Getting the Point Across: Exploring the Effects of Dynamic Virtual Humans in an Interactive Museum Exhibit on User Perceptions

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Fig. 1. The You, M.D. interactive museum exhibit dynamically selects the appearance of the virtual humans presented to museum visitors based on user information to improve learning outcomes and user perception.

Abstract—We have created “You, M.D.”, an interactive museum exhibit in which users learn about topics in public health literacy while interacting with virtual humans. You, M.D. is equipped with a weight sensor, a height sensor and a Microsoft Kinect that gather basic user information. Conceptually, You, M.D. could use this user information to dynamically select the appearance of the virtual humans in the interaction attempting to improve learning outcomes and user perception for each particular user. For this concept to be possible, a better understanding of how different elements of the visual appearance of a virtual human affects user perceptions is required. In this paper, we present the results of an initial user study with a large sample size (n =333) ran using You, M.D. The study measured users' reactions based on the user's gender and body-mass index (BMI) when facing virtual humans with BMI either concordant or discordant from the user's BMI. The results of the study indicate that concordance between the users' BMI and the virtual human's BMI affects male and female users differently. The results also show that female users rate virtual humans as more knowledgeable than male users rate the same virtual humans.

Index Terms—virtual humans, museum exhibits, user perceptions

1 INTRODUCTION

Interactive science museums are unique learning environments in the fact that they serve the broadest general public [14]. We were tasked with the creation of a museum exhibit for one of these interactive science museums in Tampa, Florida. In this exhibit, virtual humans teach museum visitors about topics in public health in order to help them make better life choices. The main objective of this museum exhibit is to increase public health literacy about asthma, melanoma and how to avoid obesity by living a healthy lifestyle. In order to achieve this objective, the virtual humans presented in the exhibit need to be very effective at transmitting the ideas presented and getting the point across.

The visual appearance of a virtual human can have both positive and negative effects on user perceptions [20, 1] and on user behavior [13]. This visual appearance is flexible, i.e. interaction designers can easily modify elements such as gender, age, ethnicity, attire and body mass-index (BMI) to create virtual humans that look different from each other. Understanding how these elements of the virtual human’s visual appearance affect the target population of an interaction can help improve the effectiveness of the interaction. Furthermore, information collected from each individual user can be used to tailor the experience for them. This tailored experience can more effectively convey information and improve learning outcomes.

We have created “You, M.D.”, an interactive museum exhibit in which users learn about topics in public health literacy while interacting with virtual humans. You, M.D. is equipped with a weight sensor,
a height sensor and a Microsoft Kinect to collect basic information from the user. Conceptually, You, M.D. could use this user information to dynamically select the visual appearance of the virtual humans in the interaction to improve the user’s experience. For this concept to be possible, a better understanding of how different elements of the visual appearance of a virtual human affects user perceptions is required. We propose that for M.D. can be used to study how these visual elements affect users of the target population. The results of such studies could later be applied to You, M.D. to create tailored experiences that have a better chance of getting the point across to museum visitors.

You M.D. was used to run an initial study (n=333) that aims to understand how the virtual human’s BMI affects user perceptions. BMI is a surrogate measure of relative excess weight in a person. BMI is a ratio between a person’s weight and squared height. BMI is usually given in kg/m^2. Values of BMI are organized in different classifications. According to the World Health Organization (WHO), there are four main classifications: Underweight (BMI less than 18.5), Normal range (BMI between 18.5 and 25), Overweight (BMI between 25 and 30), and Obese (BMI greater than 30) [17]. These classifications are the same for both genders. As a surrogate measure for body fatness, BMI has many limitations [12]. Most of these limitations arise from the fact that BMI estimates the ratio between lean body mass and body fat, rather than measure it. For example: 1) BMI is known to misrepresent people with well developed musculature as being overweight [12] and 2) men and women with the same BMI usually present different levels of body fatness [4]. Even with these limitations, BMI is well established and serves well as an educational tool [12]. For the purpose of this study, BMI was used as a perceptual metric rather than as an estimate of body fatness.

For this initial study, user perceptions were measured based on the user’s gender and BMI when facing virtual humans with BMI either concordant or discordant from the user’s BMI. These perceptions were measured both when the user acts as a learner being instructed by a virtual human and when the user acts as an instructor providing advice to the virtual human. The results of the study indicate that concordance between the users’ BMI and the virtual human’s BMI affects male and female users differently. Female users found the discordant BMI virtual human to be more knowledgeable than the concordant BMI virtual human, while male users found the discordant BMI virtual human to be more knowledgeable than the discordant BMI virtual human. The results also show that female users rate virtual humans as more knowledgeable than male users rate the same virtual humans. The direct implications from these results for You, M.D. and for similar virtual human interactions would be that displaying a virtual human with discordant BMI to female users and virtual human with discordant BMI to male users can help improve the user’s confidence in the knowledge received from the virtual human.

2 RELATED WORK

2.1 Effects of the Appearance of Virtual Agents

Multiple studies have shown users react differently based on the visual appearance of both virtual humans [6, 11, 13, 16, 20] and avatars [2, 18, 19]. Our initial study of how the appearance of virtual humans can affect user’s perceptions while interacting with the You, M.D. exhibit was designed based on the results found in these studies.

2.1.1 Virtual Humans

Virtual humans are anthropomorphic embodied conversational agents, that is computer-controlled digital representations of a human [6]. Prior research has studied the interaction between the gender of the virtual human and the gender of the users in persuasive contexts with contradicting results [6, 20]. Guadagno et al. analyzed students reactions to a persuasive communication of a virtual human about a campus security policy and found a more attitude change when the virtual human was of the same gender as the participant [6]. Zanbaka et al. analyzed a similar scenario with a persuasive message about university-wide comprehensive exams delivered by a male or female human, virtual human or virtual character (i.e. an embodied conversational agent that does not resemble a human) [20]. They found that male participants were more persuaded by female agents, while female participants were more persuaded by male agents. Additionally, their results showed that virtual humans and virtual characters were as persuasive as real people. The difference between these two results highlights the necessity to understand the target population of an interaction.

Yug et al. studied the effects of facial similarities between virtual human and user [16]. They found that when a virtual human is helpful, users respond positively to a virtual human with facial features similar to them compared to a virtual human with dissimilar facial features. However, they found that when the virtual human is unhelpful, the effect is the reverse, with the similar-looking virtual human rated negatively.

In the realm of medical training, changes in virtual humans appearance have been shown to demonstrate study potential biases in the trainees [11, 13]. Persky et al. used virtual humans to demonstrate medical students have biases against obese patients [11]. In their study, medical students rated an obese virtual patient as less healthy, less likely to adhere to advice, and significantly more responsible for causing their health issues, when treating conditions that could be related to weight issues. Rossen et al. used virtual humans to demonstrate that virtual humans with a dark skin-tone elicit user behavior consistent with real world biases towards African-Americans as measured by a psychological instrument called the implicit association test (IAT) [13]. Their study showed that IAT scores significantly correlated to participant empathy as coded by observers blind to the skin-tone of the virtual human.

2.1.2 Avatars

Avatars are digital representations of an actual person. Previous research has studied effects of different visual aspects of an avatar on users [18, 19]. Yee et al. have studied the phenomenon known as the “Proteus effects” that states that when using avatars, users display attitudes that reflect the social expectations of a person with the physical characteristics of the avatar [19]. For example, they studied how users react in self-disclosure tasks when using avatars with different levels of attractiveness, finding that users tend to be more intimate when using more attractive avatar [18]. They also studied how users react in negotiation tasks when using avatars with different virtual heights, finding that users approach the tasks more confidently when using taller avatars than when using shorter ones.

While findings in the context of avatars not necessarily transfer to virtual humans, findings on user perceptions of the visual appearance of avatars can be used to guide hypotheses in the field of virtual humans. For the presented study relating to the BMI of the virtual human, one concern was that social biases against obese people would be applied to the obese virtual humans. Our initial findings, however, do not show evidence of such social biases.

2.2 Virtual Humans as Museum Guides

Virtual human systems have been installed in multiple museums. In these museums, virtual humans are mainly used as museum guides. Examples of such museum guides include: “Pixie” in the museum exhibit “Tank Om” [3], “Max” deployed in the Heinz Nixdorf MuseumsForum in Germany [10], and “Ada and Grace” installed in the Museum of Science in Boston [15]. The success of these virtual human museum exhibits offers evidence of the acceptability of virtual humans to the general public.

You M.D., the museum exhibit described in this paper, also uses virtual humans to deliver content in an interactive museum exhibit. However, You, M.D. dynamically changes the visual appearance of the virtual human displayed to each visitor based on sensor data to improve knowledge transfer and improve learning outcomes.

3 SYSTEM DESCRIPTION – YOU, M.D.

We built You, M.D., an interactive museum exhibit where museum visitors interact with virtual humans. You, M.D.’s main objective is to raise public health literacy. To achieve this objective, the virtual humans in You, M.D. need to be effective at conveying information and
transferring knowledge to the user. We propose that this knowledge transfer can be improved by dynamically selecting the appearance of the virtual humans in the exhibit to be displayed for each individual user based on basic user information collected by using sensors. You, M.D. is currently equipped with a height sensor, a weight sensor and a Microsoft Kinect.

The name “You, M.D.” was chosen for the exhibit to show that during the interaction museum visitors learn about public health while playing the role of a medical doctor (M.D.) to a virtual patient. Therefore, during the interaction with the exhibit You (the museum visitor) are the M.D. (medical doctor).

You, M.D. is currently installed at the Museum of Science and Industry (MOSI) in Tampa, FL, USA. According to interviews with MOSI staff, MOSI is the largest science center in the southeast United States and the fifth largest in the country. MOSI receives an average of about 1650 visitors daily, with different distributions depending on the time of the year. MOSI visitors span a wide variety of age ranges. About 25% of MOSI visitors are under 18 years old, 50% are between 18 and 55, and the remaining 25% are over 55. Inside MOSI, You, M.D. is located within a larger, permanent exhibit: “The Amazing You.” The Amazing You exhibit addresses health and wellness at each stage of life, from conception to end of life. As part of The Amazing You exhibit, You, M.D. teaches visitors about topics related to public health by letting visitors interact with a series of virtual humans. To interact with these virtual humans, visitors push buttons to select from a list of possible actions. Each one of these actions triggers a response from one of the virtual humans.

The specific topics in public health literacy were chosen to be of interest to the local community and to other museum visitors. Museum visitors that interact with You, M.D. learn from one of three available lessons in public health: asthma, melanoma and living a healthy lifestyle (referred to as “health & wellness”). All three lessons follow a similar structure. The content of the lessons is described in detail in section 3.4.

3.1 Physical Setup

You, M.D. is equipped with three sensors, an input device, and two output devices. Figure 2 shows the physical layout of the exhibit. The three sensors are: an electronic scale, an ultrasonic height sensor and a Microsoft Kinect.

- The electronic scale is an Arlyn scale 320D with a capacity of up to 500lbs and a resolution of 0.1 pounds. The scale is centered in the exhibit space and is where the user is expected to stand while interacting with the scale.

- The ultrasonic height sensor is a Senix ToughSonic TSPC-30S1. This sensor is located 7.5’ above the scale. This height sensor has a resolution of 0.02 inches. The scale and height sensors are used to capture the user’s BMI.

- The Microsoft Kinect is mounted on the upper left corner of the exhibit at a height of 7.5’. The depth camera of the Kinect captures non-identifiable pictures of the users. These pictures are later used to rule out possible outliers.

A custom-made button pad is used as an input device for users to interact with the exhibit. This button pad is located directly in front of the scale at a height of 3.5’. The button pad has six buttons. Out of the six buttons, five allow the user to select from different options during the interaction, while the sixth button allows the user to restart the interaction at any time.

The output devices for the exhibit are an LCD TV and a speaker. The LCD TV is a 46’ Samsung LN46A550. This TV is mounted on the back wall of the exhibit at a height of 5’, directly on top of the button pad. The TV displays one virtual human at a time. The speaker is located between the button pad and the TV. The speaker outputs all audio from the exhibit, which includes both sound effects and the voices of the virtual humans.

![Figure 2. Physical layout of the You, M.D. exhibit.](image)

3.2 Virtual Humans in You, M.D.

During the interaction with the exhibit the user interacts with three virtual humans. The first virtual human greets users into the exhibit and provides the lesson selection. The second virtual human is a virtual doctor that teaches the user about the selected lesson. The third virtual human is a virtual patient that asks the user about advice on the selected lesson.

For each virtual human, You, M.D. has a script, four different visual appearances and pre-recorded audio files. The scripts for the virtual humans were modeled as decision trees. At the root of this decision tree the virtual human starts the interaction with a speech. For example, the virtual human could say: “Welcome to the MOSI Clinic. I’m Dr. Jones. Could you spare about four minutes of your time to help us with this research?” Following each speech, users are presented with a list of possible answers they can give to the system as a response. The user then selects an option from the list using the button pad. Each one of the options leads to a different node in the decision tree that contains the system’s response. As a response from the system, the current virtual human can speak back to the user or it can transfer control to another virtual human that would continue with the interaction.

For the initial study presented, four visual appearances for each virtual human were made available. The four visual appearances available for each virtual human correspond to: non-obese (normal) BMI male, non-obese (normal) BMI female, obese male and obese female. The non-obese BMI versions of the characters were generated to display an approximate BMI of 24, while the obese versions present a BMI of 33.

3.3 User experience

As users enter the You, M.D. exhibit they step on the electronic scale and face the TV to start the interaction. As mentioned before, all the interaction with the exhibit happens in a multiple choice fashion, by selecting a single a choice from a list of possible choices that were displayed on the screen.

Users go through four stages and interact with three virtual humans as part of their interaction with the exhibit. Figure 3 shows the general structure of a user interaction. Out of the four stages, two are meant to
be tailored to each user. These two stages are the instruction stage and the recall stage which are the ones that provide public health information to the users. The other two stages (i.e., the greeting stage and the survey stage) are used primarily for data collection.

During the greeting stage (Figure 3.a), users interact with the first virtual human. The first virtual human greeted participants inviting them to participate in the exercise. The first virtual human is a male doctor with an approximate BMI of 24. The appearance of this first virtual human is constant for all users, as this stage is used to collect the basic data from the user. During this stage, the BMI of the user is computed using information from the sensors. Users also input their gender directly during this stage. The greeting stage concludes with the lesson selection which is left to the user preference. Users selected from the three lessons available: asthma, melanoma, and health & wellness.

During the instruction stage (Figure 3.b), users act as learners while interacting with the second virtual human, a virtual doctor. The virtual doctor is referred to as Dr. Blackwell during the interaction. Dr. Blackwell provides users with general health literacy knowledge about the selected lesson. Dr. Blackwell prompts the user to input what they know about the selected lesson and corrects any misconceptions the user may have in the area. After providing this information, Dr. Blackwell invites the user to help a patient who was having problems related to the content of the lesson.

During the recall stage (Figure 3.c), users act as instructors while interacting with the third virtual human. The third virtual human is a virtual patient that asks for the user’s advice. The advice requested by the virtual patient refers back to the information provided by Dr. Blackwell.

Finally, during the survey stage (Figure 3.d), users fill out a survey. The survey serves as debriefing. The survey consists of four questions. One of these questions tests the users’ understanding of the content of the lesson. This question was used as a learning mechanism. The other three questions collected the user’s reaction to the virtual humans observed during the interaction. These survey questions are described in detail in section 4.1.

### 3.4 Public health lessons

As mentioned earlier, the You, M.D. exhibit has three lessons available for visitors: asthma, melanoma and living a healthy lifestyle (health & wellness). The three lessons are of interest to public health. This section describes the contents of each one of the lessons and the importance of effectively communicating this information to the general public.

#### 3.4.1 Asthma Lesson

Asthma is among the most common chronic diseases and at least 22 million Americans are known to have asthma [5]. The asthma lesson aims to: 1) explain the main risk factors of asthma, 2) explain how to avoid contracting asthma, 3) clarify common misconceptions regarding asthma, and 4) highlight how common asthma is. The asthma lesson explains that asthma is a lung disease that inflames and narrows the airways. The symptoms described for asthma are: difficulty breathing, a feeling of tightness in the chest, possibility of coughing and a whistling sound when breathing. The lesson describes that asthma can be caused: allergies, infections, and irritants such as smoking. The lesson clarifies that: asthma is not contagious, asthma is in fact a serious illness that needs treatment, and that it can affect people of all age groups.

#### 3.4.2 Melanoma Lesson

Melanoma is a type of skin cancer that affects 60,000 Americans each year [9]. The melanoma lesson aims to: 1) explain the main risk factors of melanoma, 2) explain how to detect if a mole has the potential to be melanoma related, 3) explain how to prevent contracting melanoma and 4) highlight how important early detection of melanoma can be. The lesson explains that melanoma is a type of cancer and that it can happen on any part of the skin. The lesson explains that the main cause for melanoma is UV radiation that damages the skin. UV radiation can come from the sun or tanning booths. The scenario explains that melanoma causes moles to appear in your skin. The lesson explains four keys to detecting if a mole can potentially be caused by melanoma. The four keys are called the A-B-C-Ds: the Asymmetrical shape, the irregular Border, the uneven Color, and the large Diameter (bigger than the eraser of a pencil) of the mole. The scenario clarifies that melanoma can affect anyone, as it is a common myth that only people with light skin tone are affected by melanoma. The scenario explains that using suntan lotion with Sun Protection Factor (SPF) higher than 30 can help reduce one’s chance of getting melanoma. Finally, the lesson explains that, if caught early, melanoma is treatable, highlighting the importance of getting suspicious moles checked by a doctor.

#### 3.4.3 Health & Wellness Lesson

Obesity is rapidly becoming a medical crisis in the United States, and its propagation has been linked to low physical activity and poor eating habits [8]. Obesity is also linked as a risk factor for diseases such as coronary heart disease. The health & wellness lesson aims to teach basic keys on living a healthy lifestyle that can avoid the problems associated with obesity. The discussed keys on living a healthy lifestyle are: eating a balanced diet, being physically active and avoiding harmful behaviors. The lesson explains that a balance diet includes foods from every food group and avoids foods that are high in fat and sugar. The lesson clarifies that sport drinks and fruit juices are often high in sugar and should be consumed in moderation. The lesson also clarifies that being skinny is not the same as being healthy, which is a misconception in the general public. The health scenario explains that being physically active varies depending on the age of every person and their time availability. For example, children should be physically active 60 minutes every day, while adults should try to be active 2.5 hours a week.

### 4 User Study

Using You, M.D. we performed an initial user study to analyze the effects and interactions of: 1) the user’s gender, 2) the user’s BMI and 3) the virtual human’s BMI on the user’s perceptions of the virtual human. Our goal with this study was to understand if dynamically selecting a virtual human with a BMI closer to the BMI of the user would improve the user’s confidence in the knowledge received from the virtual human.

For this purpose, during the greeting stage of the interaction user’s gender and BMI were collected. In addition to this data collection, users were randomly assigned to:

- Interact with either a non-obese or an obese version of the same virtual doctor in the instruction stage of the interaction.
- Interact with either a non-obese or an obese version of the same virtual patient in the recall stage of the interaction.

This assignment is presented in Figure 4. On all conditions, gender of both the virtual doctor and the virtual patient were selected to be concordant with the gender the user input. This was done to remove possible confounding factors of gender difference, considering contradicting findings in the literature relating to users’ preference for
Lesson selection was also considered as a factor during data analysis. As mentioned before, three lessons were available to the users (asthma, melanoma, and health & wellness). The lesson selection was left to the users. Lessons differed in content and duration, but were consistent in procedure and level of the information provided about each subject.

Our initial hypothesis for this study were:

**Hypothesis 1:** The virtual doctor’s BMI concordance status is expected to have an effect on the users’ perceptions of the virtual doctor as knowledgeable and the user’s confidence in the information received from the virtual doctor.

**Hypothesis 2:** The virtual patient’s BMI concordance status is expected to have an effect on the users’ belief that the patient will follow the advice they have provided.

**Hypothesis 3:** Both the virtual doctor’s BMI concordance status and the virtual patient’s BMI concordance status are expected to have an effect on the user’s willingness to apply the information received for their own life.

### 4.1 Dependent Variables

<table>
<thead>
<tr>
<th>Number</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>How knowledgeable was Dr. Blackwell about [asthma</td>
</tr>
<tr>
<td>Q2</td>
<td>How well will your patient follow your advice about [dealing with asthma</td>
</tr>
<tr>
<td>Q3</td>
<td>Asked for information that was provided to the user during the interaction.</td>
</tr>
<tr>
<td>Q4</td>
<td>After talking to Dr. Blackwell and your patient, do you plan to change [your exposure to irritants such as smoke</td>
</tr>
</tbody>
</table>

### Table 1. Survey questions

All dependent variables were measured as self-reported measures during the exit survey. The exit survey contained four questions, which are summarized in Table 1.

- Questions Q1 and Q2 asked about the virtual doctor (Dr. Blackwell) and the virtual patient (your patient) respectively. Answers to Q1 and Q2 were measured on a five-point ordinal scale with 1 being the lowest ranking (e.g., “Dr. Blackwell was not knowledgeable at all”) and 5 being the highest (e.g., “Dr. Blackwell was extremely knowledgeable”).
- Q3 was a retention question about information provided during the interaction. The information requested on this question was repeated at least two times during the lesson. Answers to Q3 were used to remove potential outliers. Participants who did not respond correctly to this question were removed from the data set.
- Q4 asked users if they would be willing to apply the knowledge received during the interaction by changing their habits regarding one of the discussed risk factors. The particular risk factor in the question depended on the selected lesson. The risk factors were: smoking (asthma), UV radiation (melanoma), and lack of physical activity (health & wellness). The answers to Q4 were different based on each lesson. Each answer categorized users into two groups: not willing to change (e.g., “I do not wear sunscreen and do not plan to change that.”) and willing to change (e.g., “I do not wear sunscreen but plan to start using it.”).

### 5 Results & Discussion

We define a complete interaction as one that went through all four stages of the procedure. A total of 780 complete interactions were...
recorded from the exhibit in the span of a year and a half. Additional refinement of the data was done using the data from the depth camera of the Kinect. Data from the following cases was excluded from the data set:

- Multiple people interacting with the exhibit at a time. 263 data points were removed by this criterion. (See Figure 5.c)
- Sensor errors that lead to height or weight being misreported. 105 data points were removed by this criterion.
- Users who fail to conclude the interaction and have someone else finish it for them. 61 data points were removed by this criterion.
- User BMI reported by the sensors between 29.8 and 30.2. These data points were excluded as there was a potential to misclassify them due to sensor imprecisions. 5 data points were removed by this criterion.

Figure 5 shows examples of users interacting with the You, M.D. exhibit. Notice that Figure 5.a and Figure 5.b are examples of the type of interactions that were included in the data analysis, while Figure 5.c is an example of an interaction that was excluded from the data set as it included multiple people interacting with the exhibit at once.

The average length of the remaining 346 interactions was 3 minutes and 52 seconds with a standard deviation of 42 seconds. Additionally, 13 interactions were ruled as outliers based on their duration. These 13 interactions were longer than the average length of interaction plus three standard deviations.

Removing these cases, a total of 333 (209 female, 124 male) interactions were recorded. From these interactions, 180 (54.1%) users selected the asthma lesson, 78 (23.4%) selected the melanoma lesson and the remaining 75 (22.5%) selected the health & wellness lesson.

One of the goals of You, M.D. is to increase public health literacy and awareness of the described lessons. The effectiveness of the interaction at raising awareness and promoting good habits was measured by Q4 in the survey. As stated before, answers to Q4 classified users into two groups: users with an intention to change their habits based on the interaction, and users with no intention to change their habits based on the interaction. Out of all the users, 37.5% reported they were likely to change their habits based on the interaction. For the health & wellness lesson, 59.0% of users reported intention to be more physical activity. For the melanoma lesson, 49.3% of users reported intention of limiting their exposure to UV radiation. Finally, for the asthma lesson, only 23.3% of users reported intention to change their exposure to irritants.

### 5.1 Perception of the Virtual Doctor’s Knowledge (Q1)

#### 5.1.1 Results

Table 2 shows the mean BMI of users by gender and BMI concordance with the virtual doctor. Responses from users to Q1 (“How knowledgeable was Dr. Blackwell about the topics discussed in the lesson”) were analyzed using a factorial ANOVA. This ANOVA included three factors: 1) BMI concordance status between user and virtual doctor, 2) user gender and 3) the selected lesson. The results of this ANOVA show a significant interaction effect ($F(11, 321) = 4.825$, $p = 0.029$) between the user’s gender and the concordance between the user’s BMI and the virtual doctor’s BMI. Female users on average reported perceiving the virtual doctor with discordant BMI as more knowledgeable ($M = 4.26, SD = 0.11$) than the virtual doctor with concordant BMI ($M = 3.93, SD = 0.10$); male users, on average, reported perceiving the virtual doctor with discordant BMI as less knowledgeable ($M = 3.53, SD = 0.16$) than the virtual doctor with concordant BMI ($M = 3.78, SD = 0.15$). The test also showed that gender was the only significant main effect ($F(11, 321) = 11.085$, $p = 0.001$). Female users reported on average perceiving the virtual doctor as more knowledgeable ($M = 4.10, SD = 0.08$) than male users ($M = 3.66, SD = 0.11$). The statistical significance of gender as a main effect is confounded by the two-way interaction effects and interpretation of this result requires caution.

### 5.1.2 Discussion

Figure 6 shows the marginal means for the statistically significant interaction effect between the BMI concordance and user gender. These results indicate that when users interact with the You, M.D. exhibit, BMI concordance between user and virtual doctor in the instruction stage can have different effects depending on the gender of the user. Female users, on average, find the virtual doctor to be more knowledgeable when the virtual doctor’s BMI is discordant from their own BMI, while male users find the virtual doctor to be more knowledgeable when the virtual doctor’s BMI is concordant with their own BMI. Vugt et al. [16] found similar results in which facial similarity between the user and the virtual human affected male and female users differently.

While user gender resulted to be a significant factor in our study, there is no evidence in medical literature that patient gender can affect knowledge transfer between doctor and patient or doctor trust. However, metaanalysis conducted by Hall et al. [7] does show that patients show more satisfaction and trust female physicians more. In our study, the virtual doctor’s gender was always concordant with the user’s gender. One possible explanation for the observed differences between genders, could be related to female users interacting with a female virtual doctor. However, it is important to notice that during interaction with the virtual doctor, users were learners and not patients. Therefore, additional research is required to identify if the differences arise from interacting with the female virtual doctor or the male virtual doctor, or just from the user’s gender.

These results support our hypothesis that the virtual doctor’s BMI concordance status can have an effect on the users’ perception of how knowledgeable the virtual doctor is. However, we did not anticipate this effects being tied to the user’s gender as well. The initial implication of these results for the You, M.D. exhibit is that for the instruction stage, dynamically selecting a virtual doctor with discordant BMI for female visitors and a virtual doctor with concordant BMI for male visitors can improve user’s confidence in the information received. However, one limitation of these results is that the result only applies to the person directly interacting with the You, M.D. exhibit and not to other users.
members that accompany the person to visit the exhibit.

Another limitation of these results regarding gender is the imbalance between genders. More male users are needed to fully understand the effects of the user’s gender on their perception of knowledge. However, given the public nature of the You, M.D. exhibit and considering the randomness desired in the population, achieving a more balanced sample of the population might not be possible.

5.2 Virtual Patient Adherence to User Advice (Q2)

5.2.1 Results

Responses from users to Q2 (“How well will your patient follow your advice about the topics discussed in the lesson?”) were analyzed using a factorial ANOVA. This ANOVA included three factors: 1) BMI concordance status between user and virtual patient, 2) user gender and 3) the selected lesson. None of these factors resulted statistically significant in our analysis. Additional analysis also looked at the effects of the virtual patient’s BMI by itself on the answers to Q2, and this was not statistically significant.

5.2.2 Discussion

Our results show that BMI concordance between the user and the virtual patient was not statistically significant factor on the answers provided for Q2. Previous results by Persky et al. [11] found that medical students rate obese virtual patients as less likely to follow their recommendations than patients with non-obese BMI. In order to understand the differences from these two sets of results, first it is important to notice that our first analysis takes into account the concordance relationship between the user’s BMI and the virtual patient’s BMI, instead of taking into account the virtual patient’s BMI by itself. While, Persky’s study did measure the medical student’s BMI, the presented results do not specify any analysis performed to test for correlations between the medical student’s BMI and the negative ratings towards obese virtual patients. Additional research is required to study if the results found by Persky hold when the user’s BMI is taken into account.

Furthermore, we performed analysis for the effects of the virtual patient’s BMI by itself, which resulted to be not statistically significant. An explanation for this difference in results is the target populations of each study. While Persky’s study looked specifically at medical students’ views, our study looks at the views of a broader audience. Our results point out that bias against obese virtual patients being less likely to follow advice than normal BMI virtual patients, could be present only on the medical community and not in the general public.

While we did not find significant results for the visual appearance of the virtual patient we believe that additional research considering other elements of the visual appearance of the virtual patient should be conducted to find if other elements can impact the user’s perception of the virtual patient, as our findings for the virtual doctor do support that an experience that is tailored for the user can improve confidence in the knowledge received. Additionally, the differences in the results are an indication that the role the user plays in the interaction (i.e. learner taking knowledge from a virtual doctor or instructor giving advice to a virtual patient) can also have effects on how the visual appearance of the virtual human affects user’s perspectives and knowledge transfer.

6 Additional Discussion

This section discusses the advantages and limitations that arise from having run the user study in the setting of an interactive museum exhibit such as You, M.D.

6.1 Advantages of You, M.D.

The main advantages of using an interactive museum exhibit for user studies similar to the one presented are: access to large sample of participants and sample diversity.

Large sample: You, M.D. has been installed at the Museum of Science and Industry (MOSI). The large number of daily museum visitors gives potential for running studies with a large user base. The presented study, for example, had a sample of 333 participants.

Sample diversity: The sample of museum visitors consists of a diverse group of people. The sample includes people from a wide range of ages, races and economical background. This sample diversity is not common in related literature which has usually studied focused groups (e.g., college students).

6.2 Limitations of You, M.D.

The main limitations of using an interactive museum exhibit such as You, M.D. for user studies similar to the one presented are: limited
attention span of participants and limited control over procedure of participants.

Limited attention span of participants: Museums visitors have a limited attention span for each exhibit they interact with. The limited attention span is caused partly by the amount of exhibits in the museum as a whole and the limited amount of time for the visit. This time constraint limited the length of the interaction and the amount of information that could be gathered from the visitors as part of the survey stage.

Limited control over procedure: The public nature of the exhibit limits control over the procedure, which can lead to many potential confounds. Some of these potential confounds were addressed using the information from the Kinect. The addressed confounds were: multiple users interacting at once, user not standing on scale, and when a user concluded the interaction for another user. However, not all potential confounds were addressed. One such confound was the possibility of having one museum visitor interact multiple times with the exhibit.

7 CONCLUSIONS

Our results show that people react differently to virtual humans depending on many factors. These factors include but are not limited to: 1) the user’s gender, 2) the concordance between the user’s BMI and the virtual human and 3) the role the user plays in the interaction. Understanding the role of these factors in the transfer of knowledge between users and virtual humans is key to creating impactful virtual human experiences that cater to each user individually. Creating such impactful experiences is made possible by both the dynamic nature of virtual humans and technology that makes gathering information from the user possible.

The presented results show that in the setting of interactive museum exhibits that teach users about health topics, using virtual humans with discordant BMI for female users and virtual humans with concordant BMI for male users can, on average, lead users to report a higher perception of knowledge from the virtual human. This perception of the virtual human as more knowledgeable can raise interest from the users and help get information to the users more effectively. However, it is important to notice that additional research is required to understand if and how this effect translates to other virtual human experiences.

8 FUTURE WORK

For this particular study, users always interacted with virtual humans with the same gender as the one selected during the greeting stage of the interaction. This was done to try to keep the number of conditions manageable and to be able to understand the effects of BMI concordance better. However, our results show that gender was in fact a significant factor in the reported perception of how knowledgeable the virtual doctor was. For future work, we would like to run a similar study in which users also interact with virtual humans of different gender, to better understand the gender effects that can arise when interacting with virtual humans in a setting like You, M.D.. We also propose that this study should include a qualitative research component with interviews of a portion of the museum visitors after interacting with the You, M.D. exhibit. These interviews can provide a better understanding of the user experience and how the elements of the visual appearance of the virtual human affect the museum visitors.

Also in future work, we plan to look at the effects of other factors of the visual appearance of virtual humans such as skin tone. We plan to study how concordance in skin tone between the user and the virtual human affects the users’ perception.

9 ACKNOWLEDGEMENTS

Funding for the You M.D. exhibit was provided by NSF Grant award IIS-0803652. David Conley, Richard Prevoznak and other members of the Museum of Science and Industry Staff helped as co-designers of the exhibit and provided the space for the exhibit. David Lind, M.D., and Juan Cendan, M.D., medical professions collaborators, provided the content for the described lessons. Joseph DiPietro, Ph.D., education collaborators, assisted in creating the structure for the described scenarios. Willie Maddox, Aaron Kotranza, Ethan Blackwelder and Lois Cao assisted in developing and deploying the system at MOSI.

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