Running head: Visual Element of Immune Attack

An Examination of the Meaning that Learners Make from the Visual Elements of Immune Attack

by

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Table of Contents

Table of Figures

Abstract

In a multimedia instructional medium, learners make meaning from both the verbal (spoken and written) content and the visuals that accompany that content. A group of undergraduate and graduate students were studied playing Immune Attack without sound and interviewing them about the meaning that they made from their purely visual experience of the game. The purpose of the study was to isolate the visual content of the game from the verbal to explore the meaning students might make from the visual content. Results showed that prior experience influences the ability to interpret more abstract visual components.

"One picture is worth a thousand words. Yes, but only if you look at the picture and say or think the thousand words."

~William Saroyan

Introduction

According to dual coding theory (Clark & Paivio, 1991), learners encode visual and verbal information using separate cognitive processing systems. Mayer (1997) carries this a step further, arguing that complementary multimodal representations of information presented simultaneously allows not only more effective encoding, but also more meaningful learning.

Mayer (1997) measured "meaningful learning" in his studies through problem-solving transfer tests through which he and his colleagues assessed both the correctness and creativity of learners' solutions. His methodology represented formal measurement of formal learning, however. In educational games, such as *Immune Attack* (Federation of American Scientists, 2007), learners may make meaning that is different and/or separate from the learning objectives intended by the designers (Alessi & Trollip, 2001). Further, Mayer's (1997) studies examine the effect of multimodal versus verbal-only instruction rather than looking discretely at what meaning learners might make from the visual representations apart from the verbal presentation.

One lens through which we can examine meaning-making is semiotics. Semiotics is most simply defined as "the study of signs," and a sign is defined as "a meaningful unit which is interpreted as [representing] something other than itself" (Chandler, 2009, glossary page). Hoffman (2007) proposes that "all cognitive systems are semiotic systems, that is systems whose representations are mediated, first of all, by signs and representations" (p. 186). In other words, cognitive processes such as encoding rely on translating the incoming sensory data from the signs and representations in the visual representations used in Mayer's (1997) studies into an understanding of what those representations signify; that is, what the representations mean.

A sign, as the fundamental unit of analysis in semiotics, can be analyzed in terms of the level of abstraction in the relationship between the sign itself and that which it signifies. According to Chandler (2009, Signs page), Charles Peirce, one of the foundational theorists in the field, suggested three basic "modes of relationship" between signifier and signified: indexical, representing a very concrete relationship where there is a direct connection between sign and signified; iconic, where the relationship is one of resemblance or imitation; and symbolic, where the relationship is so abstract that it requires one to learn to relate the sign to that which it signifies. This suggests that the more abstract the representation, the less likely it is that someone unfamiliar with its intended meaning will be able to interpret it correctly.

The meaning of highly symbolic representations in the real world is often socially or culturally negotiated since they bear no obvious relationship to that which they signify; instead, they typically exist within some set of conventions, known in semiotics terms as a code (Chandler, 2009). Oliveira and Baranauskus (1998) propose semiotics as an appropriate lens for examining computer interfaces, arguing that interfaces represent social and cultural spaces for users – spaces in which the users perceive themselves as "inhabitants." In light of this perception of interface as allowing a user to inhabit a space, the authors refer to both the human "inhabitants" and the various components of the interface as "entities," and HCI, then, as "computer-mediated interaction among [these] entities" (Oliveira & Baranauskas, 2000, p. 154).

Oliveira and Baranauskas (2000) posit that semiotics as principles of design might inform, not only software design processes, but also methods for evaluating educational software. If we examine the various "entities" that are included in the Immune Attack

(Federation of American Scientists, 2007) interface under the guise that they are semiotic signifiers which convey meaning to the human player of the game, we may be able to expose how well they carry out their mission by asking human players about what they think the signifiers represent.

Problem Statement

In a multimedia instructional medium, learners make meaning from both the verbal (spoken and written) content and the visuals that accompany that content. Multimedia designs must ensure, then, that the meaning conveyed by the verbal content is complemented by the visual content. This is to avoid cognitive overload in the presentation itself and contradictory messages conveyed by the two types of content (Mayer, 1997).

We studied a group of users playing Immune Attack without sound and interviewing them about the meaning that they made from their purely visual experience of the game. Our purpose in doing so was to isolate the visual content of the game from the verbal so that we could better understand what meaning students might be making from the visual content. This information may assist game designers and developers to correct any misinformation the visual representations provide, continue beneficial visual representations, and understand the level of accessibility the visual representations alone provide.

Accessibility in Human Computer Interaction design is an urgent challenge for users as well as designers due to an upsurge in recognizing the need for accessibility for all (Bergman & Johnson, 1995; Story, 1998). While our study did not include participants with disabilities, the results of studying users who play the game without audio may also inform accessibility design issues for those with moderate to profound hearing loss, including issues covered in the ISO standard on Information technology -- Individualized adaptability and accessibility in e-learning, education and training, (International Standards Organization, 2008). This concerns not so much the way the information is accessed, but also in what way the designers create products to encourage meaning.

Research Questions

1. How do adults interpret the visual content of the game (Immune Attack)?
2. What, if any, adjustment to design methods for accessibility should be recommended to accommodate deaf/hard of hearing adults?

Methodology

Our proposed research is an instrumental case study (Creswell, 2008) in which the cases will enlighten the issue of meaning-making and accessibility in gaming. The following outline the recruitment, sample, data collection, and analysis.

Recruitment

The recruitment targeted both designer and user samples. Researchers utilized a snowball sampling technique to recruit user participants. An initial ideal user candidate was contacted and recommendations for other participants came from the original candidate. The originally intended recruitment method was to notify deaf or hard-of-hearing students via email regarding the opportunity to participate through the University of Missouri-Columbia Office of Disability Services (ODS). However, no replies were received and due to time constraints, snowball sampling was employed. Incentives were used which involve a five dollar Starbucks coffee card and a copy of the *Immune Attack* game. The current *Immune Attack* designer was also directly asked to participate as a part of the "designer" sample.

Sample

The “user” sample included four undergraduate students and one graduate student, and the "designer" sample was composed of the one current designer on the *Immune Attack* project. Table 1 shows the demographics of the user sample.

Table 1

Demographics of user sample

Participant	Gender	Age	Yr. in College	Video Game Skills	College Biology Background
P1	M	18	1	High	Yes
P2	M	19	1	High	Yes
P3	M	37	10-Phd	Low	No
P4	M	22	4	High	No
P5	M	21	3	High	Yes

All of the participants were male and over the age of 18 years. Four out of the five were undergraduates. Four out of the five participants had high video game skills. The video game skills were rated either low or high based on their perceived skills, frequency of game play, computer and console experience, game preferences, and overall video game enjoyment.

Data Collection

There were two parts for the data collection. The first part was “creator” and the second part was the “user”. The “creator” data collection took place via a recorded Skype chat semi-structured interview, given the distance between the research team and the creator. There was one main interviewer, another assistant interviewer who interjected with follow-up questions, and a third note-taker to document researcher field notes during the session. Assisted with a series of printed screenshots from Immune Attack Level 1, the interviewers asked the creator to describe the visual intent and meaning of the images within the shot.

The “user” data collection took place face-to-face and audio recorded. The audio recording allowed more accurate capturing of the data and data analysis. At least two researchers were present at any time in order to allow at least one researcher to work directly with the student participant and the other to observe and take researcher notes.

Before the student started the game, the interviewer introduced the game as a "biology computer game called *Immune Attack*." The student was instructed to play the game for 30 minutes or until the student finished Level 1, whichever came first. After the student completed the game play, the interviewer asked the student to describe what he or she saw in three separate screenshots. The screenshots were taken from different aspects of level one that covered all objects and major different views on that level. The screenshots were shown to the student one after the other, each time asking for the student to name the objects and what they understood those objects to be, or "what it means." Follow up questions were also employed so that the student’s perspective of his or her understanding could be thoroughly understood and documented. The interview was audio recorded and researcher notes were documented.

Analysis

Analysis was performed on two levels: the "designer" level and the "user" level. An inductive or a “bottom-up” approach was be used on the designer data in order to create themes through open coding and axial coding. This was used to create the coding scheme for the collected user data. See Appendix B for the coding scheme used.

All three researchers listened to the designer interview, coded the intentions and what the designer pointed out as important objects as well as intended meaning, and came to unanimous agreement for the developed coding scheme. For the codes, the naming of the codes were labeled using the language of the designer, thus the reason why some codes are less formal, such as "green thing" and "blue thing." In addition, since the designer's main emphasis was on the objects, the coding scheme reflects the designer's emphasis on her "object-orientedness" of her description of the visuals.

A deductive or top-down approach was used in coding the user data, using the coding scheme developed from the designer interview. The researchers listened to the audio recording and transcribed statements and applied appropriate codings. The researchers read the codings and then agreed on all the placement of those codings. For example, when asked about a particular object, a student stated "I had no idea." This was in response to an "ion pump" image (according to the designer coding scheme), and was thus placed into the "ion pump" code.

After all user interviews were completed and codings completed, researchers then analyzed themes and patterns both within codes and between codes. This was done in order to understand users' visual meaning making of the *Immune Attack* visuals.

Limitations

As an instrumental case study, the sample size was relatively small (five subjects) and involved one game: *Immune Attack*. While the study provided insights into the issues of meaning-making and accessibility, the results may not be highly generalizable to the general population nor to educational games in general. In addition, the purpose of the research was to examine immediate meaning-making and did not delve into meaning-making over time or repeated use, learning, or learning over time. Our coding methodology analyzed user data through a coding scheme developed through an interview with the creator, which on one hand could be enlightening for comparison, could also possibly limit the interpretation of the data and subsequent themes.

Research Findings

Most participants attached meanings to symbols from the three screenshots which matched the intended meanings from the designer. They understood the different objects involved in the game and the actions associated with the objects were interpreted as the designer intended. Overall, the participants' interpretations of the visuals matched the designer's intended meaning of the visuals. However, there were three areas where the participants created unintended meanings from the visuals: in the inflammation visual, environment scaling, and health meter.

Figure 1. Inflammation

The inflammation was portrayed by large pink triangles, as seen in Figure 1. Participants commonly did not interpret the pink triangles as inflammation. Due to their abstracted nature and no formal access to learn the meaning of this abstract symbol, it was interpreted in different ways by different participants. While some thought they were simply crevices or borders between blood cells, others weren't sure what they were but thought it was "bad" somehow:

P1: "The pink things are crevices."

P2: “That’s supposed to be like the space between the blood vessel. Not really space, but like where it’s splitting apart.”

P2: "[They are] cracks in the blood vessel.”

P2: “It’s like those… uh… they’re break… you know. They’re not smooth. It’s like it’s broken or something…bad things can hide there.”

P4: “uh...i would guess that’s ....oh....[pause]...it’s a good question.”

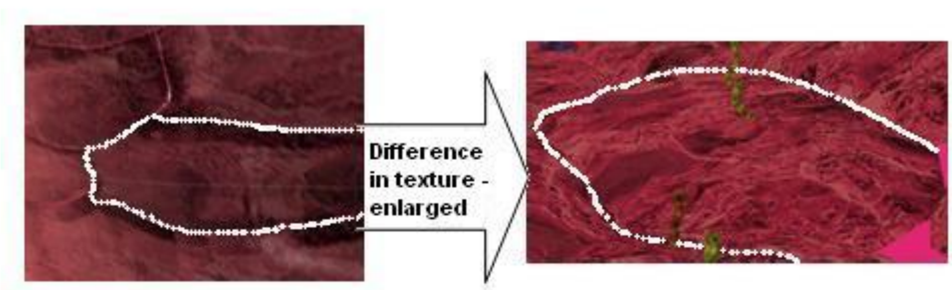

Figure 2. Change in scale denoted by difference in texture

The scaling of the environment was identified by the designer (see Figure 2). In Figure 2, the left image shows the "normal" view of the vessel wall, while the right image shows the vessel wall at a "zoomed in" scale. Most of the participants did not identify the scaling change, even when directly asked to compare the blood vessel walls in the first image (left) to those in the scaled image (right). Often they thought it was just a difference in the "terrain" and environment. However, some interpreted the perceived "rough terrain" to be the site of infection (note they did not say "inflammation"), even though the inflammation itself was intended to be indicated by the pink triangles. Only one participant, P4, interpreted the scaling visual as intended:

> P5: "The terrain is different, not as uniform, which would indicate the infection site, I suppose.”
>
> P2: “This looks like it’s more dry. Uh…infection, obviously, because this is where it was infected.”
>
> P3: “Uh… you are still inside uh… inside a vessel I guess?”
>
> P4: "I would guess this is on a much smaller cellular level."

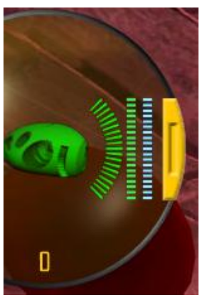

Figure 3. Health Meter

Gamers were able to derive some meaning from the health meter (see Figure 3), though some participants could not identify the purpose of the object. This is likely due to the fact that the symbols are more abstract in nature, requiring knowledge of the conventions or learning the meaning of the symbols through enough experience in the environment.

P1: “Used to see speed”

P2: “The blue bar is the boost. I don’t remember what [the straight] green one is for [the portion of the game represented in screenshot 1], but for the drone, it was the recharge for the blaster.”

The participant with the least gaming experience had a difficult time understanding the meaning of the meters and the numbers:

P3: “I saw those things blinking but I think it was all about sound. But I didn’t use them. I suspect that [the number] is your score.”

P3: “I assume that this is, you know, sound controls.”

Conclusions

By playing Immune Attack without sound, participants in the study were limited to the purely visual and experiential aspects of the game. An analysis of their interview responses provides some clues about the meaning they derived from the visual content of the game. However, it should be noted that since participants were not extensively questioned about their understanding of the underlying biological processes portrayed in the game, they may have additional misconceptions that were not exposed in the study.

Meaning-making is influenced by the interpretation of representations or signs. Signs lie on a continuum between more concrete to more abstract. The more abstracted the sign becomes, the more of the original meaning may be lost because the sign bears less of a direct relationship to that which it signifies. Therefore the more abstract a sign becomes, the more the relationship between the abstract signifier and its signified must be learned (Chandler, 2009). In areas where representations were very abstract, such as the pink triangles indicating inflammation, participants not only had greater difficulty identifying what the representations signified, but in some cases had difficulty articulating what meaning they had made from those representations.

Participants' prior knowledge, namely game skill level and exposure to college biology, was a major influencing factor in participant responses. Since Immune Attack utilized conventional gaming symbols and interaction, it was much easier for gamers to explore the environment quickly and efficiently. This in turn enabled skilled gamers to be exposed to, interact more with, and therefore identify more of the visuals in the environment. Compared to the non-gamer in our sample, gamers were very aware and comfortable with game-related visual elements and what they represent. The non-gamer did not understand the environment or know how to explore it, which influenced his ability to interact with and learn more about the visuals. Biology background, especially when it was more recent, enabled participants to attach meaning to the visuals more efficiently and accurately.

Younger players, depending on socio-economic status, may have more third-person shooter gaming experience which may influence the way they attach meaning to game visuals. For example, the highest usage of console-based video games occurs among males ages 12-17, while PC game usage is dominated by females 25-54 followed by males in the same age group; however, the usage figures for the latter age group include significant time spent playing Solitaire and other card games (The Nielsen Company, 2009). Thus, the games enjoyed most frequently by older, PC gamers have very different characteristics and controls than *Immune Attack*. Another knowledge factor observed in the analysis of demographics was the type of games that some of the participants played i.e. Halo and Call of Duty (see Figure 4). This specific gaming experience may positively influence a participant's interpretation of certain signs in *Immune Attack*. Participants with knowledge of games which seemingly have more realistic signifiers may be more readily able to identify iconic representations or understand the conventions governing symbolic representations (Chandler, 2009) associated with games like *Immune Attack*.

Figure 4. Screen shot from Call of Duty, a game with seemingly more realistic signifiers.

Implications

From the findings, there are implications for universal accessibility and visual design. Both of these implications involve the interactions between the user and the interface and addressing them may improve the use and allow for an increase in the achievement of learning outcomes.

Universal Accessibility

The term accessibility is normally used when referencing to what extent an environment, device, or service allows as many people as possible to have access, which encompasses people with disabilities, varying skill levels, and differing cultural perspectives. This research was originally intended to be conducted with participants from the deaf/hard of hearing population. While modifications to the research design used hearing participants with the sound off, the results suggest that users with moderate to profound hearing loss may be able to achieve similar ability to identify biological entities by playing the game provided that they are skilled enough at the game play. The design of the game could be improved for users with hearing loss by providing text for the spoken portions by making a transcript come to the foreground while the game is paused and the game characters are speaking.

Some of the game control graphics used (e.g. in the control panel) may not be universally accessible to all who may encounter the game. Iconic or symbolic representations may not be understood to have the same meaning across cultures. To improve accessibility for players from other cultures, accommodations should be made to include them, possibly via the help menu (Ware, 2003). Accessibility may also be reduced in the current design for those with little or no experience playing computer games. The various game controls can be iconic in meaning to gamers, but for non-gamers, the controls remain symbolic. Consequently, those with limited exposure to computer games face a learning curve beyond the biology-based learning objectives. Mouseover text explaining the various controls in the game, ideally provided as a user-selectable option in the game setup, could improve the experience for non-gamers without representing a nuisance to experienced gamers. The training level (i.e. first level of the game) should include a score to ensure that persons who continue to use the game will do so without being hindered by their skill.

Visual Design

Reducing abstract representations in educational games may improve the user experience and enhance the learning outcomes of the game. More concrete representations of at least the key objects in Immune Attack may assist users to strengthen their own mental models of the immune system and improve meaning-making from the game. Future research could explore participants' understandings of the biological processes underlying the activities in the game to further determine the impact of abstract (i.e. symbolic and iconic) representations on meaning-making. Additionally, all of the objects in the game could be evaluated to determine the appropriate level of abstraction in their visual representation and tested to determine their influence on learner misconceptions about the biological concepts intended in the learning objectives for the game.

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Appendix A: Semi-structured Interview Questions

Semi-Structured Interview Questions: "User"

Introduction

Hello [participant_name], thank you for volunteering to participate today. Today we want to gauge your understanding and interpretation of various visual images within a game called "Immune Attack." We will start by showing you a few screenshots of the game and asking you to tell us what you think the various images in the shot mean to you. We will then have you play the game for approximately 30 minutes, and then revisit the screenshots and ask you the same questions again.

There are no right or wrong answers; we are not testing you nor are we looking to see how well or how far you get into the game. We want to know your understanding of the images so the game can possibly be improved.

Do you have any questions before we begin?

First Set of Screenshots

For each screenshot, ask this question:

For this screenshot, can you use your finger and point to the various images and tell me what you think they mean?

Possible follow-up questions:

Game

Now we will have you play the game for approximately 30 minutes or until you finish Level 1.

Second Set of Screenshots

Now that you've had a chance to play the game, we'll show you the same screenshots again and ask you the same questions. Again, it's not a test, we just want to know your interpretation of the visuals in order to make the game better.

For each screenshot, ask this question:

For this screenshot, can you use your finger and point to the various images and tell me what you think they mean?

Semi-Structured Interview Questions: "Creator"

Introduction

Hello [creator_name], thank you for volunteering to participate today. Today we want to gain an understanding of your intended meaning regarding the various visual images within your game *Immune Attack*. We will start by showing you a few screenshots of the game and asking you to tell us the intended visual meaning of the imagery. Feel free to get as specific as possible.

Do you have any questions before we begin?

First Set of Screenshots

For each screenshot, ask this question:

For this screenshot, can you describe to us the various images and tell us the intended meaning behind the imagery?

Appendix B: Recruitment Letter

Dear Student,

Our team is investigating visual meaning making and accessibility in video gaming. **We are seeking 3-6 volunteers to participate in a one-hour session to play the video game *Immune Attack* and tell us about the meaning you are making from the visuals.** You do not have to be experienced with video games in order to participate.

You are being asked to participate in this study because you have been identified as receiving services from the Office of Disability Services and as such, would be a valuable participant in our research. Volunteers who are chosen to be a part of the research will receive a Starbucks coffee card and a copy of the video game *Immune Attack*.

If interested or you have questions, please contact Camille Dickson-Deane at hci_docsem@googlegroups.com **for more details.**

Thank you for your consideration,

-Camille Dickson-Deane

Appendix C: Informed Consent Form

Thank you for volunteering to participate in this research

The University of Missouri, Human Computer Interaction class is conducting interviews on the usability of an educational computing game. The purpose of the research is to determine the effectiveness of the visual content of the game. Participation in the research will involve playing the game and a subsequent interview. The entire session will take approximately 60 minutes.

Your participation is completely voluntary, and you may withdraw at any time. We do not foresee any risks or discomforts that might occur as a result of your participation in the study. By giving your consent you are agreeing only to participate in the session.

All records and information collected in these interviews will be confidential. Your information will be saved to a file that will be stored on a computer in the Center for Technology Innovations in Education at the University of Missouri. In any reporting of the data, all individuals will be anonymous, so there is no risk of your participation in this interview becoming publicly known.

If you have questions about the project you may contact Holly Henry at (573) 882-0872, Krista Galyen at (573) 864-4337 and/or Camille Dickson-Deane at (573)884-4814.

If you have questions regarding your rights as a participant, you may contact Dr. Joi L. Moore, Associate Professor, School of Information Sciences and Learning Technologies, College of Education, University of Missouri, at (573) 884-2797.

If you have any questions about human subject research you can contact the University of Missouri Campus Institutional Board at (573) 882-9585.

Do you wish to participate? Please initial here _____ if you agree to the video-taping of the interview. You are free to stop the video-taping at any time during the interview.

By your signature below, you agree to participate in the study. You will be given a copy of this form.

Participant signature		Date		Project Director		Date

Appendix D: Screenshots

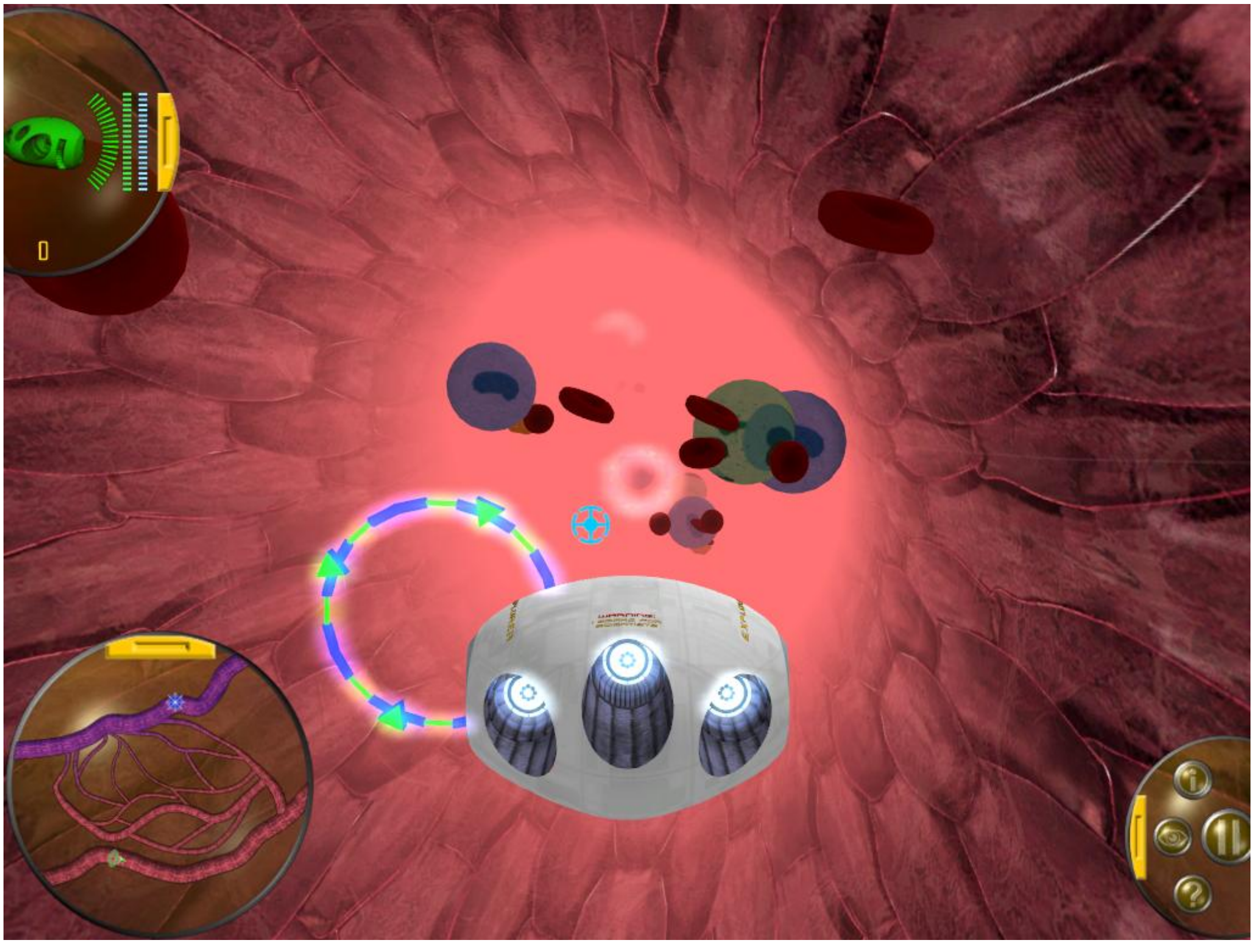

Figure 4: Screenshot 1

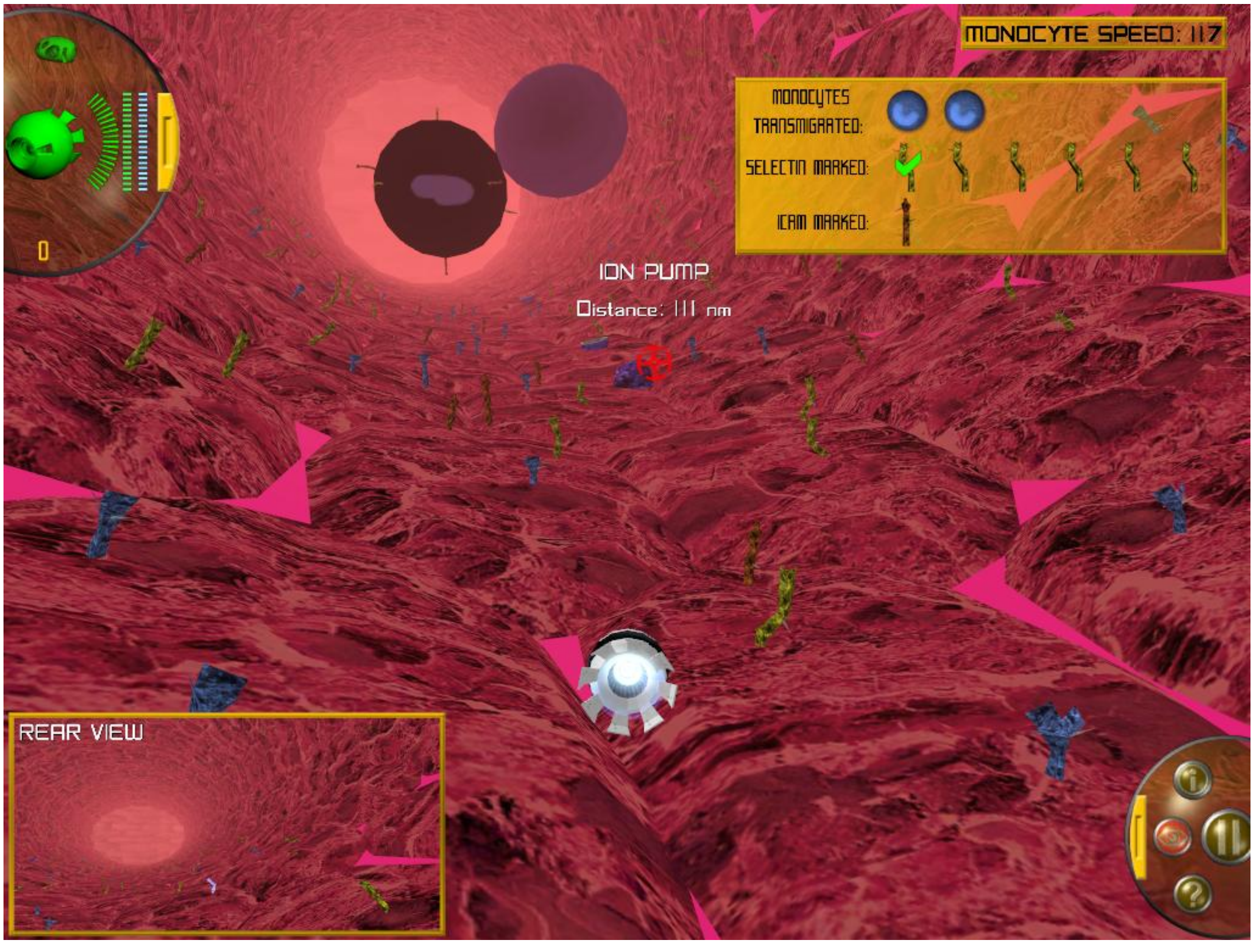

Figure 5: Screenshot 2

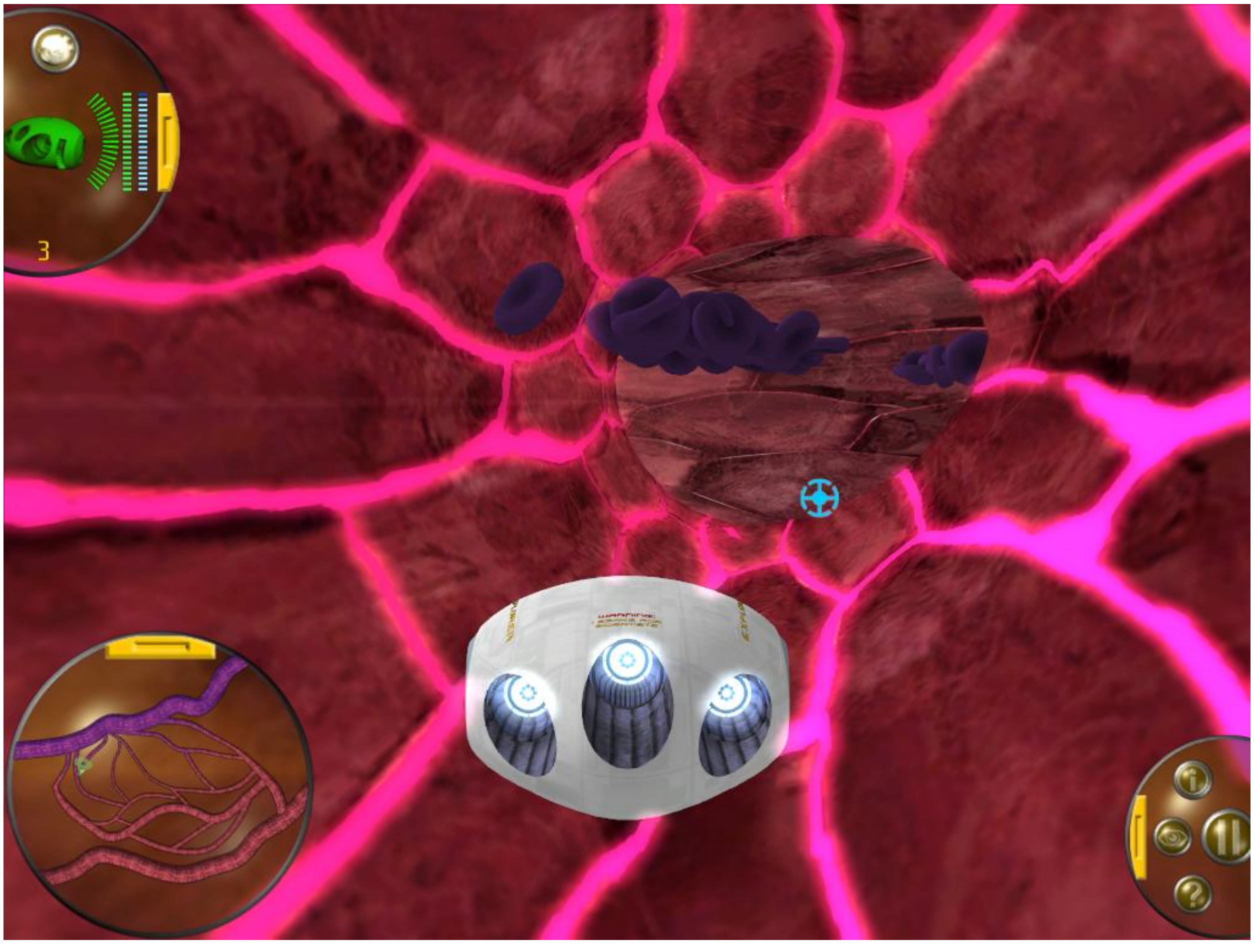

Figure 6: Screenshot 3

Appendix E: Coding Scheme (based on designer's interview)

1. Quadrant: Main
    1.1 Nanobot
    1.2 Probe
    1.3 Ion Pump
    1.4 Vessel wall
        1.4.1 texture
    1.5 Rings
    1.6 Target
    1.7 Red Blood Cells
        1.7.1 red
        1.7.2 blue
    1.8 Monocytes
    1.9 Neutrophils
    1.10 Inflammation
    1.11 Protein
        1.11.1 selectin
        1.11.2 icam
2. Quadrant: Upper Right
    2.1 Checklist
        2.1.1 selectin
        2.1.2 Icam
        2.1.3 Monocytes
    2.2 Speed
3. Quadrant: Lower Left
    3.1 Rear View
    3.2 Mini Map
        3.2.1 Artery
        3.2.2 Vein
        3.2.3 Capillary System
        3.2.4 "Green thing"
        3.2.5 Blue thing
4. Quadrant: Lower Right
    4.1 Game Control
    4.2 Pause
    4.3 top (“i”)
    4.4 Question (“?”)
    4.5 Eyeball
5. Quadrant: Upper Left
    5.1 Health
        5.1.1 Energy Counter
        5.1.2 Damage Counter
        5.1.3 Drone
    5.2 Numbers
6. Background
7. Other