

# Body as a Canvas: An Exploration on the Role of the Body as Display of Digital Information

Thuong N Hoang<sup>1,2</sup>

<sup>1</sup>School of Information Technology  
Deakin University  
Melbourne, Australia  
thuong.hoang@deakin.edu.au

Hasan S Ferdous, Frank Vetere, Martin Reinoso<sup>2</sup>

<sup>2</sup>School of Computing and Information Systems,  
The University of Melbourne  
Melbourne, Australia  
{hasan.ferdous; f.vetere; martin.reinoso}@unimelb.edu.au

## ABSTRACT

The human body in HCI is often seen as an actuator for issuing commands and providing input to digital systems. We present the concept of the *body as a canvas*, in which the body acts as both an actuator and a display for information. Body as a canvas creates an interaction loop where interaction with information causes changes in the body, which in turn changes the display of information. Our qualitative study using an on-body projection system in a public exhibition investigates this concept with regards to body characteristics, types of body input, interactions between multiple bodies, and comparison to other display technologies. Findings show that body as a canvas creates connectedness between the body and information. Finally, we discuss how body characteristics and appearances can complement the information, when the body acts as a canvas.

## Author Keywords

Body as a canvas; body display; augmented reality; virtual reality.

## ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

## INTRODUCTION

The human body is central to human-computer interactions (HCI), as our interactions with the world is mediated through the living bodies [6, 20]. Some ethnographers consider the body as a *site of knowing* [5] where the researcher absorbs their body into the subject culture as an instrument for fieldwork. In traditional human-machine systems, the body typically acts as an actuator, issuing commands and providing input signal through control devices (e.g. mouse) and language-based interactions (e.g. keyboard or voice) (Fig. 1a). In more advanced systems, the body can provide

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Figure 1: (a) In traditional human-computer systems, the body is mostly an input channel.

(b) When then body is a canvas, it acts as both input and output to the interaction.

input through sensors that detect human movement or bio-signals (e.g. body temperature or heart beat). In each case the body is a conduit for input. The output is perceived through human senses (e.g. sight, hearing, proprioception), but it is generally rendered on an external device, such as a digital display.

In this paper, we present the concept of the *body as a canvas*, in which the body acts both as an actuator and a display for information (Fig. 1b). When the body is both the mechanism for activation and the surface for rendering information, a unique *interaction loop* is created. In this loop, the interaction is enacted through the body in response to the displayed information, which simultaneously changes the way the information is displayed on the body.

The use of the human body as a canvas has been explored by others, in particular by artists who practice body-painting to transform the body into new forms or make it vanish by blending it into the background. This idea is also investigated by HCI researchers working with interactive technologies related to human bodies. For example, Levisohn placed parts of the body behind a video see-through display to explore proprioceptive and kinesthetic awareness [19]. Johnson and Sun [14] projected virtual body organs on the body in an educational game. Javornik et al. [13] overlaid virtual make-up on the faces of performers through an augmented reality mirror to assist them in getting into respective character roles. In these examples, the body serves solely as a carrier of information.

Our exploration of the body as a canvas (BAAC) specifically focuses on the role of human body as both an actuator for

input and a display for information. We investigate four issues related to body as a canvas: (i) the effect of body characteristics and appearance on the information; (ii) the type of body input signal that triggers the interaction loop; (iii) the interactions between multiple bodies as canvas; and (iv) the comparison of BAAC to other display technologies. We conducted a qualitative study of an on-body projection system in a public exhibition setting. Our findings suggest that BAAC creates connectedness between the information and the body. Body characteristics and appearances such as shape and clothing can complement the information that is displayed on it.

We begin by discussing the related work leading to our concept, and then present the findings of the study.

## RELATED WORK

### Body as an Actuator of Information

Perhaps the most obvious role of the human body is as an actuator, or a source of input for a computational device. HCI has contributed greatly to this perspective. Whole body interaction [7] has a holistic view of the body as a source of multiple input signals, including physical, physiological, cognitive, and emotional. Body tracking technologies capture bodily information such as movements [27] and bio signals [4], or appropriate body parts such as skin [10] or the ear [16] through on-body sensors. More recently, much of the discussion about the body in HCI has been influenced by notions of embodied interaction [6]. This perspective leverages our perception about our own body through physical and social interactions, and channels that familiarity into the interactions with and through computing devices. Taking this view, our bodily perception and actions are not separable, but always exist and evolve together.

The body as actuator can be considered both a mechanism for input and a conduit for other computations systems. For example, Mistry et al. [26] propose a technique to transfer information between different devices, using the body as a metaphoric medium to carry data in a copy and paste fashion. While the actual data is transferred in the cloud, the technique creates the illusion of using the body as a medium. In another work, Sakata et al. [30] consider the body as a conduit for emotions through dance movements and present a classification model to map the effects these dance movements in communicating emotions.

### Body as a Display of Information

A less common role of the body is as a display of information. In *SixthSense* [23, 25], a neck-worn projector puts a numeric keypad on the hand of the wearer and a digital watch displayed on the wrist. Levisohn [19] uses the body as a tool to explore proprioceptive and kinesthetic awareness using a mixed reality system. He built an optical see-through interaction box that displays visual distortions of the user's hands as they interact with physical objects. Levisohn's device does not render the image directly on the hand, but overlays on a see-through screen over the hand. He

discovered that delayed video and audio signal bring the user back and forth between immersion and self-awareness, or an oscillation in the user's connection with the digital information.

Johnson and Sun [14] built a game called *Augmented Anatomy* that projects virtual body organs on the body of players, who score points by correctly identifying the names of the organs. They discuss the concept of ownership of virtual artefacts through their incorporation onto the body, applied towards the context of learning in anatomy. Their study conducted with teachers and students shows an increase in the subjective level of interest in anatomy and computer science subjects. Saakes et al. [29] employ a similar on-body projection in a system called Mirror Mirror for designing t-shirts.

Instead of the whole body, Mercier-Ganady et al. [22] superimpose EEG (electroencephalography) visualization of a virtual brain on the user's head in a system called Mind-Mirror. The system uses a Microsoft Kinect camera for face and head tracking and displays a video mirror with overlay on a screen in front of the user. A pilot study was conducted to compare the system against the traditional temporal gauge visualization that displays brain concentration and relaxation levels. The result showed a comparable performance in terms of its usage as a feedback mechanism for brain computer interface.

Using a similar 'augmented mirror interface', Javornik et al. [13] developed a system that overlays digital makeup on the face using a tablet with a front facing camera. Their work aims at assisting the task of role playing, especially for theatrical performers who need to become a character through virtual make-up. An observation study in an opera dressing room with singers and make-up artists demonstrates that the visual effect makes a strong impression for the users leading to an easy and immediate transformation into the portrayed fictional character.

Displays comes in all shapes and sizes, and so do bodies. Previous work that discuss body as a display of information leave out an important discussion about the effects of body characteristics (such as size and skin tone) when considering it as a display tool. Just as Gemperle et al. [9] explain that the human form and size variations impose challenges in the design of wearable technology, we are similarly intrigued by the question of how body characteristics affects the role of the body as display of information.

### Technologies for Displaying Information on the Body

In order for the body to act as a display, information needs to be placed on the body. Virtual and augmented reality technologies are most commonly used for this purpose, as they have the visualization capability to enable information to be displayed on or as a part of the body.

Virtual reality (VR) can provide a virtual environment where information can be displayed directly on the user's virtual body [12]. In order to provide the illusion that the



**Figure 2: A demonstration of the blood circulation, skeleton, and muscular system's projection on body.**

information is displayed on the body, VR technology needs to recreate the body in a virtual environment [17] in such a way that there is a strong alignment between the physical and virtual bodies. A relevant project that demonstrates this concept is Onebody [12], a technology for teaching martial arts. Onebody is a VR remote posture training system that provides the student with a first-person view of their teacher's virtual body superimposed on their own virtual body. Using an immersive VR headset, the student can follow the movement as demonstrated by the teacher and match teacher's posture with their own.

Unlike VR, augmented reality (AR) systems allow the physical body to be present in the interaction. For example, screen-based AR employs cameras to track the body of a user standing in front of it, to produce an augmented mirror effect showing information overlay on the body [3]. Spatial AR [2] uses projection mapping to change the appearance of physical substrate, including the human body [11, 14]. Augmented Studio [11] is an example of a spatial AR system that projects virtual muscle and skeleton information on a volunteer student's body for physiotherapy education in a classroom. Students observe virtual anatomy mapped on the volunteer's body as a teacher explains the mechanics of body movements. In Augmented Studio, the body complements the virtual information (display) with direct coupling of body movements (input), enhancing the consumers' understanding of the information. Projection mapping on the body raises the question of how the different body shapes and characteristics impact on the display of the information. For Augmented Studio, accurate alignment of virtual muscles on the body is important for physiotherapy teaching.

### Body as both Actuator and Display

Instead of constraining the roles of the body either as actuator or display, Onebody and Augmented Studio integrate both functions. Onebody takes input from the teacher's movements and displays directly on the student's body. Augmented Studio has a similar approach: it captures dynamic movements of the body as input, to couple with a virtual anatomical avatar, which is then projected back onto the same body as a display.

There is a tight coupling of the body as actuator and display of information. The body as actuator inevitably requires

changes to the body, through movements or gestures. When the body also acts as a display for information, the changes enacted through body as an actuator affects the way the information is displayed on the body. Changes in the display can trigger further changes in the actuator role. We refer to this cycle as an *interaction loop*.

The interaction loop can be illustrated by a variation to SixthSense system by Mistry and Maes [24]. When the SixthSense system projects the numeric keypad on the palm and fingers of the hand, the user typically presses the buttons with the other hand. The numeric keypad projected on the hand does not change when the hand moves. If, instead, we consider the interaction on the same hand: as the thumb reaches out to touch the keypad on the fingers, the system needs to readjust the numbers as the hand moves, then we would have an interaction loop. There would be a tight coupling between the body as actuator (moving the thumb) and the display on the body (readjusting numbers). This interaction loop forms the basis for our concept of BAAC, where the body as actuator and as display are tightly coupled.

Another example of the interaction loop is a method for eye-free interaction called proprioceptive interaction [21]. A wearable bracelet captures input from the user's arm using an accelerometer and sends output to the user's arm through electrical muscle stimulations that place the wrist in certain poses. The user interacts with the input and output channel through proprioceptive sense. In this example, the interaction loop remains on the same channel (muscular actuation and stimulation). The BAAC concept in this paper further expands the input output loop from different channels, i.e. output is body surface as display, and different varieties of input, including movement and heart rate.

### AIMS

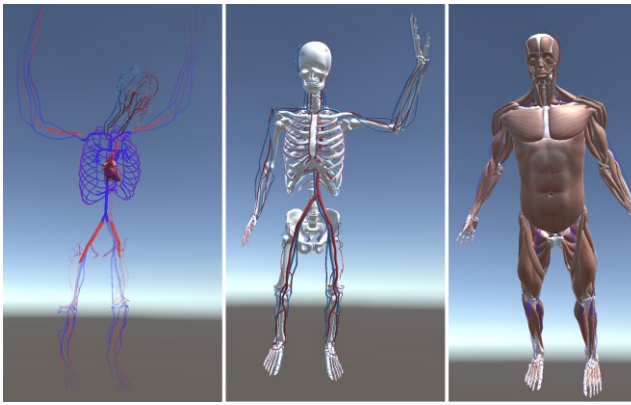
Even though there are many examples of BAAC in existing literature, there are many aspects of BAAC yet to be investigated. This paper aims to address four questions:

Q1. *What are the effects of body characteristics on the display of information?* How do particular body characteristics (e.g. body size and shape, skin tone or clothing) highlight, accentuate, or detract from the role of the body as a canvas? There could also be sensitive issues related to body image and self-perception of the body, to be considered when designing with BAAC.

Q2. *What types of input signal cause interaction loop?* In addition to the body movement (physical signal), we aim to investigate how other body input signal, such as heart rate (physiological), affects BAAC.

Q3. *What are the interactions between multiple bodies as a canvas?* We extend existing works by creating a different type of third-person view, where two people can look into and interact with the body canvas of each other.

Q4. *How does body as a canvas differ from other display technologies?* We investigate the potential benefits and



**Figure 3: Views of the Inside-Out system**

(a) Blood circulation, (b) Skeleton, and (c) Muscular view

challenges for using BAAC compared to traditional display technologies like television screen.

We explore these questions about body as canvas, through an on-body projection system called *Inside Out*. The system is based on the Augmented Studio [11], where a virtual musculoskeletal system is projected on the body and the projected skeleton and muscles move as the body moves. We extended it to project the blood circulatory system and an animated heart based on live pulse rate data. Thus the internal body structure and organs become visible from outside of the body (see Fig. 2 and Fig. 3).

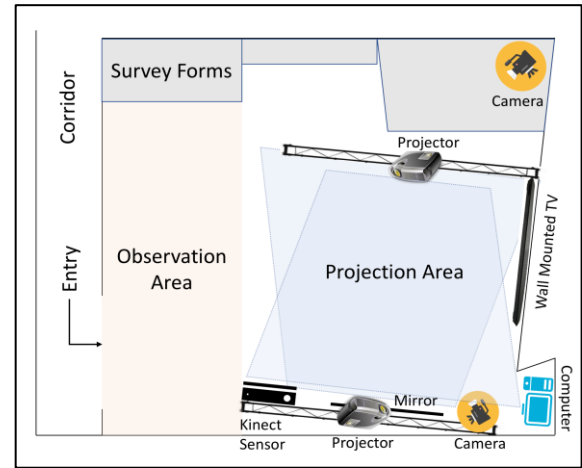
The *Inside Out* system was deployed as an installation in a public exhibition. This provided an opportunity for us to explore the effects of different body characteristics and appearances on BAAC (Q1). To explore Q1, we used a fitness wristband to capture the heart rate of a user and map to the heart beat animation and blood circulation visualization. The heart beat information introduced a physiological input signal into body canvas (Q2). We enable projection on two bodies to explore the interactions of multiple bodies as a canvas (Q3). In the exhibition, we installed a mirror and a TV screen showing the same virtual circulatory visualization as on the body to contrast screen-based display versus body canvas (Q4).

## STUDY DESIGN

### The *Inside Out* Exhibition

The *Inside Out* system includes a generic virtual circulatory visualization with a pumping heart and major arteries and veins that light up in blue or red colors to indicate blood flow to and from the heart, respectively. *Inside Out* can also switch between different views (muscular or skeletal) for the visitors. We used a Microsoft (MS) Band as the fitness tracker to capture heartrate. The visitor provides bio-signal input to the system to be projected back onto their body.

We deployed the *Inside Out* system for 6 days (Monday to Sunday in one week, except Saturday) as part of a public exhibition. Visitors who came to our installation were generally interested in the larger exhibition season that we were a part of, which had the theme *blood* and its evocation



**Figure 4: The Inside Out study setup.**

of taboo, stigma, donation, identity, health, and sport. One member of the research team demonstrated the system and invited the visitors to try it out themselves from 12PM to 6PM Monday to Friday, and 11AM to 2PM on Sunday.

We conducted a qualitative study during this exhibition opening period to investigate the user experience with regards to the four questions mentioned above. We performed observations and interviews of visitors' experiences, collected surveys, and present our findings in this paper.

### Study Protocol

As part of the BLOOD exhibition by the Science Gallery Melbourne, the *Inside Out* system was set up in a studio with projectors, television screen, and Microsoft Kinect sensors (Fig. 4). At the beginning of the exhibition, we calibrated the room using Microsoft Room Alive API [15] and placed posters in different parts of the exhibition area advertising the installation. We implemented the infrastructure as described in the Augmented Studio system [11].

The visitors would enter the room and stand in the *observation area* (Fig. 4), which was delineated by tape markings on the floor. One researcher stood in the *projection area*, wearing white clothing for maximum projection effect. The system projected a generic virtual circulatory, skeletal or muscular model onto the researcher's body and mapped to his movements. The research described the system to the visitors briefly, and then invited them to participate in the projection area. Participation was voluntary. As the participants stepped into the projection area, the researcher assisted the participant in putting on the MS Band. As the researcher stepped aside, the projection of the virtual body locked onto the participant's body instead. The research explained the circulatory system, skeletons, and muscles as it was displayed on the participant's body. The blood circulation visualization was then mapped to the participant's heart rate, as captured by the MS Band.

The system could track and project on up to two bodies in the projection area. The same anatomical model was also displayed in the large television screen (Fig. 4). Both the



participants (in the projection area) and visitors (in the observation area) could watch the on-body projection and on the television screen. The participants could also see themselves in a mirror placed in front of them. The participants could move freely around the projection area. They were not asked to perform any particular task. They were allowed to explore the system in any way for as long as they wished. A researcher manually switched between different layers upon request or as needed. One researcher undertook an informal interview about the participants' experience of the system. Participant then completed a short survey upon exit.

### Participants

Participants were visitors who voluntarily came to the exhibition. About 600 visitors visited the installation to watched the demonstration, among which 275 people (mostly adults, 117 male and 158 female) participated in the projection area, either alone or with another visitor. Average participation time was 2.7 minutes, with standard deviation of 1.05 minutes.

### Data Collection

One researcher observed and took field-notes throughout participation. The installation area was video recorded using two video cameras – one recording the overall area including the visitors and participants, another recording the participant's activities in the projection area.

We collected observational field notes during the 33-hour deployment period, 66 hours of video recorded observations (with two cameras) that included participants interaction with the system as well as their informal interview with the research team members, and 206 survey responses. In order to avoid confirmation bias in the participants' responses, at no point during the interaction with the visitors did the researcher mention or discuss the concept of BAAC.

We designed an exit survey to capture an understanding of the user experience of the system. We asked the visitors 3 questions regarding their experience, and their connection to the information that was projected on their body. We used visual analog scale response to the questions by asking the



**Figure 5: A participant interacting with the Inside Out system.**

participants to mark their answer on a line with “Completely Agree” on one end and “Completely Disagree” on the other. Two of the questions focused on the user satisfaction metrics of user experience [1] and asked about engagement with the system and novelty of the visualization: *I find engaging with the system as good fun*, and *I feel intrigued by the system because it shows internal body organs externally*. We asked one question regarding their connection to the virtual anatomy: *I could relate to the projection as my own body systems*. The survey was conducted after their interaction and discussion with the researcher, in order not to introduce confirmation bias to the field notes and interview analysis. We also asked them to write comments on their experience.

### Analysis

We performed descriptive statistical analysis on the survey data and thematic analysis on field notes, interview transcripts, and video recorded observational data to add detailed notes of all interactions with the *Inside Out* system and among the visitors themselves. These notes were coded in Nvivo and refined through discussions amongst the authors. The analysis focused on the impact of the four issues in Q1-4 above on participants interactions with the system and with one another. This analysis was done iteratively to identify common themes across participants as well as their unique activities.

### FINDINGS

We present the findings based on this field study. We begin with an overview of the survey data analysis and then focus on findings based on qualitative analysis of our field notes, interviews, and video recorded observation data.

#### Survey Data

Out of the 206 responses, we have 148 fully completed responses. We converted the visual analog scale to a numeric value, with 0 for completely disagree and 100 for completely agree. We summarized the descriptive statistics of the three questions regarding engagement, intrigue, and relation. A high mean score of 87.37 for engagement (SD 18.3) and 69.8 for intrigue (SD 29.8) indicates a fun and engaging user experience interacting with *Inside Out*. Participants also rated that they highly relate to the projection as their own body system (mean 77.2, SD 23.2). While the survey data does not add to the core research questions, the questions were focused on measuring engagement and intrigue, which was useful information for our exhibition partner. We include in the analysis for completeness.

#### Interaction Loop

*Inside Out* is designed to explore the interaction loop concept with the heartbeat sensor as input and the virtual heart animation on body as output. Our analysis highlighted different aspects of this interaction loop related to self-reflection, connectedness, and education.

#### Connectedness with Information

*Inside Out* used generic anatomical models for projection; only two aspects were personalized: a) the heart-beat animation reflected the pulse-rate of the participant wearing

the Microsoft Band, and b) the movement of the anatomical models reflected the movement of the participants in the projection area, as tracked by the Kinect sensor. Despite such minimal personalization, many of our participants could closely connect themselves with what they saw on the screen and the image projected on their body. A common question among the participants about the projection of blood circulation system was “*Is that [emphasis] ‘my’ beating heart?*”. Similar reaction was also observed when we projected only the heart animation. When we explained them about the generic model, some of them wished they could see their “*own*” body’s internal organs. In one instance, when we switched the wristband from one participant to another, it was still showing an elevated heartrate of the previous wearer. The new participant noticed the higher heartrate and exclaimed “*That’s not my heart-rate*” and when it readjusted to hers after a few seconds, she said “*That’s more like me*”.

In many cases (12 instances counted in the video analysis and notes) the participants tried to do some exercise on-spot to see the elevation in their pulse rates. They expressed their satisfaction when they could notice the differences both in the MS band and on their projected animation of quicker heartbeat and blood flow. This solidified their perception of the heart being their *own*.

#### *Reflection of Body Perception*

On many occasions (19 instances), participants reflected about their own body comparing to the anatomical model, when their body became a canvas for the 3D model. Most of the participants tried to flex their biceps muscles and looked at the mirror to compare it on the anatomical model on screen. One of them commented, “*My muscles are appeared (sic) large on screen than they are, but this is appreciated.*” The virtual muscular model used in the exhibition was purchased from a 3D model store, which depicts an ideal human male body. Overall our participants’ activities highlighted their perception of how this *ideal human body* compared to their own body and their inherent desire to achieve one.

Our participants were also aware about how their body was different from the idealized anatomy model. Many of them found humor (18 instances) about the *six-pack* abdominal muscles of the model projected on them and said, “*I don’t have a six-pack*”. While some of them already knew, but the rest of them found it engaging to know, through discussion with the researchers, that all humans have a six-pack muscle structure, which is often not visible or as prominent as the anatomical model shown.

Participants’ reflection about the body was not limited to how their body looked, but also how it functioned. For example, when their pulse rate was a bit deviated from the typical rest heartrate, some of the participants hurriedly explained that they “*were nervous*” or expressed uneasiness about it. A male visitor in a pair said to his friend: “*your heartrate is high [pointing to screen and then gesturing on*

*her body that her heart is moving quickly, both laughs]*”. She replied: “*It looks like I am nervous [laughs]*”.

Another scenario was that sometimes the *Inside Out* system appeared to single out or draw attention to the participants’ physical appearance. Examples include when the system failed to track a very tall person due to its limited vertical field of view, or when the projection of the anatomy model may have highlighted obesity for some participants. These are sensitive issues related to self-reflection, equal participation, and body shaming, that needs to be considered when designing for BAAC.

#### *Gender*

An interesting contrast appeared around the perception of gender of the anatomy models used in the *Inside Out* system. We happened to purchase a male anatomy model for the project, but one of the participants noted in the survey, “*Such an interesting way to experience the biology. Muscle system was very masculine, is there male female variations?*” Some of the visitors suggested incorporating a female anatomy model too and expressed their opinion that the projection should reflect the correct gender identity. One of the visitors explained about a female participant in the projection area, “*She does not understand, underneath she is a male [in the projected skeleton model]*”. Such gender related concerns around the perception of body were further highlighted when some of our female participants (sometimes jokingly) covered their chest region when the bare muscles were projected on their body. Notably here, none of the male participants exhibited such gestures.

The model used for the exhibition is from an anatomy education project [12]. We found that the female virtual model by the same designer used exactly the same skeletal, circulatory and muscular (with the exception of added breast tissues) components. There was little difference between the male and female models. We discussed this concern with a physiotherapy lecturer, who confirmed that the current model was sufficient to be used in a physiotherapy classroom. Nonetheless, we anticipate that using only the male muscular model could lead to false representation. Therefore, throughout the study, we always clarified that the virtual projection was generic and did not result from scanning their bodies, to reduce false representation.

#### *Creating Connectedness with Others*

On the other hand, the *Inside Out* system highlighted the similarity that we all share in terms of our internal body organs, despite the differences in our outward appearances. Our visitors could not help but notice the similarity when they saw the projection on multiple people (including or excluding themselves). For example, one participant said about the projected skeleton view on her, “*Now I look like everyone else. We all have skeleton inside.*”

One interesting instance involved two friends participating together in the projection area. One participant who was wearing the MS band tried to elevate her heartrate by jogging

on the spot in the projection area, while her friend watched. After a while they both noticed the heart rate increasing. While the system only tracked one participant's pulse rate, the other person (who did not exercise) saw the same projection of quicker heart-beating on her body, placed her hand on the projected heart, and reported, "I feel my heartbeat growing!" Another participant commented about



**Figure 6: Two participants looking at the projection on each other.**

the two of them while standing in the projection area, "We are skeleton twins!", thus expressing the solidarity of their relationship. This scenario was found in 13 other instances in the video analysis and observation notes.

The effect of the interaction loop can be seen here for physiological signal: by displaying an elevated heart rate on the body, *Inside Out* causes the participants to feel as if their heart rate actually increases.

#### **Educational Reflections**

While we did not have any learning objective in this public exhibition setting with this particular system, our visitors and participants noticed the potential of using it for educational purposes. While compared to another VR headset based project in the same exhibition, one participant explained that he was a teacher and thinks, "for small group sizes, that's [VR] okay, but when you want to have a larger class size, this sort of arrangement is more practically useful". There was a consensus that this (or similar) systems could benefit the learning experience in the classrooms at various levels of education and domains.

One participant responded in the survey: "(the system) contextualize(s) internal body system beyond theoretical ideas and demonstrate(s) how it applies to my own body - particularly useful in classrooms and schools." The on-body aspect of the system was interesting to the users, one of whom noted: "I have done basic anatomy at uni, so have basic understanding. But seeing it on yourself makes it more real and relatable." Some of them thought similar system could be helpful in hospital settings too: "An interesting and informative way to learn about body systems. Could be used to help explain medical conditions really well."

On-body projection complements the participant's understanding of the anatomy. One participant commented: "To be able to see this system projected on to myself, was like seeing inside of my body. This perspective really helps to relate the internal to the external." Another participant reflected about the viewers' strong connection with the information presented on his/her body: "It helped me relate the system to myself on a personal level, as opposed to learning from a text book". Our participants expressed that such systems could benefit both the general public as well as people with extensive anatomical knowledge in disseminating their knowledge: "By seeing my muscles and skeletons in a way I have never seen before, I gain insight into how my body looks and operates", and "[the system provides] clear understanding of the spatial arrangement of blood vessels, of the rate of blood flow to different regions and relationship with the skeleton.". Another interesting response was: "It made my previous learning feel more relevant and applicable. I didn't learn more, but learned more about what it meant."

#### **Multiple Bodies as Canvas**

##### **From Spectator to Participant**

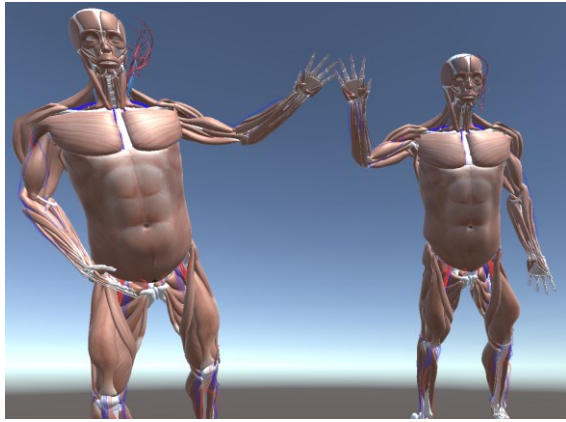
There were three different ways people engaged with the system – a) as a visitor, observing others in the projection area, b) participating in the projection area alone, and c) participating in the projection area with another, thus watching the projection both on his/her body and on the other participant at the same time. These three scenarios create different types of experiences among our participants.

At the beginning, a person entering the installation area would see one of the researchers or another participant walking in the projection area and may notice that person being tracked through the anatomy model shown on the television screen. The researcher in attendance made the effort of standing in the projection area whenever there was no visitor nearby. The intention was for the eye-catching nature of the visualization to draw the attention of visitors passing by the installation area. Through observation, such practice generally prompted curious visitors to approach for a closer inspection, and the research team member would describe the system and answer their queries. Many visitors asked us about the technology, especially how the person is being tracked. Some even thought that the system was using "X-Ray" to detect and display internal body organs. The researcher assured them otherwise and invited them to participate by standing in the projection area.

The transition from a spectator to a participant happened in a single step. At any point that the visitor stepped into the projection area, the system would start tracking their body movement and project the virtual skeleton, muscle or circulatory system directly on their body. The system tracked up to two persons in the projection area (Fig. 6) and ignored the rest if there are more than 2 people in the Kinect's tracking range. As an example, when one visitor from a large group of friends finally joined the projection area, he

exclaimed, “Now I see what you were doing [and made various body postures while looking at the projection and TV screen]”.

#### *Between Visitors and Participants*



**Figure 7: It was sometimes difficult to see who-is-who in the television screen.**

Many of our participants visited in groups, and tested out the system in turns. Both the visualization on the body and the live tracking of the person shown on the large screen brought enjoyment to the experience for all group members. In these cases, the functionality of the system was not of much significance, but the representation on the body, as well as the awkward poses of skeleton, muscles, and blood circulatory system made it enjoyable as a group.

In one scenario, a group of 5-6 friends were trying out the system. A couple of them joined the projection area and started making some dance movements and jumps. Other group members suggested they make different body postures and everyone laughed. At one instance, the visitors of this group chanted “*muscles, muscles*” to the research team member to bring out the muscles projection. As we did so, everyone including the participant busted into laughter, possibly at the contrast to the not so well-built body of the participants. As this group were leaving, their tracked virtual bodies on the screen twisted into irregular shapes as the participants were going outside of the tracking range, and multiple audience members burst into laughter. Finally, they waved goodbye to their respective anatomical model on the television screen. Similar farewell gestures were noticed for some other participants. All these interactions highlight the lighthearted enjoyment of the visitors as a group.

#### **Comparison between Different Display Options**

##### *Projection on Body versus Displayed on TV Screen*

There was no consensus on which output is better, but our participants highlighted the general ways these two display modalities enable different experiences. While the TV screen could provide more details of the anatomical model due to the screen quality and image resolution, the on-body projection could create a sense of spatiality of the anatomical body parts among the participants.

This was evident, for example, when there were multiple people in the projection area. The participants sometimes momentarily lost the understanding of who was whom in the TV screen, and they made various hand gestures to match them with their avatars on the screen (Fig. 7). One of them explained: “*You are disconnected there [point at TV], whereas you can instantly see it [the connection with the anatomical system] on body.*” In another instance, when two participants differed greatly in their heights, they explained, “*I could not see the height difference in the screen, but feels more personal on the body*”.

We placed a mirror in front of the participants to provide a viewpoint of themselves. Many participants (9 instances) commented on the mirror and the screen: “*I like the double view, people can stand there and watch you on the TV or projection and I can see myself on the mirror too. It’s unlike the VR system downstairs [referring to another VR installation in the exhibition], where people can’t see what I see on headset*”.

#### **Significance of Clothes in the Body as a Canvas**

There were many cases where the participants voluntarily altered their clothing to examine the projected information on their body. The exhibition occurred during the winter months where many visitors came in with layers of clothings. Without the researcher asking them to do so, many removed their coats or accessories (e.g., hand bag, scarf, etc.) to see the projection on a different layer of clothing. Some wanted to view it on different colored clothes. The visitors commented that circulatory system looked better on red clothes; the skeletal system looked great on black and the muscular system on white. The researcher often wore a white long sleeve t-shirt and white jeans on the day to demonstrate the projection on white clothing.

#### **DISCUSSION**

The themes of the finding largely address the four questions stated in the aims. Furthermore, the findings of the study highlight two effects of BAAC relating to the relationship between the consumer and information.

##### **Connectedness**

Our findings show that the *visitors had a strong connection with the information displayed on their body*. Many participants commented that when seeing the fast heartbeat animation on their body, they felt as if their heart actually beat faster. This happened especially during changeover of the MS Band when the device still showed the previous wearer’s heart rate. Another observation emerged when two friends interacted in the projection space. We used a single MS band to drive two virtual bodies, resulting in a situation where a visitor would see their friend’s heartbeat on their own body. After noticing the same projected animation of heartbeat on both of their bodies, many (mistakenly) exclaimed that both of them were in sync with their heartbeats, before understanding that the projection used one person’s heartbeat only to project on both. The visitors in fact reached out to feel each other’s heartbeats on the chest or on



the wrist. We were unable to confirm if this were in fact actually happening, but we can draw the conclusion that *BAAC connects the visitors to the information and to one another*.

We argue that there are two scenarios from our study observations that demonstrated a strong sense of connectedness with the information and with one another. The first scenario relates to the contrasting observations that while the participants felt as if the virtual anatomy were their own body, it also caused them to reflect on their own physical body (“*I don’t have a six-pack*”) in comparison.

The second scenario is when there are two bodies as canvas. Where two friends were interacting, both of them were told explicitly by the researcher that the visualization only shows one heart rate of whomever wore the MS band. Yet, the person, who was not wearing the band, empathized with the heartbeat animation on their body, both as their own (“*I feel my heart beat growing*”) and as the other’s (“*We are skeleton twins*”).

In effect, BAAC causes the participants to have emotional responses inwards to the self and outwards to others. We observed *a meaningful connection with the information, the self, and others when one’s body acts as a canvas*. We believe it was the connectedness that made the participants feel that the projection was their own skeleton, that their heartbeat was growing in tandem with the virtual heart, that their friend was their skeleton twin, that they look like everyone else because “*we all have skeleton inside*”, and that they wanted to wave goodbye to the skeletons.

We may attribute this connectedness towards the information loop and argue that the tight coupling of the interaction loop brings the body or the human closer to the information. The information in these two scenarios are visual body image and physiological signal. Through the close connection with visual body image and heartbeat, the individual reflects about themselves and connects to others.

### **The effects of body characteristics on information**

Through *body as a canvas*, the characteristics and appearance of the human body can *change the way information is displayed by enacting changes through their bodies*. In this section, we discuss how the body’s shape and clothing can affect the information.

The body effectively shapes the information. This type of interaction was only previously explored in other display technologies, including deformable [18] and shape changing display [8, 28]. Rasmussen et al. [28] approach the shape changing interface paradigm from a similar perspective as our body as a canvas: the convergence of both input and output onto the display technology. Their work outlines different types of changes in shape. We discuss the ones that apply to the human body.

Change in orientation is enacted through body movements. Change in volume applies to muscle contractions, such as

arm flexing to increase the volume of the bicep muscle. We observed body flexing behaviors in many of our exhibition visitors. Even though we did not implement a proper animation of virtual muscle flexing, the visitors did report the visual illusion of seeing the virtual muscle increase in size when they flexed their arms. Shape change can be achieved through adding or subtracting units. Our BAAC concept extends to multiple bodies. There is an opportunity for further exploration of information displayed over multiple bodies. When there were two visitors in the space, we observed that many of them reach out to each other to see if the virtual avatars on the TV screen would do the same.

Compared to other display technology and methods, BAAC enriches the information. BAAC colors the information, through clothing. Participants altered their layers of clothing to see their virtual anatomy on different colored canvases, without being prompted by the researchers. BAAC complements the information, as seen by the educational reflections of *Inside Out* and as previously reported in the Augmented Studio system [11].

The exhibition setup of the current study does not allow a deeper informative analysis for research question Q4. A between-subject setup where the participants are exposed to the body projection and screen display separately would be preferred for a comparative analysis. We discuss Q4 in this study to highlight the breadth of research questions evoked by the BAAC concept. Considering the resolution of the model for instance, the projection on the body is relatively at lower resolution than the one on the TV screen (larger pixel size due to the distance between the projector and participants’ bodies). How the fidelity is compensated by seeing the projection on their own body? How the on-body projection helps localizing parts of the anatomy model more accurately than when displayed on an external medium. These are some interesting questions that could inspire further studies on the BAAC concept.

### **CONCLUSION**

Body as a canvas merges the role of input actuator and display on the human body. Interaction loop demonstrates a tight coupling of both roles, where interaction enacted through the body in response to the on-body information simultaneously changes the way the information is displayed. Through a public exhibition, we explore the concept via on-body projection of real time heartbeat animations and virtual skeletal muscular anatomy. Our findings suggest that information loop can be triggered with physiological body signal such as heart rate. Other aspects of the body characteristics and appearances such as body shape and clothing can complement the information that is displayed on it. The interactions among multiple bodies create fun and engaging experience. Body as a canvas also brings connectedness between the information and the body.

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