Pelachaud, C., Peters, C., Poggi, I. & Rehm, M. (2011). Non-verbal Persuasion and Communication in an Affective Agent. *Cognitive Technologies*, 6, 585-608
3. Backlund, S., Gustafsson, A., Gyllenswärd, M., Ilstedt-Hjelm, S., Mazé, & R. Redström, J. (2006) Static! The Aesthetics of Energy in Everyday Things. In Friedman, K., Love, T. and Corte-Real, E. (Eds.) *Proceedings of Design Research Society Wonderground International Conference 2006*.
4. Bateson, M., Nettle, D. & Roberts, G. (2006). Cues of being watched enhance cooperation in a real-world setting. *Biology Letters*, 2, 412-414
5. Bergboer, N.H., Postma, E.O., & Herik, H.J. van den (2006). Context-based object detection in still images. *Image and Vision Computing* 24 (9), 987-1000
6. Bradski, G. & Kaehler, A. (2008). *Learning OpenCV: Computer Vision with the OpenCV Library*. O'Reilly, Cambridge, MA
7. Brehm, J. W. (1966). *A theory of psychological reactance*, New York: Academic Press
8. Carter, J. (1982). *The Moral Equivalent of War*. Retrieved from <http://www.time.com/time/magazine/article/0,9171,949597,00.html>
9. Croon, G. de, Postma E.O., & Herik H.J. van den (2006). A situated model for sensory-motor coordination in gaze control *Pattern Recognition Letters*, 27 (11), 1181-1190.
10. Darrell, T., Gordon J., Woodfill J. & Harville M. (1998). A Virtual Mirror Interface using Real-time Robust Face Tracking. *Proceedings of the Third International Conference on Face and Gesture Recognition*.
11. Gore, A.A. (2006). *An inconvenient truth: The planetary emergency of global warming and what we can do about It*. Emmaus, PA: Rodale Press

12. Fogg, B.J. (2002). Persuasive technology: using computers to change what we think and do. *Ubiquity*, 12, 89-120
13. Freund, Y., & Schapire, R. (1999). *A Short Introduction to Boosting*. Japanese Society for Artificial Intelligence, 14 (5), 771-780.
14. Ham, J.R.C., Midden, C. J. H. & Beute, F. (2009). Can ambient persuasive technology persuade unconsciously? Using subliminal feedback to influence energy consumption ratings of household appliances. In S. Chatterjee & P. Dev (Eds.), *Persuasive '09 Proceedings of the 4th International Conference on Persuasive Technology* (29).
15. King, A. & Schneider, B. (1993). *The first global revolution: Club of Rome*. Retrieved from: www.archive.org
16. Lee, E.C. & Park, K.R. (2009). A robust eye gaze tracking method based on a virtual eyeball model. *Machine Vision and Applications*, 20(5), 319-337.
17. Lichtenauer, J., Hendriks, E. & Reinders, M. (2005) Isophote properties as features for object detection. In *CVPR*, 2, 649–654
18. Mattheij, R.J.H., Szilvasi, L.M.F., De Beer, L.M.A.T., Rakiman, K.C. & Shahid, C.S. (2011, in press). GooGreen: Towards increasing the environmental awareness of households. *Proceedings of the HCI 2011 Conference*
19. Midden, C. J. H., Meter, J. F., Weenig, M. H. & Zieverink, H. J. A. (1983). Using feedback, reinforcement and information to reduce energy consumption in households: A field-experiment. *Journal of Economic Psychology*, 3(1), 65-86
20. Mita, T., Kaneko, T., & Hori, O. (2005). *Joint Haar-like Features for Face Detection*. Computer Vision, IEEE International Conference on, 2, 1619-1626
21. Moeslund, T.B. & Granum, E. (2000). A Survey of Computer Vision-Based Human Motion Capture. *Computer Vision and Image Understanding*, 81(3), 231–268 (2001)
22. Roubroeks, J.A.K., Midden, C. J. H. & Ham, J.R.C. (2009). Does it make a difference who tells you what to do? Exploring the effect of social agency on psychological reactance. In S. Chatterjee & P. Dev (Eds.), *Persuasive '09 Proceedings of the 4th International Conference on Persuasive Technology* (15)
23. Valenti, R. & Gevers, T. (2008). *Accurate eye center location and tracking using isophote curvature*. In IEEE Conference on Computer Vision and Pattern Recognition
24. Viola, P., & Jones, M. (2001). *Rapid Object Detection using a Boosted Cascade of Simple Features*. In Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition. (1), 511-518. IEEE Computer Society.
25. Vossen, S. H., Ham, J.R.C. & Midden, C. J. H. (2009). Social influence of a persuasive agent: the role of agent embodiment and evaluative feedback. In S. Chatterjee & P. Dev (Eds.), *Proceedings of the 4th International Conference on Persuasive Technology*. (46)

26. Wren, C., Azarbayejani, A., Darrell, T. & Pentland, A. (1997). *Pfinder: Real-Time Tracking of the Human Body*. IEEE Transactions on Pattern Analysis and Machine Intelligence. (19), 780-785

APPENDIX A

Questionnaire

Onderzoek waterbesparing

Inleiding

Dit onderzoek onderzoekt een nieuwe manier om water te besparen. In dit specifieke onderzoek zal een virtueel persoon u feedback geven over uw persoonlijke waterverbruik. Alle gegevens over u worden vertrouwelijk behandeld. Deelname aan dit onderzoek gebeurt volledig anoniem.

Persoonsgegevens

Geslacht:

Leeftijd:

Lichaamslengte:

Onderzoek waterbesparing

Vragenlijst

- 1) Is u iets opgevallen aan de avatar? Zo ja, wat?
- 2) Had u het idee dat de avatar u volgde? Zo ja, hoe deed ze dat?
- 3) Heeft u gezien dat de avatar bepaalde emoties toonde? Zo ja, welke?
- 4) Deden deze emoties iets met u? Zo ja, wat?