**The Effects of Art Styles on Learning in Serious Video Games**

BY

MIKAELA MUERSCH
B.F.A., American Academy of Art, 2016

PROJECT RESEARCH

Submitted in partial fulfillment of the requirements
for the Degree of Master of Science in Biomedical Visualization
in the Graduate College of the
University of Illinois at Chicago, 2021

Chicago, Illinois

Defense Committee:

Samantha Bond, Chair and Advisor
Leah Lebowicz
John Daugherty

**TABLE OF CONTENTS**

CHAPTER PAGE

**Table of Contents**

## SUMMARY

The Humaginarium project was founded in an endeavor to create a AAA-quality game that with the educational goals of a serious game for health. Even though AAA games devote much time and attention to graphics and aesthetics, not as much attention is given to this area in serious games, causing a lack of peer reviewed literature on concept art and art styles. Concept art is an important step in game design, but there is no quantitative way to assess it yet. Currently, it appears no tool exists to objectively measure visual styles for proper comparison. Since AAA games have so many different aesthetic styles, this study seeks to uncover a way to place concept art on the realism-abstraction spectrum in order to quantitatively evaluate the artwork of serious games for health. This study aims to contribute to the Humaginarium project by creating a framework to assist in future investigation into visual style and its relationship to learning.

# I. INTRODUCTION

## A. Overview of research problem

*Serious games,* or educational video and tabletop games, are defined as games designed for both entertainment as well as a separate beneficial purpose, such as education or simulation training (Baranowski et al., 2016). With this underlying motive in addition to entertaining, serious games are commonly designed specifically to teach one area in an unlimited range of subjects. Often however, serious games may not incorporate the fun of traditional games appropriately within the learning experience, which is likely why they tend to be less enjoyable and engaging (Baranowski et al., 2016).

One subcategory within serious games includes *games for health*, or games designed to teach medical and healthcare-related content. Games for health are often rooted in academic funding and can sometimes lack the resources to create the robust, engaging experiences created for more entertainment-focused, large studio/production budget games, also known as *AAA games* (Baranowski et al., 2016). The term *AAA*, or *Triple-A* games, refers to a high-quality game with robust graphics and a strong narrative, traditionally created by a large team with a very high budget (Schultz, 2018). Potentially due to this lack of funding, resources, and perceived importance, little emphasis can be placed on the aesthetic decisions in serious games in academic literature. Some sources state they do not see a need to place emphasis on this category due to the captive audience of its users, who are using the game specifically to learn (Baranowski et al., 2016). Others state that the *game mechanics,* or the rules and boundaries of a game, are more important in terms of learning, while the artistic style and level of realism of the assets within the game can be interchangeable (Habgood et al., 2005). Even though AAA

games devote much time and attention to graphics and aesthetics in a game, not as much attention is given to this area in serious games, causing a lack of peer reviewed literature on concept art and art styles. There is also conflicting evidence on the effectiveness of specific aesthetic decisions, including levels of photorealism or levels of fantasy, in the artistic development of serious games. Greater attention to this topic is needed to begin discussions on how the development of artistic styles in learning games impact the overall experience; as such, it is unclear how to quantitatively evaluate these styles as they apply to serious games for health.

*Diabetes Agonistes* is a proposed video game by the *Humaginarium* group, with the aim to help enable adults to gain more control over chronic illness. The narrative arc of Diabetes Agonistes starts with homeostasis, leading to metabolic syndrome, and eventually progressing to type 2 diabetes. As with serious games, the game intends to prioritize user experience to make the game engaging and cathartic, with education as a secondary bonus. With the game still in its preliminary planning phases, this study aimed to solely investigate the development of concept art. The remaining components of the game will be developed in the future by a large team after assessing the qualitative results of this study. Concept art is an important step in game design, but there is no quantitative way to assess it yet. This standardization is necessary in order to effectively compare various styles as well as eventually determine which attributes within a style are most conducive to preference and learning.

### B. Significance of the problem

The “art style” of a game is an element of the game’s aesthetics, and is recognized by many professionals in the game industry as highly important (Slav, 2020; Riot Games, 2018a; Riot Games, 2018b). Despite this understanding, budget restrictions aside, the art style in serious games is often seen as trivial to learning and engagement (Baranowski et al., 2016), and this lack of attention leaves a gap in the current literature. Though studies exist on effectiveness of visual imagery in educational resources, there is a perceived lack of need to allocate resources for graphics in educational games (Baranowski et al., 2016). This lack of allocation is due to the captive audience of serious games (Baranowski et al., 2016).

The Humaginarium project was founded in an endeavor to create a AAA-quality game that with the educational goals of a serious game for health. Since AAA games have so many different aesthetic styles, this study seeks to uncover a way to place concept art on the realism-abstraction spectrum in order to quantitatively evaluate the artwork of serious games for health. There is very little research on the effectiveness of art styles in serious games, and even less on evaluating the level of realism or abstraction within a style. Before it can be known how certain art styles within a game can influence how people learn, it must be determined if and how these styles can be objectively classified.

# II. LITERATURE REVIEW

This research project, as an exploration into visualization concepts in Game-Based Learning as a part of the *Humagniarium* Project, specifically aimed to investigate the quantitative evaluation of medical game concept art. As there has been little to no research on quantitative measurement of art on the spectrum of realistic to abstract, this research hoped to gain an understanding of how to measure those variables. To best understand the context and importance of the question, the literature review includes an overview of the use of catharsis in medical games, current homeostasis education practices, game-based learning for health topics, and the development of concept art for games. In addition, however, the literature concludes with a brief review of methods of validation for research instruments outside of the context of the *Humaginarium* project to best understand evaluation of the final research stimulus.

## A. Catharsis and the *Humaginarium* Project

Serious games, designed specifically for a non-entertainment purpose like education, are commonly perceived as lacking in the aesthetic component of AAA-quality games (Baranowski et al., 2016). The goal of the ongoing Humaginarium project is to develop a game for health with visuals that meet the standards of modern, AAA games. As with AAA game development standards, concept art was necessary for the creation of this game. Though the primary objective of the game at the focus of the study is education, a secondary benefit of learning through a serious video game is the cathartic effects derived from games (Russoniello et al., 2009). In the proposed Humaginarium game, players will be asked to oppose their chronic illness in a 3D environment in hopes to both 1.) educate the player and 2.) trigger a

state of catharsis, as shown beneficial by serious games in prior literature (Russoniello et al., 2009). Though this project primarily aimed to develop a tool to quantitatively evaluate the realism of concept art in games for health, the context for the goals of the Humaginarium project are important to the scope of the research.

Catharsis in this sense refers to an emotional relief from stressors (Catharsis, n.d.). A patient with a chronic illness may need a form of therapeutic escape when dealing with physical pain arising from their health condition. In a study by Wohlheiter and Dahlquist (2013), the efficacy of a video game's use of distraction as a tool to instill catharsis was hypothesized. The study evaluated the significance between pain management and active and passive distraction in children (Wohlheiter & Dahlquist, 2013). A baseline test was given with no video game distraction in order to compare the results with the passive and interactive distraction tests (Wohlheiter & Dahlquist, 2013). The participants stuck their hand in water for the cold-pressor test while playing a video game for the interactive distraction trial of the study (Wohlheiter & Dahlquist, 2013). For the passive distraction portion of the study, the participants watched prerecorded games play while they were given the cold-pressor test. It was revealed that pain tolerance was higher in both distraction tests compared to the baseline trial, with interactive distraction being the most effective (Wohlheiter & Dahlquist, 2013); the authors found that age and attention level did not correlate in any significant way to the considerable difference between baseline and distraction tests. This study corroborates with Griffith's (2005) conclusion stating that the user's attention needed to play a game may assist with pain management by providing a distraction to the user's pain. While the study focused only on young children, this information is still applicable to broader categories of game development

due to the broad age range of its users (Wohlheiter & Dalquist, 2013). Since the study found no significant correlation with age and distraction, it could also be extrapolated that video games might provide relief from chronic pain in older users as well (Wohlheiter & Dalquist, 2013).

Due to the longevity and potential lifelong diagnosis of chronic health conditions, it is reasonable to assume a toll is taken on a patients' mental and psychological well-being. Anxiety, depression, and chronic disease are intimately linked, a factor elucidated in a study by Gerontoukou et al. (2015) that assessed patients with chronic illnesses and evaluated their anxiety and depression levels. The authors found higher anxiety and depression rates in individuals with a chronic health condition in comparison to the general population (Gerontoukou et al., 2015). Interestingly, the authors found a link between anxiety and education, with higher education levels connecting to lower levels of anxiety (Gerontoukou et al., 2015). Eighty-six percent of patients with a primary education level developed anxiety, while that rate was close to zero for patients with a graduate level education (Gerontoukou et al., 2015). These findings may support the notion that improvement in a patient's ability to understand their health condition may help them feel more in control or empowered. While a serious game can trigger catharsis in passive distraction, it can also educate a player, which in return, may contribute further to reducing anxiety and depression (Gerontoukou et al., 2015; Wohlheiter & Dahlquist, 2013).

### B. Health Literacy

To best understand how to develop games for health, the intended audience's level of preliminary knowledge must be understood. *Health literacy* is the ability to process and understand health information and then act upon that knowledge for healthy outcomes (Doak

& Doak, 2004; Schillinger et al., 2002). Poor health literacy tends to affect people with lower socioeconomic status, as well as the elderly and ethnic minorities the most (Schillinger et al., 2002). In a study by Schillinger et al. (2002), the correlation of health literacy and health outcomes was evaluated amongst type 2 diabetes patients. They tested this by doing a cross-sectional study on 413 people and found that low health literacy is directly connected with poor health. Specifically, Schillinger et al. (2002) discovered a positive correlation between poor glycemic control and higher rates of retinopathy, with health literacy as an independent variable. Poor glycemic control was found in 30% of patients with poor health literacy compared to 20% with adequate health literacy (Schillinger et al., 2002). Ninety-five percent of patients with inadequate health literacy reported retinopathy (Schillinger et al., 2002). Compared to patients with adequate health literacy, patients with poor health literacy were twice as likely to have retinopathy (Schillinger et al., 2002). Furthermore, poor health literacy patients were higher in self-reported complications of diabetes (Schillinger et al., 2002). This connection between literacy levels and health was verified in a later study by Schillinger et al. (2004) in which the authors saw a positive correlation between lower health literacy and a lower health status.

Schillinger's (2004) study not only shows a correlation between poor health literacy and a lower health status, but they tested patient-doctor communication in order to see if patients who struggle with reading and writing comprehension also struggle with other modes of communication in relation to medical directions. Domains that are vital to self-managing chronic disease include, "physician's explanations of their condition; explanations of processes of care; empowerment; and consideration of patient's desire and/or ability to adhere to

treatment plans" (Schillinger et al., 2004, pg. 320). In all categories, reports showed that patients with poor health literacy scored lower in relation to communication (Schillinger et al., 2004). As stated in Kripalani and Weiss (2006), patients with low health literacy ask fewer questions and remember less than half of what their doctors tell them, possibly because physicians overestimate patients' health literacy. This could be due to the lack of questions asked; after asking only a few questions, the doctor might feel as though the patient is understanding the information if they are not actively participating in conversation (Kripalani and Weiss, 2006). Someone newly diagnosed with diabetes might not know the questions they should be asking their doctor since, without prior knowledge or the right vocabulary to communicate, they do not know what to ask. Patients might not know action steps to take or be motivated to change their lifestyle or behavior. Schillinger et al. (2004) listed empowerment and capability of sticking to treatment plans as vital to managing chronic conditions. If physicians overestimate health literacy levels, then these two domains could be negatively impacted. Patients had less trouble understanding self-care health behaviors compared to the other domains, which is most likely due to this particular category using less medical jargon (Schillinger et al., 2004). Even though patients understood self-care behaviors, the explanatory domains showed that patients struggled with knowledge about their health condition as well as application of care (Schillinger et al., 2004). If patients and doctors are unable to effectively communicate, then patient health could be compromised. Not only could serious games empower the user, but it could also be used to potentially bridge the communication gap with a visual narrative.

Kripalani and Weiss (2006) discuss different strategies for bridging the communication

gap between medical professionals and patients. One of the recommended strategies to communicate health information is to provide helpful educational materials (Kripalani & Weiss, 2006). This could be useful in the context of a serious video game, which would scaffold educational material to assist with a deficit in prior knowledge. In a game that seeks to empower individuals through increased health literacy, the primary emphasis must be on the patient, their emotions, and their concerns (Doak & Doak, 2004). Improvements in health literacy have the potential to empower individuals regarding their own healthcare, prevent medication errors, and promote preventative care (Doak & Doak, 2004; Schillinger et al., 2002).

### C. Homeostasis Education

In order to create a game on metabolic homeostasis, it is important to first understand homeostasis and how it is currently taught to the intended audience, including the learning goals and timeline of education. Billman (2020) describes homeostasis as the self-regulation of body systems attempting to reach an optimal state in the midst of external conditions. There are two types of feedback loops involved in this self-regulation process: positive feedback and negative feedback (Billman, 2020; Zullo, 2013). Negative feedback is initiated by the body triggering systems to return a certain measurement into balance if it moves out of its normal range, while positive feedback intentionally moves the body from its normal state (Zullo, 2013). Homeostasis contains a multitude of these feedback loops working and interacting with each other to properly regulate the human body (Billman, 2020; Zullo, 2013). Both Zullo (2013) and Billman (2020) express a lack of adequate education in reference to the complexities of homeostasis. Billman (2020) states further there is a lack of holistic understanding on the topic, with science education taking a reductionist approach in recent years.

A small review of curricula and class syllabi has shown that, on average, seventh grade is when homeostasis is first introduced in U.S. public schools (DeSoto ISD, n.d.; Markham Woods, 2019; St. Mary's Catholic School, n.d.). Middle school students are taught about the structures involved in homeostasis as well as its function in cells and humans as a whole (DeSoto ISD, n.d.; Markham Woods, 2019; St. Mary's Catholic School). High school and college-level classes focused on these topics as well, but at a slightly more advanced level, also exploring diseases and medical interventions (Saylor Academy, n.d.; Uppsala University, n.d.; Zullo, 2013). The role of the endocrine system is stressed, with some courses requiring students to identify tissue types and structures on a microscopic level (Uppsala University, n.d.; Zullo, 2013). Across all curriculum and education levels, feedback loops were emphasized in all the syllabi found on this topic (DeSoto ISD, n.d.; Markham Woods, 2019; Saylor Academy, n.d.; St. Mary's Catholic School, n.d; Uppsala University, n.d.; Zullo, 2013). This indicates an importance in understanding the relationship between systems.

### D. Metabolic Syndrome and Type Two Diabetes

The Diabetes Agonistes narrative arc begins with homeostasis and then moves to metabolic syndrome and type 2 diabetes. It is necessary to understand the mechanisms underlying homeostasis in order to compare normal conditions to disease states. One disease state, Metabolic syndrome, is a cluster of comorbidities that include insulin resistance, hypertension, excessive abdominal fat, and excessive cholesterol or fat in the blood (Mendrick et al., 2018; Saklayen, 2018).

These coexisting conditions are interdependent due to processes of energy homeostasis. After a meal, under normal conditions, glucose and triglycerides circulate, and

interact with the nervous system as well as several organs (Castillo-Armengol et al., 2019). Beta cells in the pancreas sense the elevated glucose levels and produce insulin for secretion (Castillo-Armengol et al., 2019). Organs such as the liver, muscle, adipose tissue, and brain are targeted by insulin in order for glucose uptake to occur (Castillo-Armengol et al., 2019; Cerf, 2013; DeFronzo, 2009). However, insulin resistance develops mainly from excessive fatty acids in blood circulation (Eckel et al., 2005). When insulin sensitive tissues encounter fatty acids, glucose uptake is inhibited (Eckel et al., 2005). Not only does prolonged and excessive amounts of free fatty acids lead to insulin resistance of target organs, but these levels can deplete insulin secretion due to stress placed on beta cells (Cerf, 2013; Eckel et al., 2005).

Diabetes mellitus is caused by issues with insulin secretion by beta cells in the pancreas and insulin resistance in target organs (Cerf, 2013; DeFronzo, 2009; Roh, Song, & Kim, 2016). Therefore, metabolic syndrome increases the risk of diabetes (Fändriks, 2017). Key organs in type 2 diabetes include adipose tissue, the gastrointestinal tract, kidneys, skeletal muscle, the pancreas, and the brain (DeFronzo, 2009). Genetics play a role in the development of type 2 diabetes, with onset of the disease arising with exposure to epigenetic factors such as obesity, a sedentary lifestyle, and a diet high in sugar and fats (Chatterjee, 2017). Physical inactivity and obesity have led to the increased prevalence of diabetes due to these factors being inflammatory, insulin-resistant states (Chatterjee, 2017; DeFronzo, 2009; Saltiel, & Olefsky, 2017). Beta cells will increase their insulin production under these conditions, but it puts great stress on the cells (DeFronzo, 2009). This resistance coupled with beta cell failure ultimately leads to type 2 diabetes (Cerf, 2013; DeFronzo, 2009). Lifestyle preventative measures, such as diet and exercise, can delay or reverse this condition (Chatterjee, 2017). While these lifestyle

changes are effective in managing diabetes, adherence to these changes remains an issue for many patients (Chatterjee, 2017).

### E. Key Elements of Game-Based Learning

Game-based learning (GBL) is defined as balancing learning goals while emphasizing gameplay (Plass et al., 2015). Within a game using GBL, learning outcomes are explained and artificial conflict and rules are implemented to help users obtain these outcomes (Plass et al., 2015). These characteristics distinguish GBL from *gamification*, a term that references the application of game design elements in non-game scenarios (Plass et al., 2015). Both game-based learning and gamification utilize elements of games such as play, flow, engagement, and scaffolding. These elements are distinct, but their relationship is closely interwoven and integral in creating a successful game (Plass et al., 2015).

The concept of play is defined as, "physical activity that encourages learning and creativity, develops and satisfies psychological and social needs, and involves aspects of competition and collaboration" (O'Brien & Toms, 2008, p. 939). Plass et al. (2015) states that *play* is an element in games that is thought to be essential in human development. Game-based learning is important because it motivates users to play over extended periods of time, engages users, tailors learning and game experiences, and provides "graceful failure" (Hoffman & Nadelson, 2010; Plass et al., 2015). Plass et al. (2015) define "graceful failure" as the concept that failure is not only a possibility for a player but expected in the game play experience. It encourages players to take more risks and explore, as well as assist with learning (Kapur, 2008; Plass et al., 2015). Players can learn from failure in a low-risk environment without fear of consequences (Klopfer et al., 2009).

Plass et al. (2015) propose three elements are at the core of nearly all games: challenge, response, and feedback. Game design features, like aesthetics, are at the center of this, which influences these three elements (Plass et al., 2015). These proposed core elements in games are also attributes in engagement. Engagement is a player's willingness to play, typically measured by duration and frequency of interaction (Maheu-Cadotte et al., 2018). O'Brien and Toms (2008) describe engagement as, "...a category of user experience characterized by attributes of challenge, positive affect, endurability, aesthetic and sensory appeal, attention, feedback, variety/novelty, interactivity, and perceived user control" (p. 941). The authors note the attributes of play as inherent to engagement, a few of which are related to competition and fulfillment of social and psychological needs (O'Brien & Toms, 2008). These traits can be found in games as well. Lazzaro (2005) defines key elements of games similarly to the studies by O'Brien and Toms (2008) and Plass et al. (2005). An analysis of bestselling games indicates these games generally all have at least three of the four keys to emotion: internal experience, challenge and strategy, immersion, and social experience (Lazzaro, 2005). These keys are important in games because they elevate a player's satisfaction and engagement (Lazzaro, 2005).

Lazzaro (2005) observed verbal and non-verbal emotional cues to determine what players enjoy about their experiences of play. Interestingly, the author found that older players wanted to feel a sense of accomplishment from playing (Lazarro, 2005). Most participants in the study wanted to get more meaning out of the games, and player enjoyment was found to fade quicker if the game did not stimulate or relate to the player's life (Lazzaro, 2005). These keys are necessary for engaging users in gameplay and could be beneficial for improving serious

games (Lazzaro, 2005). Currently, serious games are lacking in engagement, possibly due to overlooking these emotional elements (Baranowski et al., 2016). A common thread in the studies by Lazzaro (2005) and Plass et al. (2015) appears to be a need for challenge and emotional appeal in the game experience, and the necessity of fun to keep users in the period of engagement.

The element of play is a strength of game-based learning because of its ability to keep users engaged (O'Brien & Toms, 2008; Plass et al., 2015). A similar concept in a game player's experience, *flow* is a state in which a user is fully immersed and focused on a task (Habgood et al., 2005). Most all of the participants in the Lazzaro (2005) study played games for some kind of catharsis and wanted to feel completely absorbed in the game (Lazzaro, 2005).

Though engagement is a separate concept from flow, they are closely related. Habgood et al. (2005) claim that flow is missing in serious games, and likely why the learning is extrinsic; flow tends to be interrupted or the learning goals are not woven in with the gameplay. The article claims core mechanics are more important than the fantasy because you can swap out the fantasy with one equally as compelling, and it would not disrupt the flow experience (Habgood et al., 2005). However, too much integration can reduce learning since flow prevents critical awareness (Habgood et al., 2005).

While the concepts of both play and flow are key elements in game-based learning, other variables, including level of aesthetic realism, can further impact these elements. Spek et al. (2014) tested two types of games: one with a realistic story and realistic aesthetic against a fantasy-based story and aesthetic. By comparing two different aesthetic styles, the results showed the game with familiar or real-world aesthetics correlated with increased learning,

while the game with fantasy aesthetics correlated with increased engagement (Spek et al., 2014). This corroborates with Habgood et al. (2005) stating that too much abstraction from the learning material harms learning but promotes engagement. The authors state that intrinsic, or endogenous, integration with fantasy yields better results over extrinsic, or exogenous, integration (Habgood et al., 2005). While flow is great for motivation or catharsis, it can be potentially harmful to learning (Habgood et al., 2005). The study by Habgood et al. (2005) claims serious games would be more effective if the intrinsic learning content and fantasy metaphor are relevant to the learning goals. This would keep the user in a flow state while also promoting learning since the fantasy is assisting in the scaffolding of information (Habgood et al., 2005).

As these concepts of play, flow, and aesthetic design contribute to a game player's engagement, engagement will in turn correlate with the concept of generative processing (Mayer & Moreno, 2007). Generative processing occurs when a learner begins mentally organizing new information while learning and integrating the new knowledge with prior knowledge (Mayer & Moreno, 2007). This process correlates with engagement; because if the user is not motivated to learn, even if they have the cognitive capacity to learn, then generative processing might not take place (Mayer & Moreno, 2007). If users lack engagement, they will not participate in generative processing, and therefore will not take away the learning objectives (Mayer & Moreno, 2007). However, it is important that the environment does not lead to cognitive overload, or too much information to process at once (Mayer & Moreno, 2007). Notably, this concept is where serious games can excel for education (Plass et al., 2015).

Games are a great way to prevent cognitive overload due to information scaffolding (Plass et al., 2015).

Scaffolding, a technique used to assist in learning by providing support that gradually tapers as the learner progresses towards greater understanding of the subject, helps prevent negative emotion and frustration by providing guidance ("Scaffolding", 2013). The subject is broken up into parts, and as the learner gains knowledge and understanding, the supports are gradually removed as needed (Obikwelu et al., 2012; Plass et al., 2015; "Scaffolding", 2013). Not only do games allow the player to explore chunks of information at a time, but the level of difficulty is tailored to the player as well (Obikwelu et al., 2012; Plass et al., 2015). In order for a player to progress through a game, and thus fade initial supports, they must be motivated and engaged (O'Brien & Toms, 2008). Though players may disengage out of frustration, scaffolding can help prevent this by limiting information and controlling difficulty (O'Brien & Toms, 2008).

**F. Game Concept Art**

There is little to no scientific literature on production and decision-making for concept art and art styles in game development; however, a review of grey literature provides an industry-driven perspective on these terms for the purposes of this study.

AAA game development begins with a process of goal setting, sketches, and ideation (Martel & Pitchford, 2010; Nava, 2013; Plourde, 2014; Veryovka, 2015). This structure was repeated by numerous professionals in the game industry, as well as blogs and books on the topic ("Designing Game's Visual Style", 2019; Martel & Pitchford, 2010; Nava, 2013; Plourde, 2014; Solarski, 2012; Veryovka, 2015). One industry leader, Riot Games, described the role of the concept artist as, "[helping] teams solve problems by designing visual solutions" (Riot

Games, 2018b, 00:23). Concept art is first created by developing a concept and a set of guidelines in order to design with intent (Martel & Pitchford, 2010; Nava, 2013; Solarski, 2012; Riot Games, 2018b). Three things must be established before creating concept art: understanding the problem, working with a set of guidelines, and doing research (Riot Games, 2018b). Rex Crowle, lead creator on the game Tearaway, describes paper as being the ethos of the game, not just an art style (Crowle, 2013). He describes this theme of paper as, "…the way everything was constructed, the way it moved, the way you interacted with it" (Crowle, 2013, 13:13). Because of this limitation, it directed the type of game they created (Crowle, 2013, 2013).

**Figure 1**
Note: *Tearaway*. Reprinted from *Youtube*, by IGN, 2015, https://www.youtube.com/watch?v=glDHMKtpztw. Reprinted without permission.

Many professionals mentioned using mood boards and color palettes before even sketching ideas (Martel & Pitchford, 2010; Nava, 2013; Veryovka, 2015). The artists behind one game, *Never Alone,* used many mood boards and color palettes to represent different environments and characters (Veryovka, 2015). The game's visuals are almost indistinguishable from their reference images (Veryovka, 2015). Never Alone is a good example of drawing

inspiration from the environment, and culture (Veryovka, 2015). They looked at traditional artwork and modeled their aesthetic from this (Veryovka, 2015). The game was thoughtfully created, and had meaning behind every decision (Veryovka, 2015).

Color coding is strategically selecting color to help distinguish categories or cue the viewer to important information. One concept artist, Janice Chu, gave advice in an online interview about creating game art ("Designing Game's Visual Style", 2019). Chu (2019) mentions how she color codes elements due to the importance of readability ("Designing Game's Visual Style", 2019). She makes sure to stay consistent with object shape, color, and silhouettes so the user doesn't get confused ("Designing Game's Visual Style", 2019). This helps the player pick up on patterns ("Designing Game's Visual Style", 2019).

This concept is also reinforced by artist, Robh Ruppel (2014), with his example of iconography in Charlie and the Chocolate Factory (Ruppel, 2014). Ruppel (2014), a production designer for games and films, gave a talk on creating meaningful aesthetics for video games through the use of allegory, alliteration and iconography (Ruppel, 2014). In Charlie and the Chocolate Factory, each character has a simple, distinguishable silhouette (Ruppel, 2014). There is a strong suggestion of personality of characters without having any details (Ruppel, 2014; Solarski, 2012). Ruppel stresses the need to go back to earlier game designs for this readability (Ruppel, 2014). He states it is easy to get caught up in the details with all the advancements in technology, but simplicity and clarity need to be prioritized; things need to be easily recognizable (Ruppel, 2014).

It is also important to focus on character shape in the thumbnail development. This is another concept that is widely expressed by many professionals ("Designing Game's Visual

Style", 2019; Ruppel, 2014; Solarski, 2012). Not only does object shape play a key role in emotions, but it provides clarity and iconography (Ruppel, 2014; Solarski, 2012). Using these visual concepts will help connect with the users on a deeper level (Ruppel, 2014). In a video by Riot Games, the importance of simplicity and clarity in games is emphasized (Riot Games, 2018a). Excessive detail distracts from hierarchy, and the most important elements should stand out first (Riot Games, 2018a). These concepts are essential to character shape and iconography. Silhouettes should be exaggerated to add clarity as well as create a more appealing visual (Solarski, 2012). This clarity makes it easy to distinguish, even from a distance, and implies character personality without detail (Ruppel, 2014; Solarski, 2012).

Concept art is iterated on many times before reaching a final look (Martel & Pitchford, 2010; Nava, 2013). A good example of ideation is the design of the main character in Journey (Nava, 2013). In 2013, Matt Nava, the art director for Journey, gave a talk on the process and creation of the artwork at the Game Developers Conference (GDC) (Nava, 2013). The first initial sketch is completely different from the final, although, some elements stay consistent like the focus on the character's eyes (Nava, 2013). Nava (2013) decided that he needed to simplify his design and take away any extraneous detail that was not relevant to gameplay (Nava, 2013). The game was about walking at this point, so he took away the arms of the protagonist (Nava, 2013). At this point, the character developed into the iconic rendering in the final version (Nava, 2013). This iterative development shows the importance of making revisions based on audience focus during the development process, and how it is important for concept art to retain a less polished look in order to quickly work through ideas (Nava, 2013). Visual hierarchy, research, working with constraints, creation of mood boards, and design iteration were themes

consistently repeated by professionals in the field of game art (“Designing Game's Visual Style”, 2019; Martel & Pitchford, 2010; Nava, 2013; Plourde, 2014, Solarski, 2012; Veryovka, 2015).

Elements in the ideation process, such as object shapes, mood boards, and color palettes, collectively add to the aesthetics of the game. Aesthetics can be defined as comprising of components such as sound, text, and image (Abubakar et al., 2016). It refers to the visual and auditory components the player experiences (Hjelte, 2019). Aesthetics can improve or assist with gameplay, but they also create a mood or a feeling for the user. In a study by Abubakar et al. (2016), experts were interviewed about the components of game aesthetics and its efficacy in perceived learning. The experts unanimously ranked images (or the external environment view in the game) as being the most influential component in aesthetics (Abubakar et al., 2016). After images, other attributes that ranked in playing a significant role in perceived learning were text, visual perspective, color, and graphics (Abubakar et al., 2016). The authors note that these terms can be confusing due to them somewhat overlapping one another (Abubakar et al., 2016). They describe graphics as any visual representation in the game—including icons (Abubakar et al., 2016). Aspects of graphics in games include character design, environment design, and interface (Visual Styles, 2012).

One example of the influence of aesthetics is demonstrated by the game Merchant of Skies (Slav, 2020). Vladimir Slav, owner and director of Coldwild Games, gave a talk on how they made art before making the game itself (Slav, 2020). Previously, they would create a prototype first and then pick the art after (Slav, 2020). For their game, Merchant of Skies, they focused on art and aesthetic first as opposed to gameplay, then tested what their audience liked (Slav, 2020). Compared to their other game “Lazy Galaxy”, which had six thousand sales over two

years, this art-first game “Merchant of Skies” sold ten thousand copies in the first seven months (Slav, 2020). While this strategy was successful for them, Slav admits that their informal study had a small sample size and it is difficult to say if these results are replicable (Slav, 2020). Though there is a significant lack of peer reviewed literature on these aesthetic decisions in games, it remains valuable to keep the experiences of these industry leaders in mind.

### a. 2D v. 3D Games

Though game art can be classified in a wide variety of ways, one major classification is in dividing *2D* and *3D* games. An article from the Unity game engine website described 2D games as the use of flat graphics (or sprites) with no use of camera perspective due to the lack of 3D depth (only X and Y dimensions) in the scene (Create 2D and 3D games…, n.d.). Three-dimensional games, on the other hand, allow the user to move into the space due to a 3D environment (X, Y, and Z dimensions) (Create 2D and 3D games…, n.d.). Two and a half-dimensional (or “2.5D”) games do exist, but they can usually be split into 2D or 3D elements still. For example, isometric graphics, like in the hit game *Monument Valley*, can be considered 2.5D because they are creating a fake 3D perspective (Create 2D and 3D games…, n.d.). Another form includes parallax scrolling, a term used to describe when the background moves slower than foreground images to replicate a sense of environmental depth.

Some examples of 3D games include *Overwatch*, *Legend of Zelda: Breathe of the Wild*, *Borderlands* and *Red Dead Redemption*—to name a few. Even from these few examples, it is clear to see the massive range within one category.

a.

b.


c.

d.

**Figure 2**

a. Note: *Overwatch* Reprinted from *Playstation Lifestyle*, by Author B. Reeves, 2020, https://www.playstationlifestyle.net/2020/01/07/overwatch-2-release-date-rumor. Reprinted without permission. b. Note: *Borderlands* Reprinted from *USA Today*, by Author B. Molina, 2019, https://www.usatoday.com/story/tech/gaming/2019/09/13/borderlands-3-out-now-everything-we-know-game-so-far/2309322001/. Reprinted without permission. c. Note: *Legend of Zelda* Reprinted from *Nintendo Life*, n.d., https://www.nintendolife.com/games/nintendo-switch/legend_of_zelda_breath_of_the_wild. Copyright [2017] by the Name of Nintendo. Reprinted without permission. d. Note: *Red Dead Redemption* Reprinted from *The Verge*, by Author A. Webster, 2018, https://www.theverge.com/2018/10/15/17979606/rockstar-red-dead-redemption-2-crunch-100-hour-work-week. Copyright [2018] by the Name of Rockstar Games. Reprinted without permission.

**b.** Visual Style

A game's visual style falls under the umbrella of aesthetics and can divide 2D and 3D games into even further categories. While there is no official taxonomy, there are still widely recognized styles used in AAA games. One article mentions four main styles in video games as cel-shaded, photorealistic, exaggerated, and abstract ("Visual Styles", 2012). Photorealistic style is thought to be the most mainstream and typically used in AAA games ("Visual Styles", 2012).


**Figure 3**
Note: An example of a photorealistic style in the game, *Hellblade.* Reprinted from *Hellblade,* n.d., https://www.hellblade.com/new-hellblade-title-poster/. Copyright [2017] by the Name of Ninja Theory. Reprinted without permission.

Cel-shaded style utilizes thick, black outlines in its graphics and little to no gradients. This art style can be applied to either 2D or 3D games.

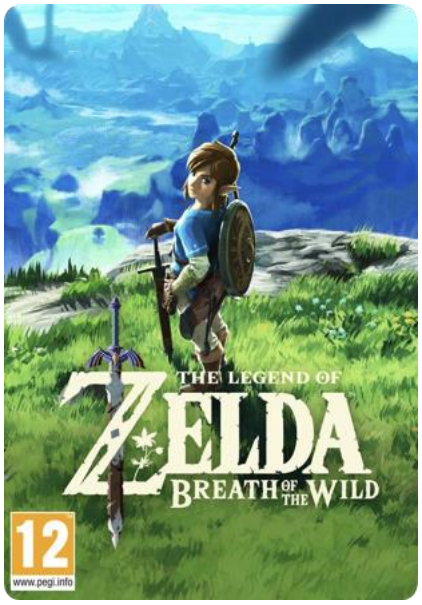



**Figure 4**
Note: An example of a cel-shaded style in the game, *Legend of Zelda.* Reprinted from *Nintendo Life*, n.d., https://www.nintendolife.com/games/nintendo-switch/legend_of_zelda_breath_of_the_wild. Copyright [2017] by the Name of Nintendo. Reprinted without permission.

Exaggerated is more so a feature than an art style, but it features exaggerated elements like facial expressions.

**Figure 5**
Note: An example of an exaggerated style in the game, *Overwatch.* Reprinted from *Playstation Lifestyle*, by Author B. Reeves, 2020, https://www.playstationlifestyle.net/2020/01/07/overwatch-2-release-date-rumor. Reprinted without permission.

Abstract games are not typically based on an existing style or true to life visuals (Visual Styles, 2012). It can also mean a game that focuses more on emotions rather than a message or gameplay.

**Figure 6**
Note: An example of an abstract style in the game, *Flower.* Reprinted from *Steam*, https://store.steampowered.com/app/966330/Flower/. Copyright [2009] by the Name of Sony Interactive Entertainment LLC. Reprinted without permission.

Another article classifies art styles specifically for 3D games ("Top 6 Styles…", n.d.). These classifications are similar to the prior listed categories, but with more distinctions: Realism, photorealism, unreal realism, "cartoony animation", anime, and collages ("Top 6 Styles…", n.d.). A *realism* style is based on how we visually see the world but is not trying to create identical replications necessarily. A *photorealistic* style is nearly identical to a photograph, in which the true to life visuals are taken as far as they can go (like in *Red Dead Redemption* or *Hellblade*). An *unreal realism* style, though considered fantasy, still follows fundamentals of the real world in properties like physics and color. Lastly, a *collage* style is a combination of different media, while a *cartoony* style can include *World of Warcraft* or *Borderlands* ("Top 6 Styles…", n.d.).

The lines dividing categories of art styles can be blurred, with overlapping properties and aesthetic decisions. For example, realism can apply to 2D games as well. Even if elements are rendered in a cartoony style, the textures can be highly detailed (Townsend, 2016). Even without an official taxonomy, art style is a recognizable element of aesthetics and strategically selected in games. As elucidated in Martel & Pitchford (2010) and Nava (2013), not everything translates well or is as effective in one particular style. Matt Nava mentioned in his talk how they tested out a scene in Journey in a 3D graphic style which, ultimately, was not as successful (Nava, 2013). They decided to make it more illustrative and less 3D (Nava, 2013). Borderlands experienced a similar situation with their drastic art style change (Martel & Pitchford, 2010). The creators of the game Borderlands understood late in the production process what the style of the game needed to be (Martel & Pitchford, 2010). They had issues with art quality and over the top action which created disjointedness, and subsequently, the exaggerated actions did not

match the photorealistic style initially chosen (Martel & Pitchford, 2010). They ended up reverting to their original concept art guidelines and stylesheets, and this is where they landed on a more fitting style (Martel & Pitchford, 2010). Despite this risky move, the developers noted that the game likely would not have been as successful without the switch (Martel & Pitchford, 2010). It is clear from these industry-provided insights that much time and emphasis are placed on aesthetic design in AAA games, but educational games lack this attention.

### G. Level of Aesthetic Realism in Serious Games

Games display a multitude of varying art styles, with many different aesthetic decisions that can only be considered on a range of continuums. This study will be focusing on one of those aesthetic continuums by looking at the level of *realism* in visuals for serious games for health.

The term realism is elusive and can mean a variety of things in different contexts. Realism is commonly thought of as a depiction that closely mimics objects as they appear in real life (Armstrong, 2006; Realism, 2018). However, Armstrong (2006) argues the flaw in this line of thinking, giving the example of Rembrandt's drawing *A Canal with a Rowing Boat*. It may look realistic defined in those terms, but the viewer was not there to see what the actual scene looked like and, therefore, cannot say if it is in fact true to life (Armstrong, 2006). It was mentioned that a generalized representation of the objects in the scene could still be considered realistic, since it depicts real objects in a lifelike way (Armstrong, 2006). Though, this may be more abstract than initially thought. Abstraction in visual art is a relative term and can be defined as art that which does not represent real life and is a schematic representation of an object (Abstract art, 1994; Abstraction,

2011). Rather than envisioning individuals, such as in the example of different dog breeds, a reduced, singular schematic or generic representation of the object is used (Abstraction, 2011). By this definition, Rembrandt's painting would closer align with abstraction rather than realism.

Visual art is comprised of several elements: color, line, form, shape, value, texture, space, and movement (art elements, 2018; formal art element, 2018). These elements can be broken up into further subcategories such as line with outline presence, outline quality, and implied lines (art elements, 2018). Or with color and its components of value, hue, and saturation (color, 2012). Elements in the realism continuum include but are not limited to proportion, color, and rendering style, as well as the many sub-elements of each.

Certain attributes in visual art make a scene more realistic over others. These include attributes such as the level of detail, environmental space, perspective, and depiction of weight and movement (Armstrong, 2006). A 3D object—or even a "shaded" object—is closer to realism than a flat one because it puts the object in a space, which alludes to its form as it pertains to real life (Armstrong, 2006). Objects need to be anchored in space in relation to other objects in the scene (Armstrong, 2006). This gives a sense of believable perspective (Armstrong, 2006). Illumination, focus, and level of detail also lend to this believability because the detail of an object will change at a given distance in relation to how in focus it is or the level of its clarity (Armstrong, 2006). Weight and movement in a piece can also be suggestive of realism, but these would relate to the relationship of the subject being depicted and how it sits in a scene due to forces acting upon it (Armstrong, 2006).

Similar to realism, brush strokes, color, shape, and texture can impact the level of abstraction (Abstract art, 1994). In expressionism, color is a tool for emotional persuasion and in cubism, simplified, geometric shapes are used to represent objects (Abstract art, 1994). Armstrong (2006)

mentions how attributes of realism can be shown but not all may be represented. An object can be realistic in structure but perhaps not in color, or perhaps realistic in tonal value but not in level of detail (Armstrong, 2006).

Realism can define many different types of visual art—like impressionism with its minimal detail yet accurate tonal values (Armstrong, 2006). Some other types of realism include revelatory realism, which refers to realism that arises from another (Kulvicki, 2006; McIver Lopes, 2006). This could mean visualizing subject matter that would otherwise not be visible in real life due to its size, for example (McIver Lopes, 2006). Realism can also refer to idealized forms as seen in renaissance art (McIver Lopes, 2006). Realism can mean how much something mimics life through the visualization techniques implemented, and it can also refer to the subject content and whether everyday subject matter is being depicted (realism, 2018). In this context, the level of realism in a game's aesthetics is defined as the varying degrees of abstraction from photorealistic representation, a concept with conflicting impact in prior literature.

In the article by Baranowski et al. (2016), it is mentioned that games for health have a captive market, and therefore do not need a high budget for advanced graphics as seen in AAA games. In fact, in a meta-analysis by Wouters et al. (2013) it was found that a high budget to prioritize AAA-quality aesthetics was irrelevant to learning because a simple style, cartoon game was equally as effective as a highly realistic one. Interestingly, two studies in this meta-analysis found that realism didn't promote more learning in serious games (Wouters et al., 2013). However, the category of "realism" was inconsistent, often vague, and not broken up into any further sub-categories. In fact, many studies are lacking in defining realism. For example, in the study by Spek et al. (2014), a cartoon style with a realistic environment and

characters was considered to be representative of realism. Perhaps this lack of consistent classification in the literature could explain the conflicting evidence found on whether a realistic or cartoon art style aides in learning. Baranowski et al. (2016) state the aesthetics of the game would not affect learning, but it has been stated that aesthetics does affect flow and engagement—elements that are necessary for holding user's attention to learn the material (O'Brien & Toms, 2008).

### H. Types of Validity

*Validity* refers to the assessment of an instrument's accuracy in measuring what it intended to measure (Bolarinwa, 2016; Litwin, 1995). There are many different types of validity that can be used, which can be distinguished as: face validity, content validity, criterion validity, and construct validity (Bolarinwa, 2016; Litwin, 1995; Polit, 2015). Face validity is when the instrument looks good at "face value" (Bolarinwa, 2016; Litwin, 1995; Polit, 2015). This can be done by an expert or non-expert (Bolarinwa, 2016; Litwin, 1995; Polit, 2015). Content validity goes further, and tests if the instrument is comprehensive and worded properly (Bolarinwa, 2016; Litwin, 1995; Polit, 2015). This type would be done by a panel of experts or a relevant sample population. (Bolarinwa, 2016; Litwin, 1995; Polit, 2015). Criterion validity measures how well the instrument works in comparison to an existing validated instrument (Bolarinwa, 2016; Litwin, 1995; Polit, 2015). Lastly, Construct validity measures how accurate the instrument is in practical use (Bolarinwa, 2016; Litwin, 1995).

Reliability is the ability for a test to be repeated with similar results (Litwin, 1995). An instrument can be valid, but this does not mean that it is reliable (Litwin, 1995). Likewise, an

instrument may be reliable, but that does not mean it is measuring the intended target (Bolarinwa, 2016; Litwin, 1995). This is why content validity is useful for assessing if an instrument is representative of what it is measuring (Bolarinwa, 2016). Content validity is considered highly important, but it should be seen as an early step towards construct validity (Polit, 2015). Since content validity seeks confirmation from experts relating to a subject, it is more valuable than face validity. It is also the most relevant to this study considering there appears to be no test or standard to compare the created instrument to—in the case of criterion validity. Additionally, construct validity is not suitable either considering it needed to be determined what attributes represent this continuum, therefore, the instrument cannot be put to practical use yet.

**I. Research gap**

Although research has been done on serious games in areas like motivation, engagement, and gameplay, little research has been done on the influence of *art style* in serious games. Though some research does examine aesthetics, little emphasis is placed on fully understanding, defining and comparing aesthetic categories, particularly when compared to the research on other game-based learning properties like game mechanics and scaffolding. In the research that did cover aesthetics, visual style is rarely mentioned or even considered as a tool for learning and engagement. Furthermore, conflicting evidence on the impact of level of realism in the visuals of these games can be associated with unclear or misunderstood definitions of these terms. Studies discussing aesthetics and testing serious games did not specify their reasoning for choosing their game's art style, though game industry leaders have

frequently remarked on the undeniable importance of these decisions in engagement. It is interesting that such a large defining characteristic of aesthetics—a defining characteristic of engagement—is, seemingly, arbitrarily chosen. Further research is needed to define these attributes and determine if distinctly different art styles used in serious games have an effect on learning and understanding. In order to effectively study the influence of visual art, an instrument is needed to objectively compare different art styles. However, to the knowledge of the researchers, no attempts have been made to classify or characterize serious game concept art as to the level of realism by quantifying the elements of visual art.

# III. RESEARCH SIGNIFICANCE

## A. Significance of research study

This study aimed to make art more objective by quantifying its place on the realism continuum. By creating this framework, the researchers anticipate that the new instrument could help provide future insight on the effectiveness of different art styles and its role in patient learning. Currently, there is a lack of research on the variables of visualization. The studies that do evaluate art styles have no framework for proper comparison. The ability to quantitatively evaluate a single continuum of visualization might pave the way for future investigation, leading to potentially powerful insight for medical illustrators and game developers alike. This could impact game development researchers, specifically for serious games, by elucidating user preferences. It will give insight on preferences users may have on aesthetics in relation to medical content. The *Humaginarium* project will benefit by using this knowledge to inform design decisions. Patients, in turn, will benefit by enhanced understanding of medical content, which will promote better health outcomes. This would increase treatment adherence, diagnosis understanding, catharsis, and anxiety reduction.

## B. Research question

Can a valid instrument be developed to measure the levels of realism in serious game concept art by quantifying elements of visual art?

# IV. METHODS

## A. Research study design

In order to answer the primary question of this research, the research committee validated an instrument using *content validity*. Concept art was developed in varying levels of realism, which were used to evaluate the efficacy of the constructed instrument. For the purposes of this project, the realism continuum was defined by a visual's fidelity to the real-world—or its level of abstraction from photorealism. The concept art focused on communicating information relating to metabolic homeostasis. Artwork was evaluated on a scale that quantified varying levels of realism, and the committee provided feedback on wording, comprehensiveness, and point value.

Since the effectiveness of levels of realism has not been well studied, the researchers aimed to create a new type of framework for visualization research. While this research might not be directly applicable to *Diabetes Agonistes*, this is a first step for contextualizing the influence of art style in serious games.

## B. Stimulus design plan

Concept art in different art styles were created in order to make a "look book" or series of still images. The six created concept art pieces focus on the topic of homeostasis. The software used to create the material included programs such as Autodesk 3DS Max, Pixologic ZBrush, Luxion KeyShot, and the Adobe Creative Suite.

The continuum may be defined as being from high-fidelity (or true to life proportion, color, and rendering) to low-fidelity (or abstraction from life-like visual qualities). An instrument for

scoring where an image falls on this continuum was created, and the concept art was evaluated using this test in order to assess the realism or fantasy of the artwork. Six different art pieces were assigned a point value correlating to the instrument's variables. The concept art was then rendered using these allotted scores. Within each art style, one of the elements (proportion, color, or rendering) were altered per concept art piece. For further breakdown and clarification on how these categories were adjusted, see table four and table five in the Appendix.

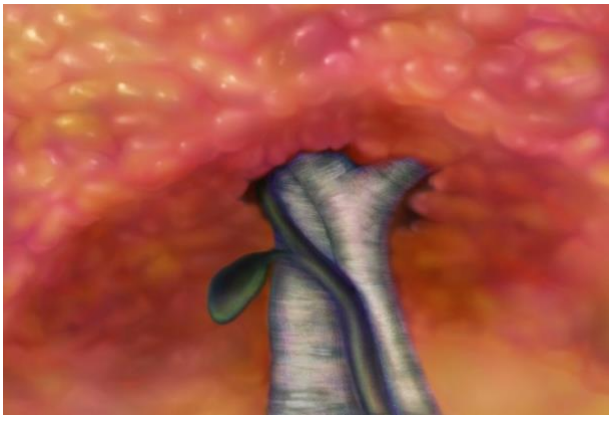
The medium was kept the same for all the art styles and each piece has a similar level of fidelity. The art was created using digital software, but the methods of production vary between the six styles. In games, digital art is the most commonly used for aesthetic design, however, this does not mean digital art has to look digital.

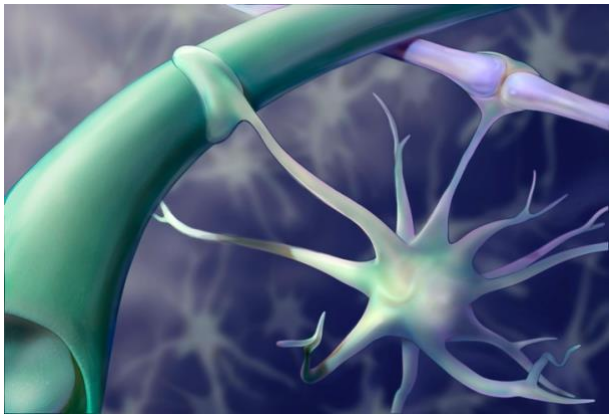
The instrument was created by looking at illustrations, listing the attributes that made illustrations more realistic or more abstract, and categorizing those attributes based upon the principles of visual art. A Likert scale scoring system was implemented to account for the nuances within each attribute. For example, two illustrations may both have outlines, but the difference in line weight and color could make one more abstract looking over the other. After looking at art principles on color, light, form, perspective, etc., questions were synthesized or expanded upon in attempt to fully represent each main category section. Random artwork in varying art styles and perceived levels on the realism continuum were put through the test in order to see if the scores they received reflected their subjective ranking. This process was repeated, and questions were fine-tuned until reaching the framework of the initial instrument.

Color, rendering, and proportion were the categories of focus for testing due to their initially perceived importance in influencing the realism scale. Before creating the concept art,

values were assigned for all three categories per concept art piece. The six images' scores evenly spanned along the range of the instrument in order to have sufficient representation of the continuum. After creating point values, qualitative attributes for each piece were assigned to reflect this score.

The subject of each concept art piece was chosen to reflect a structure relating to type 2 diabetes. Thumbnail sketches were created for each of the six subjects and later narrowed down to one. Refinement of the rough sketches as well as color comps were created to flesh out each piece. This helped keep the range of artwork distributed across the spectrum. Finally, 3D modeling programs, such as Pixologic ZBrush and Autodesk 3ds Max, were used for the 3D rendered images and Adobe Photoshop was used for compositing purposes. The remaining illustrations were created in Adobe Photoshop and Adobe Fresco.





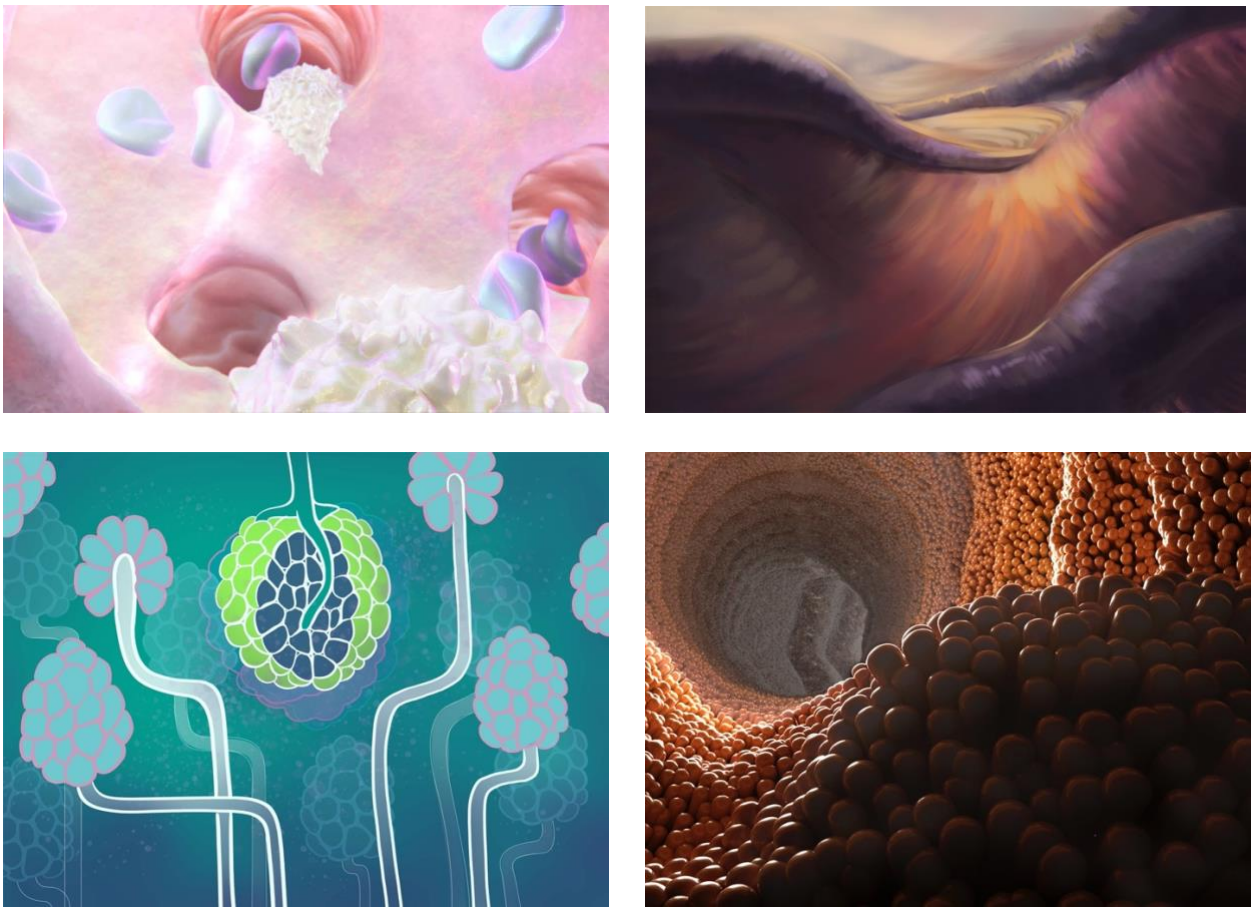


**Figure 7**

*Note:* The six concept art pieces created for the study

Testing was broken up into two parts: first, the committee met to review the instrument; second, the committee members individually assessed the concept art using the instrument. In the first phase, after creating the instrument and concept art, a committee meeting was held to discuss the validity of the instrument. During the meeting, the comprehensiveness of the instrument was discussed as well as question wording. Some of the biggest points of feedback were about terminology and the use of the word fantasy. One of the panel members had brought up the point that fantasy is based on fiction—which none of this

anatomical content is showing. Fantasy was changed to the word abstraction since this more appropriately addressed the spectrum.

Some of the original wording made it seem that the value “abstract” was wrong or of a lower value than realism—which is not what the instrument is trying to convey. It needed to be worded in a way that showed an illustration was leaning more towards abstract or realistic, rather than one is more correct over the other. As medical illustrators, it is challenging to not regard realistic visual quality as being the best or most true. A challenge for creating this instrument was taking a step back to address the attributes of this spectrum neutrally.

There were sentences the committee felt were confusing to answer based on how they were worded, or the terminology used. Considering the way certain words could be interpreted, especially with different media, it was suggested to have a brief definition under what some terms meant. This would ensure that the attribute being judged was clear. Other questions needed the wording adjusted to accurately represent what they were asking—like using color instead of hue. Also, it was mentioned that the context of what the artist intended for each piece would help, as well as rephrase questions in a way that would nod to what the illustration is actually showing. For example, in regard to the “Transitions” questions (Appendix Table 5, Page 62), an object may be striped, giving it large jumps between values or hues. This would make the illustration skew more abstract on the scale, even if the depiction was true to life. Another interesting point that was brought up was that some things might not have a right or wrong hue to them (like molecular level scenes) while other subjects do have a definitive hue that is truer to life. Therefore, the instrument needs to ask questions in a way that takes into account the object being shown.

Another major point discussed was the use of a 0-point category. Some questions were not applicable but giving there was no choice for that at the time, it made answering difficult. A new answer choice was added for questions needing this response option. The only issue with this, however, was the results getting skewed after tallying up the points. For example, two equally realistic images would get different scores if one used linear perspective and the other did not (and selected not applicable).

It was brought up that some questions, like lighting, might be encompassed in some of the other questions, although, it was decided not to eliminate them just yet. The original instrument had a fictional elements section for foreign items, anthropomorphized anatomy, and visual metaphor. This section was removed since it seemed this section was answering fantasy. It seemed as though the section was answering content accuracy as opposed to other sections that were more-so about rendering. It was also uncertain if some questions, like brush strokes, should weigh as much as others. It was suggested to evaluate the individual scores of the category sections with the overall score to see how much weight each section was pulling, and if that was appropriate.

After the feedback from the committee, the instrument went through another round of revisions based upon what was discussed. The newly revised version of the instrument was then sent out to the three committee members to individually evaluate the group of concept art pieces using the test, facilitated via a Google Form survey. Committee members were asked to first rank the artwork based upon their initial judgment of where they fall on the continuum in relation to one another. They then evaluated each piece of artwork using the instrument. At the end of each image's section, an optional feedback response area was given if there were

any other revisions they thought might be necessary. The feedback received was that perhaps wording certain questions to include exaggeration of attributes rather than it being only based on if it was present or not (i.e., surface textures and reflected light). Also, it was mentioned that there is still room for refinement in regard to addressing how objects relate to one another. It was mentioned that there are not individual pieces in the tested concept art to break up where the phrase “in relation to each other” would be relevant. Further refinement of wording is still needed.

## C. Evaluation plan

A meeting was held for the committee to determine the validity of the instrument in assessing art on the realism continuum. Adjustments were made to the instrument based upon this feedback.

The concept art was then given to the committee members and the artwork was ranked individually. After ranking the artwork, each piece was then quantified using the instrument. This was done in order to assess whether the score received reflected the initial judgement of the concept art.

### 1. Study setting

Evaluation of the final research stimulus was conducted online through a video meeting platform and lasted approximately 60 minutes.

### 2. Sample or population sampling methods

#### a. Selection criteria

Content validity requires a panel of experts; the research committee were selected to test the instrument and assess the realism or fantasy of the artwork.

#### b. Selection strategy

The research committee was selected based upon their expertise. The committee included three Board-Certified Medical Illustrators, some of whom had related background in serious game development.

#### c. Size

The committee was comprised of three members.

#### d. Data collection

Data was collected from the committee members during the online video discussion. This included qualitative and quantitative data. The feedback from the committee members was recorded as well as their individual scores and initial ranking for the artwork. Results were then synthesized into a table in excel.

#### e. Method of analysis

The data was interpreted by examining the committee member's qualitative feedback on the instrument. This feedback also included the individual scoring and the subjective ranking of artwork using the final instrument. The results were used to compare how successful the instrument was in placing the artwork on the realism continuum, and the overall

comprehensiveness of the test.

## V. RESULTS

After all committee members submitted their responses, the data was exported to an excel spreadsheet for further interpretation. In the instrument, certain questions had a "not applicable" option, which was given a value of 0 points. This was to account for the differences in illustration content, such as linear perspective, where it cannot objectively be "wrong" or "right", but still needs to be considered when implemented. An average was given for each category where the 0 was excluded. The formula for this was:

$$A = \frac{Total\ Category\ Points}{Number\ of\ Category\ Questions\ Answered}$$

Since the current instrument gives equal weight to each question, in order to account for the different number of questions in each section, the following formula was used to determine the weight of each category:

$$W = \frac{Number\ of\ Category\ Questions}{Number\ of\ Total\ Questions\ Answered}$$

The weighted average was then determined. This was done by adding up the product of each category. The formula for this was:

$$(A_1W_1) + (A_2W_2)\ (A_3W_3) + (A_4W_4) + (A_5W_5) = \textit{Weighted Average}$$

The data was organized to show the initial ranking of the artwork against the score they received. This helps uncover if the qualitative attributes of the artwork can be given a quantitative value that will reflect the discernment of the experts. The validity and comprehensiveness of the instrument cannot be assumed from this, but it does imply the possibility to create such an instrument. It also helps determine if perhaps certain categories or questions should be further investigated into how much weight they pull.

The lowest of the 3 scores for each image was subtracted from the highest scores to get the range in values between the content validity members. The possible range was 0-2, with 0 being the most precise. The highest range of the six images was .39, which suggests a relatively high precision rate between the individual rankings. While precision does not equate to validity of what the instrument intends to measure, it is important to note that this instrument, after revisions from the experts' suggestions, is potentially reliable amongst different individuals and different art styles.

The scores of the images closely reflected the initial scores given prior to running them through (either a 0- or 1-point difference), with the exception of one of the 18 scores. The possible range for ranking between what was selected initially and the order the image fell in after a score was 0-5, and image 4 had a range of 2. Comparing the before and after ranking is important to note since a lower range suggests the instrument is able to quantify the expert's rankings on the continuum. Although, this still cannot say whether the instrument is indeed valid given the small number of experts, potential lack of categories, and needed wording refinement of current questions. The fact that the scores are relatively close, though, is promising.

Although there is consistency with the results, this still does not prove that the instrument is valid as there may be essential questions missing from the instrument. So, it may be precise, but it still might not be accurate. The fact that there was a low range between responses, however, does suggest a pattern and potential for an objective, quantifiable score.

For a comprehensive look at the data collected, see table six in the Appendix.

Table 1

*Weighted Averages of Images Amongst Evaluators*

| | **Image 1 Weighted Averages** | | | |
|---|---|---|---|---|
| | P1 Score: | P2 Score: | P3 Score: | Range 0-2 |
| Color | 0.21782609 | 0.26086957 | 0.39130435 | 0.17347826 |
| Rendering | 0.3926087 | 0.34782609 | 0.39130435 | 0.04478261 |
| Use of Perspective and Environmental Space | 0.30434783 | 0.30434783 | 0.2173913 | 0.08695653 |
| Lighting | 0.39130435 | 0.43478261 | 0.43478261 | 0.04347826 |
| Proportions | 0.2173913 | 0.26086957 | 0.17391304 | 0.08695652 |
| **Image Score Total:** | 1.52347826 | 1.60869565 | 1.60869565 | 0.08521739 |
| | **Image 2 Weighted Averages** | | | |
| | P1 Score: | P2 Score: | P3 Score: | Range 0-2 |
| Color | 0.375 | 0.36 | 0.29166667 | 0.08333333 |
| Rendering | 0.49875 | 0.32 | 0.375 | 0.17875 |
| Use of Perspective and Environmental Space | 0.33333333 | 0.44 | 0.29166667 | 0.14833333 |
| Lighting | 0.58333333 | 0.52 | 0.45833333 | 0.125 |
| Proportions | 0.20833333 | 0.24 | 0.25 | 0.04166667 |
| **Image Score Total:** | 1.99875 | 1.88 | 1.66666667 | 0.33208333 |
| | **Image 3 Weighted Averages** | | | |
| | P1 Score: | P2 Score: | P3 Score: | Range 0-2 |
| Color | 0.33333333 | 0.33333333 | 0.34782609 | 0.01449275 |

| | | | | |
|---|---|---|---|---|
| Rendering | 0.79041667 | 0.66666667 | 0.65217391 | 0.13824275 |
| Use of Perspective and Environmental Space | 0.33333333 | 0.33333333 | 0.30434783 | 0.0289855 |
| Lighting | 0.5 | 0.54166667 | 0.47826087 | 0.0634058 |
| Proportions | 0.25 | 0.33333333 | 0.2173913 | 0.11594203 |
| **Image Score Total:** | 2.20708333 | 2.20833333 | 2 | 0.20833333 |
| | | **Image 4 Weighted Averages** | | |
| | P1 Score: | P2 Score: | P3 Score: | Range 0-2 |
| Color | 0.33333333 | 0.22222222 | 0.2962963 | 0.11111111 |
| Rendering | 0.76923077 | 0.55555556 | 0.62962963 | 0.21367521 |
| Use of Perspective and Environmental Space | 0.15384615 | 0.22222222 | 0.22222222 | 0.06837607 |
| Lighting | 0.38461538 | 0.22222222 | 0.25925926 | 0.16239316 |
| Proportions | 0.11538462 | 0.14814815 | 0.18518519 | 0.06980057 |
| **Image Score Total:** | 1.75641026 | 1.37037037 | 1.59259259 | 0.38603989 |
| | | **Image 5 Weighted Averages** | | |
| | P1 Score: | P2 Score: | P3 Score: | Range 0-2 |
| Color | 0.46153846 | 0.42857143 | 0.40740741 | 0.05413105 |
| Rendering | 1.07692308 | 1.07142857 | 1.03703704 | 0.03988604 |
| Use of Perspective and Environmental Space | 0.30769231 | 0.53571429 | 0.37037037 | 0.22802198 |
| Lighting | 0.61538462 | 0.64285714 | 0.66666667 | 0.05128205 |
| Proportions | 0.15384615 | 0.32142857 | 0.2962963 | 0.16758242 |
| **Image Score Total:** | 2.61538462 | 3 | 2.77777778 | 0.38461538 |
| | | **Image 6 Weighted Averages** | | |
| | P1 Score: | P2 Score: | P3 Score: | Range 0-2 |
| Color | 0.29166667 | 0.13636364 | 0.14285714 | 0.15530303 |
| Rendering | 0.3325 | 0.27272727 | 0.28571429 | 0.05977273 |
| Use of Perspective and Environmental Space | 0.25 | 0.22727273 | 0.14285714 | 0.10714286 |
| Lighting | 0.33333333 | 0.27272727 | 0.28571429 | 0.06060606 |
| Proportions | 0.08333333 | 0.09090909 | 0.14285714 | 0.05952381 |
| **Image Score Total:** | 1.29083333 | 1 | 1 | 0.29083333 |

*Note.* The weighted averages of each image, from each committee member is shown. The total weighted average of each image is displayed as well as the weighted average of each category. The table includes the range of each category; lower values indicate higher precision. P1 = Evaluator 1, P2 = Evaluator 2, P3 = Evaluator 3

Table 2

*Initial Ranking of Concept Art by Content Validity Committee*

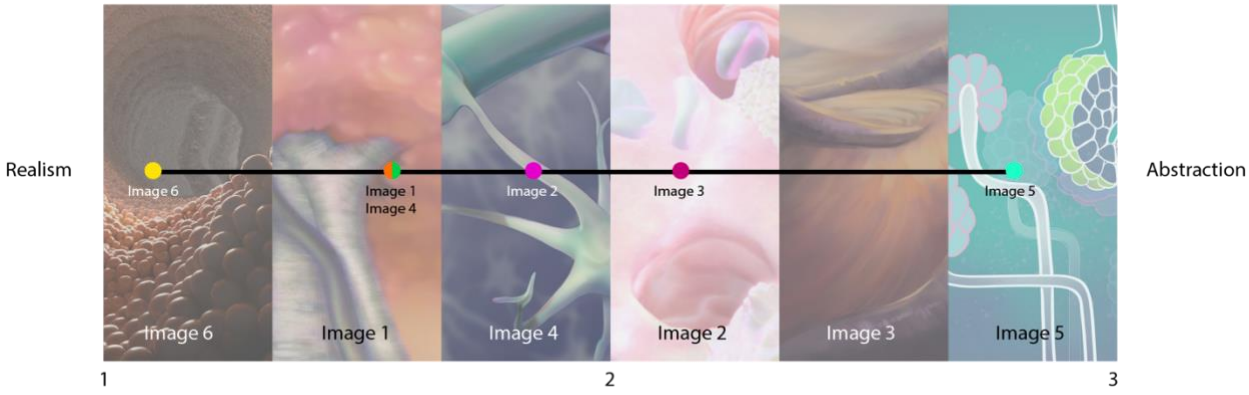
| | Image 1 | Image 2 | Image 3 | Image 4 | Image 5 | Image 6 |
|---|---|---|---|---|---|---|
| P1 Initial: | 3 | 4 | 5 | 4 | 6 | 1 |
| P2 Initial: | 3 | 4 | 5 | 2 | 6 | 1 |
| P3 Initial: | 2 | 3 | 5 | 4 | 6 | 1 |

*Note.* The initial rankings of the concept art by the committee are shown. These rankings were created prior to running the artwork through the instrument. Lower numbers represent images closer to realism, higher numbers represent images closer to abstraction. P1 = Evaluator 1, P2 = Evaluator 2, P3 = Evaluator 3

Table 3

*Comparison of Initial Ranking of Concept Art with Instrument Score*

*A.*



B.

| | Image 1 | Image 2 | Image 3 | Image 4 | Image 5 | Image 6 |
|---|---|---|---|---|---|---|
| P1 Score: | 1.52 | 2.00 | 2.21 | 1.76 | 2.62 | 1.29 |
| P2 Score: | 1.61 | 1.88 | 2.21 | 1.37 | 3.00 | 1.00 |
| P3 Score: | 1.61 | 1.67 | 2.00 | 1.59 | 2.78 | 1.00 |
| Average | **1.57** | **1.85** | **2.14** | **1.57** | **2.80** | **1.10** |

*Note.* A. The average of the initial rankings of concept art placed in order, with the average of the weighted scores plotted on a line for comparison. B. The weighted averages of the concept art by the committee members. These scores were created by running the concept art through the instrument and finding their weighted average. P1 = Evaluator 1, P2 = Evaluator 2, P3 = Evaluator 3

# VI. DISCUSSION

## A. Review of Key Points

Though prior studies have investigated engagement with serious games and the benefits for learning, very little research has been done on the influence of art style in serious games; furthermore, research that examines aesthetics rarely mention this prominent attribute of aesthetic design (Spek et al., 2014; Thompson, 2012). Even fewer still, studies that do look into the influence of graphics in learning can have questionable methodology. Only little importance is placed on aesthetics in the serious games genre, and for a variety of reasons, it is commonly perceived as lacking in AAA quality visual standards. By creating an instrument that generates objective scores to compare artwork, this study springboards future research on artistic style. Serious game concept artwork can be classified or characterized as to the level of realism by quantifying the elements of visual art. Though only evaluating a single continuum of the visual quality, this instrument aimed to create a starting framework for objectively analyzing art for the purpose of bettering education and visualization in the future. This study suggests that a valid instrument can be developed to measure the level of realism. This insight could, in turn, be used to help determine aesthetic decisions for medical illustrations by studying the relationship between learning and user preference.

## B. Limitations

A major limitation of this study was due to COVID and remotely working, since an in-person focus group would have replaced the video meeting.

There are only a handful of illustrations that were looked at, and this is something that needs to be tested and retested with multiple pieces. With that being said, there are many variables to account for that could make scoring the current concept art against each other difficult. It may be more helpful to compare different types of similar artwork (i.e., all 3D rendered) to see how they score with the instrument before covering a broader spectrum.

Something briefly mentioned, but not addressed with this research question, is the weight of the individual questions. It is unclear if certain questions are more influential to the spectrum and should therefore weigh more than others. Currently, all questions were weighted equally. Only three categories in the test were focused on when making the concept art. While these were deemed, at face value, the most critical for swaying the continuum, the remaining categories were not taken into account when creating the concept art. Therefore, the images were not properly spread out in those categories (i.e., no pieces included linear perspective).

Another limitation lies in the potential for bias in testing. The committee saw the instrument prior to testing, which could have allowed them to anticipate how to answer their initial ranking. There will also inevitably be some degree of subjectivity given the nature of Likert scales, so discrepancies in scoring will occur.

### C. Future Implications

This study helps to provide a starting framework for an instrument that was otherwise nonexistent. With more testing and refinement, a valid instrument could be created to objectively measure the realism-abstraction continuum. This instrument is the first step in testing how people learn from different art styles as it provides a way to compare subjective content. Translating this qualitative data into quantifiable values will give structure and validity

to future research. With enough data, a valid instrument could potentially be used to create a machine learning model to objectively evaluate artwork. This would provide even further uniformity amongst studies.

There are many art styles for games, and while the selection of the styles for testing were strategically chosen, it represents only a small fraction of styles on the market. There also are many variables or continuums even within one style. This study aimed to help contribute to the field of medical illustration for artists interested in creating effective serious games. By analyzing if one art style is more effective in how people learn, medical illustrators will be able to make decisions in serious games with more understanding and awareness. This study could potentially help inform artistic decisions in game design for increased engagement by creating visual content with user preference in mind.

**CITED LITERATURE**

Abubakar, J. A., Ahmad, M. K., Zulkifli, A. N., & Bahrin, A. S. (2016, August). Conceptual model of game aesthetics for perceived learning in narrative games. In *2016 4th International Conference on User Science and Engineering (i-USEr)* (pp. 111-115). IEEE. https://doi: 10.1109/IUSER.2016.7857944.

Abstract art. (1994). In H. E. Read, & N. Stangos (Eds.), *The Thames & Hudson Dictionary of Art and Artists* (2nd ed.). Thames & Hudson. Credo Reference: http://proxy.cc.uic.edu/login?url=https://search.credoreference.com/content/entry/thaa/abstract_art/0?institutionId=1361

Abstraction. (2011). In B. Sandywell, *Dictionary of visual discourse: a dialectical lexicon of terms*. Ashgate Publishing. Credo Reference: http://proxy.cc.uic.edu/login?url=https://search.credoreference.com/content/entry/ashgtvd/abstraction/0?institutionId=1361

Armstrong, J. (2006). Depiction and the Sense of Reality. *Contemporary Aesthetics*, *4*.

art elements. (2018). In Helicon (Ed.), *The Hutchinson unabridged encyclopedia with atlas and weather guide*. Helicon. Credo Reference: http://proxy.cc.uic.edu/login?url=https://search.credoreference.com/content/entry/heliconhe/art_elements/0?institutionId=1361

Baranowski, T., Blumberg, F., Buday, R., DeSmet, A., Fiellin, L. E., Green, C. S., … Young, K. (2016). Games for Health for Children—Current Status and Needed Research. *Games for Health Journal*, *5*(1), 1-12. https://doi.org/10.1089/g4h.2015.0026'

Billman, G. E. (2020). Homeostasis : The Underappreciated and Far Too Often Ignored Central Organizing Principle of Physiology. *Frontiers in Physiology*, *11*, 200. https://doi.org/10.3389/fphys.2020.00200

Bolarinwa, O. (2016). Principles and methods of validity and reliability testing of questionnaires used in social and health science researches. *The Nigerian Postgraduate Medical Journal*, *22*, 195–201. https://doi.org/10.4103/1117-1936.173959

Castillo-Armengol, J., Fajas, L., & Lopez-Mejia, I. C. (2019). Inter-organ communication: a gatekeeper for metabolic health. EMBO reports, 20(9), e47903. https://doi.org/10.15252/embr.201947903

Catharsis (2016). In Editors of the American Heritage Dictionaries (Ed.), *The American Heritage (R) dictionary of the English language* (6th ed.). Houghton Mifflin. Credo Reference: http://proxy.cc.uic.edu/login?url=https://search.credoreference.com/content/entry/hmdictenglang/catharsis/0?institutionId=1361

Cerf M. E. (2013). Beta cell dysfunction and insulin resistance. Frontiers in endocrinology, 4, 37. https://doi.org/10.3389/fendo.2013.00037

Chatterjee, S., Khunti, K., & Davies, M. J. (2017). Type 2 diabetes. *The Lancet*, *389*(10085), 2239–2251. https://doi.org/10.1016/S0140-6736(17)30058-2

color. (2012). In *Merriam-Webster's collegiate(R) dictionary* (11th ed.). Merriam-Webster. Credo Reference: http://proxy.cc.uic.edu/login?url=https://search.credoreference.com/content/entry/mwcollegiate/color_1/0?institutionId=1361

Create 2D and 3D games in Unity (n.d.). *Unity*. Retrieved from https://unity.com/how-to/difference-between-2D-and-3D-games

Crowle, R. (2013). *Building the touchy-feely world of Tearaway* [Conference presentation]. Game Developers Conference, 2013. Retrieved from https://www.gdcvault.com/play/1017845/Building-the-Touchy-Feely-World

DeFronzo, R. A. (2009). From the Triumvirate to the Ominous Octet: A New Paradigm for the Treatment of Type 2 Diabetes Mellitus. Diabetes, 58(4), 773–795. https://doi.org/10.2337/db09-9028

Designing Game's Visual Style. (2015, December 3). *80 Level.* Retrieved from https://80.lv/articles/designing-games-visual-style/

*Designing Game's Visual Style*. (2019, July 16). https://80.lv/articles/designing-games-visual-style/

*DeSoto ISD* (n.d.). *2019-2020 Middle school course catalog.* Retrieved from http://www.desotoisd.org/UserFiles/Servers/Server_165690/File/District%20Information/DeSoto%20Middle%20School%20Course%20Catalog%2019-20.pdf

Doak, C., & Doak, L. (2004) Pfizer principles for clear health communication: A handbook for creating patient education materials that enhance understanding and promote health outcomes (2nd ed.). *New York: Pfizer.*

Eckel, R. H., Grundy, S. M., & Zimmet, P. Z. (2005). The metabolic syndrome. Lancet (London, England), 365(9468), 1415–1428. https://doi.org/10.1016/S0140-6736(05)66378-7

Fändriks, L. (2017). Roles of the gut in the metabolic syndrome: An overview. *Journal of Internal Medicine*, *281*(4), 319–336. https://doi.org/10.1111/joim.12584

formal art element. (2018). In Helicon (Ed.), *The Hutchinson unabridged encyclopedia with atlas and weather guide*. Helicon. Credo Reference: http://proxy.cc.uic.edu/login?url=https://search.credoreference.com/content/entry/heliconhe/formal_art_element/0?institutionId=1361

Gerontoukou, E. I., Michaelidoy, S., Rekleiti, M., Saridi, M., & Souliotis, K. (2015). Investigation of Anxiety and Depression in Patients with Chronic Diseases. *Health Psychology Research*, *3*(2). https://doi.org/10.4081/hpr.2015.2123

Griffiths, M. (2005). Video games and health. *BMJ: British Medical Journal*, *331*(7509), 122-123.

Habgood, M. J., Ainsworth, S. E., & Benford, S. (2005). Endogenous fantasy and learning in digital games. *Simulation & Gaming*, *36*(4), 483-498. Retrieved from https://journals-sagepub-com.proxy.cc.uic.edu/doi/abs/10.1177/1046878105282276

Hjelte, R. (2019, January 2). *2. A theory of games—Games as aesthetic experiences*. Medium. https://medium.com/@Krumbukt/2-a-theory-of-games-games-as-aesthetic-experiences-5674b0395cdd

Hoffman, B., & Nadelson, L. (2010). Motivational engagement and video gaming: A mixed methods study. *Educational Technology Research & Development*, *58*(3), 245-270. https://doi.org/10.1007/s11423-009-9134-9

Kapur, M. (2008). Productive Failure. *Cognition and Instruction,26*(3), 379-425. Retrieved from http://www.jstor.org/stable/27739887

Klopfer, E., Osterweil, S., & Salen, K. (2009). Moving learning games forward. *Cambridge, MA: The Education Arcade*.

Kulvicki, J. (2006). Pictorial Realism as Verity. *Journal of Aesthetics & Art Criticism*, *64*(3), 343–354. https://doi-org.proxy.cc.uic.edu/10.1111/j.1540-594X.2006.00212.x

Kripalani, S., & Weiss, B. D. (2006). Teaching about health literacy and clear communication. *Journal of general internal medicine*, *21*(8), 888.

Lazzaro, N. (2004, March). Why we play games: Four keys to more emotion in player experiences. In *Proceedings of GDC* (Vol. 306, pp. 1-8).

Litwin, M. S. (1995). Validity. In *How to measure survey reliability and validity* (pp. 33-46). SAGE Publications, Inc., https://www-doi-org.proxy.cc.uic.edu/10.4135/9781483348957

Maheu-Cadotte, M.-A., Cossette, S., Dubé, V., Fontaine, G., Mailhot, T., Lavoie, P., … Mathieu-Dupuis, G. (2018). Effectiveness of serious games and impact of design elements on engagement and educational outcomes in healthcare professionals and students: A systematic review and meta-analysis protocol. *BMJ Open*, *8*(3). https://doi.org/10.1136/bmjopen-2017-019871

Markham Woods (2019). *2019-2020 Middle school catalog*. Retrieved from http://www.mwms.scps.k12.fl.usPortals/119/19-20%20MKMS%20Curriculum%20Guide%203.pdf?ver=2019-02-11-111309-893

Martel, B. & Pitchford, R. (2010). *Borderlands and the 11th Hour Art Style Change. Or: Kids, Don't Try this at Home!* [Conference presentation]. Game Developers Conference, 2010. Retrieved from https://www.gdcvault.com/play/1012220/Borderlands-and-the-11th-Hour

Mayer, R., & Moreno, R. (2007). Interactive multimodal learning environments. *Educational psychology review*, 19, 309-326. http://dx.doi.org/10.1007/s10648-007-9047-2

McIver Lopes, D. (2006). *The Special and General Theory of Realism: Reply to Abell, Armstrong, and McMahon*. Ann Arbor, MI: Michigan Publishing, University of Michigan Library.

Mendrick, D. L., Diehl, A. M., Topor, L. S., Dietert, R. R., Will, Y., La Merrill, M. A., Bouret, S., Varma, V., Hastings, K. L., Schug, T. T., Emeigh Hart, S. G., & Burleson, F. G. (2018). Metabolic Syndrome and Associated Diseases: From the Bench to the Clinic. Toxicological sciences: an official journal of the Society of Toxicology, 162(1), 36–42. https://doi.org/10.1093/toxsci/kfx233

Nava, M. (2013). *The art of journey* [Conference presentation]. Game Developers Conference, 2013. Retrieved from https://www.gdcvault.com/play/1017799/The-Art-of

Obikwelu, C., Read, J., & Sim, G. (2012). The scaffolding mechanism in serious games. *Fun and Game*, *9*, 4-6.

O'Brien, H. L., & Toms, E. G. (2008). What is user engagement? A conceptual framework for defining user engagement with technology. *Journal of the American Society for Information Science and Technology*, *59*(6), 938-955. https://doi.org/10.1002/asi.20801

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of Game-Based Learning. *Educational Psychologist*, *50*(4), 258-283. https://doi.org/10.1080/00461520.2015.1122533

Plourde, P. (2014). *The art of child of light* [Conference presentation]. Game Developers Conference, 2014. Retrieved from https://www.gdcvault.com/play/1020561/The-Art-of-Child-of

Polit, D. F. (2015). Assessing measurement in health: Beyond reliability and validity. *International journal of nursing studies*, *52*(11), 1746-1753.

realism. (2018). In Helicon (Ed.), *The Hutchinson unabridged encyclopedia with atlas and weather guide*. Helicon. Credo Reference: https://search.credoreference.com/content/entry/heliconhe/realism/0

Riot Games (2018a, December 13). *Episode 1: intro to game art* [Video File]. Retrieved from https://www.youtube.com/watch?v=RqRoXLLwJ8g

Riot Games (2018b, December 13). *Episode 2: concept art* [Video file]. Retrieved from https://www.youtube.com/watch?v=FqX-UMVTLHI

Ruppel, R. (2014). *Art Direction is Not Just Googling Images* [Conference presentation]. Game Developers Conference, 2014. Retrieved from https://www.gdcvault.com/play/1020339/Art-Direction-is-Not-Just

Russoniello, C. V., O'Brien, K., & Parks, J. M. (2009). The effectiveness of casual video games in improving mood and decreasing stress. *Journal of Cyber Therapy & Rehabilitation*, *2*(1), 53-66.

Saklayen M. G. (2018). The Global Epidemic of the Metabolic Syndrome. Current hypertension reports, 20(2), 12. https://doi.org/10.1007/s11906-018-0812-z

Saltiel, A. R., & Olefsky, J. M. (2017). Inflammatory mechanisms linking obesity and metabolic disease. *The Journal of Clinical Investigation*, *127*(1), 1–4. https://doi.org/10.1172/JCI92035

Saylor Academy (n.d.). BIO304 Human Physiology [Course Syllabus]. Retrieved from http://bezak.umms.med.umich.edu/CIRHT/Content/Other%20Health%20Open%20Educ

ational%20Resources/Physiology//Syllabus-BIO304-Human%20Physiology%20Lab-Saylor-CC%20BY.html

Scaffolding (2013). In *the Glossary of Education Reform*. Retrieved from https://www.edglossary.org/scaffolding/

Schillinger, D., Bindman, A., Wang, F., Stewart, A., & Piette, J. (2004). Functional health literacy and the quality of physician–patient communication among diabetes patients. *Patient Education and Counseling*, *52*(3), 315-323. https://doi.org/10.1016/S0738-3991(03)00107-1

Schillinger, D., Grumbach, K., Piette, J., Wang, F., Osmond, D., Daher, C., Palacios, J., Sullivan, G. D., Bindman, A. B. (2002). Association of health literacy with diabetes outcomes. *JAMA*, *288*(4), 475-482. https://doi.org/10.1001/jama.288.4.475

Schultz, W. (2018). What is a AAA video game. *ThoughtCo.* Retrieved from https://www.thoughtco.com/what-is-aaa-game-1393920

Slav, V. (2020). *Aesthetic Driven Development: Choosing Your Art Before Making a Game* [Conference presentation]. Game Developers Conference, 2020. Retrieved from https://www.gdcvault.com/play/1026601/Aesthetic-Driven-Development-Choosing-Your

Solarski, C. (2012). Drawing basics and video game art: classics to cutting-edge art techniques for winning video game design. Watson-Guptill.

Spek, E., Sidorenkova, T., Porskamp, P., & Rauterberg, M. (2014). The Effect of Familiar and Fantasy Aesthetics on Learning and Experience of Serious Games (pp. 133-138). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-45212-7_17

St. Mary's Catholic School (n.d.). *7th grad science syllabus* [Course syllabus]. Retrieved from https://stmarys-temple.org/7th-grade-science-syllabus

Thompson, D., Baranowski, T., Buday, R., Baranowski, J., Thompson, V., Jago, R., & Griffith, M. J. (2012). Serious Video Games for Health: How Behavioral Science Guided the Development of a Serious Video Game. *Simulation & Gaming*, *41*(4), 587–606. https://doi.org/10.1177/1046878108328087

Top 6 Styles for 3D Art Development (n.d.). *3D-Ace Studio.* Retrieved from https://3d-ace.com/press-room/articles/top-6-styles-3d-art-development

Townsend, D. (2016, January 1). 2D video game art styles. *Spritely Games*. Retrieved from https://spritelygames.com/blog/2015/2d-video-game-art-styles/

Uppsala University (n.d). *Syllabus for homeostasis and endocrinology* [Course Syllabus]. Retrieved from https://www.uu.se/en/admissions/master/selma/kursplan/?kpid=27955&kKod=3FM015&lasar=&siteNodeId=79266&contentId=-1

Veryovka, D. (2015). *Never alone: the art and the people of the story* [Conference presentation]. Game Developers Conference, 2015. Retrieved from https://www.gdcvault.com/play/1022424/Never-Alone-the-Art-and

Visual Styles (2012, December 10). *Kyfanstevens*. Retrieved from https://kyfanstevens.wordpress.com/games-development/visual-styles/

Wohlheiter, K. A., & Dahlquist, L. M. (2013). Interactive Versus Passive Distraction for Acute Pain Management in Young Children: The Role of Selective Attention and Development. *Journal of Pediatric Psychology*, *38*(2), 202-212. https://doi.org/10.1093/jpepsy/jss108

Wouters, P., van Nimwegen, C., van Oostendorp, H., & van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology*, *105*(2), 249-265. https://doi.org/10.1037/a0031311

Zullo, A. (2013). The Role of Hormones in Homeostasis. *Yale National Initiative*. Retrieved from https://teachers.yale.edu/curriculum/viewer/initiative_15.06.09_u

# APPENDIX

Table 4

*First Draft of the Realism Continuum Instrument*

| | | | | |
|---|---|---|---|---|
| **Rendering** | **Hue Fill** | | | |
| | Are the hues flat? | **1 points** Fill is multiple hues and includes shadows. | **2 points** Fill is mostly one flat hue with some flat shadow. | **3 points** Fill is one flat hue with no indication of shadow. |
| | **Transitions** | | | |
| | How realistic are the value transitions? | **1 points** Subtle value transitions. | **2 points** Values somewhat blend together but there is still a jump between values. | **3 points** Little to no value transitions. If an object is more than one value, the values barely blend together. |
| | How realistic are the hue transitions? | **1 points** Subtle hue transitions between colors. | **2 points** Hues somewhat blend together but there is still somewhat of a jump between hues. | **3 points** Little to no hue transitions. If an object is more than one hue, the hues barely blend together. |
| | **Edges** | | | |
| | Outlines on objects: | | | |
| | Line thickness | **1 points** No outlines present. | **2 points** Thin to medium outlines used. | **3 points** Very heavy and noticeable outlines used. |
| | Color contrast of lines | **1 points** N/A | **2 points** Outlines are similar color to the fill color. | **3 points** Outlines are a starkly different color from the fill color. |
| | Line Continuity | **1 points** N/A | **2 points** Lines are broken up for implied lines. | **3 points** Lines on object are solid throughout with no line breaks. |
| | Appropriate use of edges (i.e. soft edge for fur) | **1 points** Any edges that should be hard or soft are appropriately implemented. | **2 points** Some (but not all) edges that should be hard or soft are appropriately implemented. | **3 points** Edges are mostly or entirely used inappropriately. |
| | **Photorealistic vs. Painterly Marks** | | | |
| | How simplified are the shapes? | **1 points** Shapes are organic and true to life. | **2 points** Shapes are somewhat organic and representative of life. | **3 points** Shapes are generalized or loosely suggestive of the object. |
| | How simplified are the surface textures in context of the scene? | **1 points** Every detail is present and accurate to life. | **2 points** Some but not all detail is present. | **3 points** Little to no detail is present. |
| | Precision of marks— Are strokes from the brush/paint visible? | **1 points** No brush strokes are visible. | **2 points** Very little brush strokes are visible. | **3 points** Bold, expressive strokes are clearly visible. |

*cont.*

| | | | | |
|---|---|---|---|---|
| **Use of Perspective and Environmental Space** | **Basic Principles** | | | |
| | Does it follow the basic principles of perspective? | **1 point**<br>The relationships between objects in the foreground, mid ground, and background are appropriate. | **2 points**<br>The relationships between objects is somewhat appropriate but some discrepancies are present. | **3 points**<br>Objects in the foreground, mid ground, and background are equal size and/or completely inaccurate to their size relationship in life. |
| | **Atmospheric Perspective** | | | |
| | Amount of texture/detail in the distance | **1 point**<br>Minimal detail is used in the distance. | **2 points**<br>More detail than necessary is used in the background but it is still somewhat less detailed than the foreground. | **3 points**<br>Detail in the distance is equal to the foreground. |
| | Amount of color value in the distance | **1 point**<br>High values of objects in the distance in comparison to the foreground. | **2 points**<br>Values in the distance are somewhat close to values in the foreground. | **3 points**<br>Values in the distance are greater than or equal to the overall foreground value. |
| | Amount of saturation in the distance | **1 point**<br>Objects in the distance are desaturated in comparison to the foreground. | **2 points**<br>Saturation of objects in the distance are somewhat close to the foreground. | **3 points**<br>Saturation of objects in the distance are greater than or equal to the overall foreground saturation. |
| | **Linear Perspective** | | | |
| | Does it follow the principles pertaining to one point, two point, or three point perspective? | **1 point**<br>Lines appropriately converge to their vanishing point(s) based upon which type of perspective is applicable to the scene (one point, two point, or three point perspective).<br><br>OR<br><br>No linear perspective is used but lines that need to be parallel/vertical/ horizontal are accurate, and basic principles of perspective are followed. | **2 points**<br>Some but not all lines converge to their vanishing point(s).<br><br>OR<br><br>No linear perspective is used but lines that need to be parallel/vertical/ horizontal are somewhat accurate, and basic principles of perspective are mostly followed. | **3 points**<br>Lines seldomly converge, if at all, to their vanishing point(s).<br><br>OR<br><br>No linear perspective is used but lines that need to be parallel/vertical/ horizontal are inaccurate, and basic principles of perspective are not followed. |
| **Lighting** | **Realism of Light on Form** | | | |
| | Is the direction of light consistent? | **1 point**<br>Yes | **2 points**<br>No | |
| | Appropriate use of: | | | |
| | Cast shadow | **1 point**<br>Yes | **2 points**<br>No | |
| | Ambient occlusion | **1 point**<br>Yes | **2 points**<br>No | |
| | Reflected light | **1 point**<br>Yes | **2 points**<br>No | |
| | Form shadow | **1 point**<br>Yes | **2 points**<br>No | |
| | Core shadow | **1 point**<br>Yes | **2 points**<br>No | |
| | Half tone | **1 point**<br>Yes | **2 points**<br>No | |
| | Form light | **1 point**<br>Yes | **2 points**<br>No | |
| | Highlight | **1 point**<br>Yes | **2 points**<br>No | |

*cont.*

| | | | | |
|---|---|---|---|---|
| **Color** | **Value** | | | |
| | Are the values reflective of real life? | **1 point**<br>Values of objects are accurate in respects to the scene. | **2 points**<br>Values of objects are somewhat inaccurate in respects to the scene. | **3 points**<br>Values of objects are mostly or completely inaccurate in respects to the scene. |
| | **Hue** | | | |
| | Are colors reflective of real life? | **1 point**<br>Hues are accurate for the object/scene. The hues of objects interact with one another (when applicable). | **2 points**<br>Hues are somewhat accurate for the object/scene. Likewise, the hues of objects somewhat interact with one another (when applicable). | **3 points**<br>Hues are mostly or completely inaccurate for the object/scene. Likewise, the hues of objects do not interact with one another (when applicable). |
| | **Saturation** | | | |
| | Is saturation reflective of real life? | **1 point**<br>Objects are desaturated in respects to the scene, and any objects higher in saturation are accurate to real life. | **2 points**<br>Objects are somewhat saturated and relatively inaccurate to real life. | **3 points**<br>Objects are highly saturated and mostly or completely inaccurate to real life. |
| **Fictional Elements** | **External Items** | | | |
| | Are there objects that are alien to the scene? (i.e. people, spaceships, etc.) | **1 point**<br>No | | **3 points**<br>Yes |
| | **Anthropomorphized Anatomy** | | | |
| | Is there anatomy in the scene that is anthropomorphized? | **1 point**<br>No | | **3 points**<br>Yes |
| | **Personification/Visual Metaphor** | | | |
| | Is personification being used? | **1 point**<br>No | | **3 points**<br>Yes |
| **Proportions** | Is there an accurate size scale relationship between objects? | **1 point**<br>The relationship between object sizes are accurate. | **2 points**<br>The relationship between object sizes are somewhat accurate. | **3 points**<br>The relationship between object sizes are mostly or completely inaccurate. |
| | Are the objects exaggerated? (i.e. large eyes in comparison to the head) | **1 point**<br>No exaggeration of objects. | **2 points**<br>Objects are somewhat exaggerated. | **3 points**<br>Objects are highly exaggerated. |
| | Are anatomical/key landmarks on objects accurately placed? | **1 point**<br>No exaggeration of objects. | **2 points**<br>Objects are somewhat exaggerated. | **3 points**<br>Objects are highly exaggerated. |

*Note.* Elements in the realism continuum are broken down in order to quantify where an image falls on the scale. Table 1 represents the initial, unedited instrument, prior to the committee meeting discussion.

Table 5

*Revised and Final Realism Continuum Instrument*

| | | | | | |
|---|---|---|---|---|---|
| **Color** | **Value** | | | | |
| | Values:<br>How light or dark a color is | | **1 point**<br>In relation to lighting and objects present, values of objects are reflective of life. | **2 points**<br>In relation to lighting and objects present, values of objects are somewhat reflective of life. | **3 points**<br>In relation to lighting and objects present, values of objects are mostly or completely different than what is shown in life. |
| | **Hue** | | | | |
| | Object hues:<br>Visible light of an object | **0 points**<br>**N/A** | **1 point**<br>In relation to lighting and objects present, hues are reflective of life. | **2 points**<br>In relation to lighting and objects present, hues are somewhat reflective of life. | **3 points**<br>In relation to lighting and objects present, hues are mostly or completely different than what is shown in life. |
| | Interaction of hues:<br>Visible light of objects reacting to one another | | **1 point**<br>The hues of objects and the environment interact with one another. | **2 points**<br>The hues of objects and the environment somewhat interact with one another. | **3 points**<br>The hues of objects and the environment do not interact with one another. |
| | **Saturation** | | | | |
| | Saturation:<br>Pureness of a color, away from neutral gray | | **1 point**<br>In relation to lighting and objects present, objects are desaturated. Any objects higher in saturation are appropriate to life. | **2 points**<br>In relation to lighting and objects present, objects are somewhat saturated and relatively different than shown in life. | **3 points**<br>In relation to lighting and objects present, objects are highly saturated and mostly or completely different than shown in life. |
| **Rendering** | **Fill** | | | | |
| | Range of value | | **1 points**<br>In the same form with the same lighting, fill is multiple values and includes shadows. | **2 points**<br>In the same form with the same lighting, fill is mostly one flat value with some flat shadow. | **3 points**<br>In the same form with the same lighting, fill is one flat value with no indication of shadow. |
| | **Transitions** | | | | |
| | Value transitions | | **1 points**<br>In the same form with the same lighting, subtle value transitions are present as appropriate to life. | **2 points**<br>In the same form with the same lighting, values somewhat blend together but there is still a jump between values in areas that would be blended in life. | **3 points**<br>In the same form with the same lighting, little to no value transitions are present as appropriate to life. If an object is more than one value, the values barely blend together. |
| | Hue transitions | **0 points**<br>**N/A** | **1 points**<br>In the same form with the same lighting, hues are blended as appropriate to life. | **2 points**<br>In the same form with the same lighting, hues somewhat blend together but there is still somewhat of a jump between hues in areas that would be blended in life. | **3 points**<br>In the same form with the same lighting, hues barely blend together, if at all, in areas that would be blended in life. |
| | **Edges** | | | | |
| | Outlines on objects: | | | | |
| | Line thickness | **0 points**<br>**N/A** | | **2 points**<br>Thin to medium outlines used. | **3 points**<br>Very heavy and noticeable outlines used. |
| | Color contrast of lines | **0 points**<br>**N/A** | | **2 points**<br>Outlines are similar color to the fill color. | **3 points**<br>Outlines are a starkly different color from the fill color. |
| | Line Continuity | **0 points**<br>**N/A** | | **2 points**<br>Lines are broken up for implied lines. | **3 points**<br>Lines on object are solid throughout with no line breaks. |
| | Edges of objects | | **1 points**<br>All edges are hard or soft as shown in life.<br>(i.e. soft edge for fur) | **2 points**<br>Some (but not all) edges that would be hard or soft in life are shown. | **3 points**<br>Edges are mostly or entirely different than what is shown in life. |
| | **Photorealistic vs. Painterly Marks** | | | | |
| | Shape of objects | | **1 points**<br>Shapes are organic and true to life. | **2 points**<br>Shapes are somewhat organic and representative of life. | **3 points**<br>Shapes are generalized or loosely suggestive of the object. |
| | Surface textures | | **1 points**<br>In relation to lighting and objects present, every detail is shown and reflective of life. | **2 points**<br>In relation to lighting and objects present, some but not all detail is shown. | **3 points**<br>In relation to lighting and objects present, little to no detail is shown. |
| | Precision of marks | | **1 points**<br>No brush strokes are visible. | **2 points**<br>Very little brush strokes are visible. | **3 points**<br>Bold, expressive strokes are clearly visible. |

*cont.*

| | | | | | |
|---|---|---|---|---|---|
| **Use of Perspective and Environmental Space** | **Environment** | | | | |
| | Objects in environment | **0 points N/A** | **1 point** The size relationships between objects in the foreground, mid ground, and background are reflective of life. | **2 points** The size relationships between objects in the foreground, mid ground, and background are somewhat reflective of life, but not all relationships are representative of what is seen in life. | **3 points** Objects in the foreground, mid ground, and background are equal size and/or not reflective to their size relationship in life. |
| | **Atmospheric Perspective** | | | | |
| | Amount of texture/detail | | **1 point** In relation to lighting and objects present, minimal detail is used in areas outside of the focal point. | **2 points** In relation to lighting and objects present, more detail than necessary is used in areas outside of the focal point but it is still somewhat less detailed than the area in focus. | **3 points** Detail in areas outside of the focal point is equal to the area in focus. |
| | Amount of contrast | | **1 point** In relation to lighting and objects present, value is lower contrast in areas outside of the focal point. | **2 points** In relation to lighting and objects present, values in areas outside of the focal point are somewhat close to value contrast of the area in focus. | **3 points** Values in areas outside of the focal point are higher contrast or equal to the contrast of the area in focus. |
| | Amount of saturation | | **1 point** In relation to lighting and objects present, objects are more desaturated in areas outside of the focal point. | **2 points** In relation to lighting and objects present, saturation of objects in areas outside of the focal point are somewhat close in saturation to the area in focus. | **3 points** Saturation of objects in areas outside of the focal point are greater in saturation or equal to the saturation of the area in focus. |
| | **Linear Perspective** | | | | |
| | Principles of one point, two point, or three point perspective | **0 points N/A** | **1 point** Lines converge to their vanishing point(s) based upon which type of perspective is applicable to the scene (one point, two point, or three point perspective), and lines that need to be parallel/ vertical/ horizontal as seen in life are implemented. | **2 points** Some but not all lines converge to their vanishing point(s), and lines that need to be parallel/vertical/ horizontal as seen in life are somewhat implemented. | **3 points** Lines seldomly converge, if at all, to their vanishing point(s), and lines that need to be parallel/vertical/ horizontal as seen in life are not implemented. |
| **Lighting** | **Use of Lighting** | | | | |
| | Direction of light | | **1 point** Objects in the scene are lit in the same way as appropriate to life. | **2 points** Objects in the scene are somewhat lit in the same way as appropriate to life. | **3 points** Objects in the scene are mostly lit differently or not at all lit in the same way as appropriate to life. |
| | **Form** | | | | |
| | Cast shadow: A shadow cast by an object | | **1 point** Cast shadows are appropriately used as shown in life. | **2 points** Some use of cast shadows but not all objects have it as shown in life. | **3 points** Cast shadows on objects are mostly absent as appropriate to life. |
| | Reflected light: Light cast on an object from its environment | | **1 point** Reflected light is appropriately used as shown in life. | **2 points** Some use of reflected light but not all objects have it as shown in life. | **3 points** Reflected light on objects are mostly absent as appropriate to life. |
| | Core shadow: Where light and dark meet and form the darkest area of a shadow | | **1 point** Core shadows are appropriately used as shown in life. | **2 points** Some use of core shadows but not all objects have it as shown in life. | **3 points** Core shadows on objects are mostly absent as appropriate to life. |
| | Middle light (local value): Closer to the light source and receives direct light | | **1 point** Middle light values are appropriately used as shown in life. | **2 points** Some use of middle light but not all objects have it as shown in life. | **3 points** Middle light values on objects are mostly absent as appropriate to life. |
| | Highlight: Brightest area on an object | | **1 point** Highlights are appropriately used as shown in life. | **2 points** Some use of highlights but not all objects have it as shown in life. | **3 points** Highlights on objects are mostly absent as appropriate to life. |

*cont.*

| | | | | | |
|---|---|---|---|---|---|
| **Proportions** | Size relationship between objects | **0 points**<br>**N/A** | **1 point**<br>The relationship between object sizes are appropriate to life. | **2 points**<br>The relationship between object sizes are somewhat appropriate to life. | **3 points**<br>The relationship between object sizes are mostly or completely different than shown in life. |
| | Object exaggeration | | **1 point**<br>No exaggeration of object proportions as shown in life. | **2 points**<br>Proportion of objects are somewhat exaggerated from life. | **3 points**<br>Proportion of objects are highly exaggerated from life. (i.e. large eyes in comparison to the head) |
| | Anatomical/key landmarks placement | | **1 point**<br>Key landmarks are appropriately placed in the scene as shown in life. | **2 points**<br>Key landmarks are somewhat appropriately placed in the scene as shown in life. | **3 points**<br>Key landmarks are placed differently in the scene than what is shown in life. |

*Note.* The final instrument is shown with revisions from the content validity members applied.

Table 6

*Breakdown of Point Values*

| | | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Color | P1, Image 1: | 1 | 0 | 2 | 2 | | | | | | | 5 |
| | P1, Image 2: | 3 | 1 | 3 | 2 | | | | | | | 9 |
| | P1, Image 3: | 2 | 2 | 3 | 1 | | | | | | | 8 |
| | P1, Image 4: | 1 | 2 | 3 | 2 | | | | | | | 8 |
| | P1, Image 5: | 3 | 3 | 3 | 3 | | | | | | | 12 |
| | P1, Image 6: | 2 | 1 | 2 | 2 | | | | | | | 7 |
| | P2, Image 1: | 1 | 1 | 2 | 2 | | | | | | | 6 |
| | P2, Image 2: | 3 | 3 | 1 | 2 | | | | | | | 9 |
| | P2, Image 3: | 2 | 2 | 2 | 2 | | | | | | | 8 |
| | P2, Image 4: | 2 | 2 | 1 | 1 | | | | | | | 6 |
| | P2, Image 5: | 3 | 3 | 3 | 3 | | | | | | | 12 |
| | P2, Image 6: | 1 | 0 | 1 | 1 | | | | | | | 3 |
| | P3, Image 1: | 2 | 2 | 3 | 2 | | | | | | | 9 |
| | P3, Image 2: | 2 | 2 | 2 | 1 | | | | | | | 7 |
| | P3, Image 3: | 2 | 2 | 2 | 2 | | | | | | | 8 |
| | P3, Image 4: | 1 | 3 | 2 | 2 | | | | | | | 8 |
| | P3, Image 5: | 3 | 3 | 3 | 2 | | | | | | | 11 |
| | P3, Image 6: | 1 | 0 | 1 | 1 | | | | | | | 3 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rendering | P1, Image 1: | 1 | 1 | 1 | 0 | 0 | 0 | 2 | 1 | 1 | 2 | 9 |
| | P1, Image 2: | 3 | 1 | 2 | 0 | 0 | 0 | 2 | 1 | 2 | 1 | 12 |
| | P1, Image 3: | 3 | 2 | 3 | 0 | 0 | 0 | 2 | 3 | 3 | 3 | 19 |
| | P1, Image 4: | 2 | 1 | 2 | 2 | 2 | 3 | 2 | 1 | 3 | 2 | 20 |
| | P1, Image 5: | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 2 | 28 |
| | P1, Image 6: | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 2 | 1 | 8 |
| | P2, Image 1: | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 2 | 8 |
| | P2, Image 2: | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 2 | 1 | 8 |
| | P2, Image 3: | 1 | 2 | 3 | 0 | 0 | 0 | 2 | 2 | 3 | 3 | 16 |
| | P2, Image 4: | 1 | 1 | 0 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 15 |
| | P2, Image 5: | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 30 |
| | P2, Image 6: | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| | P3, Image 1: | 2 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 9 |
| | P3, Image 2: | 2 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 9 |
| | P3, Image 3: | 1 | 2 | 2 | 0 | 0 | 0 | 2 | 2 | 3 | 3 | 15 |
| | P3, Image 4: | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 17 |
| | P3, Image 5: | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 28 |
| | P3, Image 6: | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 6 |
| Use of Perspective and Environmental Space | P1, Image 1: | 1 | 2 | 2 | 2 | 0 | | | | | | 7 |
| | P1, Image 2: | 1 | 2 | 2 | 3 | 0 | | | | | | 8 |
| | P1, Image 3: | 0 | 3 | 2 | 2 | 1 | | | | | | 8 |
| | P1, Image 4: | 0 | 1 | 2 | 1 | 0 | | | | | | 4 |
| | P1, Image 5: | 0 | 3 | 2 | 3 | 0 | | | | | | 8 |
| | P1, Image 6: | 1 | 2 | 1 | 1 | 1 | | | | | | 6 |
| | P2, Image 1: | 2 | 1 | 2 | 2 | 0 | | | | | | 7 |
| | P2, Image 2: | 1 | 3 | 3 | 3 | 1 | | | | | | 11 |
| | P2, Image 3: | 2 | 2 | 2 | 2 | 0 | | | | | | 8 |
| | P2, Image 4: | 1 | 1 | 1 | 1 | 2 | | | | | | 6 |
| | P2, Image 5: | 3 | 3 | 3 | 3 | 3 | | | | | | 15 |
| | P2, Image 6: | 1 | 1 | 1 | 1 | 1 | | | | | | 5 |
| | P3, Image 1: | 0 | 1 | 2 | 2 | 0 | | | | | | 5 |
| | P3, Image 2: | 1 | 2 | 2 | 2 | 0 | | | | | | 7 |
| | P3, Image 3: | 1 | 2 | 2 | 2 | 0 | | | | | | 7 |
| | P3, Image 4: | 1 | 1 | 2 | 2 | 0 | | | | | | 6 |
| | P3, Image 5: | 3 | 3 | 2 | 2 | 0 | | | | | | 10 |
| | P3, Image 6: | 0 | 1 | 1 | 1 | 0 | | | | | | 3 |
| Lighting | P1, Image 1: | 1 | 1 | 2 | 2 | 2 | 1 | | | | | 9 |
| | P1, Image 2: | 3 | 3 | 3 | 2 | 2 | 1 | | | | | 14 |
| | P1, Image 3: | 2 | 2 | 2 | 2 | 2 | 2 | | | | | 12 |
| | P1, Image 4: | 1 | 1 | 3 | 2 | 1 | 2 | | | | | 10 |
| | P1, Image 5: | 3 | 3 | 3 | 3 | 1 | 3 | | | | | 16 |
| | P1, Image 6: | 1 | 1 | 2 | 2 | 1 | 1 | | | | | 8 |
| | P2, Image 1: | 1 | 2 | 2 | 2 | 2 | 1 | | | | | 10 |
| | P2, Image 2: | 3 | 3 | 2 | 1 | 2 | 2 | | | | | 13 |
| | P2, Image 3: | 2 | 3 | 2 | 2 | 2 | 2 | | | | | 13 |
| | P2, Image 4: | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 6 |
| | P2, Image 5: | 3 | 3 | 3 | 3 | 3 | 3 | | | | | 18 |
| | P2, Image 6: | 1 | 1 | 1 | 1 | 1 | 1 | | | | | 6 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | P3, Image 1: | 2 | 2 | 2 | 1 | 1 | 2 | 10 |
| | P3, Image 2: | 2 | 2 | 1 | 2 | 2 | 2 | 11 |
| | P3, Image 3: | 1 | 2 | 2 | 2 | 2 | 2 | 11 |
| | P3, Image 4: | 1 | 1 | 1 | 1 | 1 | 2 | 7 |
| | P3, Image 5: | 3 | 3 | 3 | 3 | 3 | 3 | 18 |
| | P3, Image 6: | 1 | 1 | 1 | 1 | 1 | 1 | 6 |
| | | | | | | | | |
| Proportions | P1, Image 1: | 2 | 2 | 1 | | | | 5 |
| | P1, Image 2: | 2 | 1 | 2 | | | | 5 |
| | P1, Image 3: | 1 | 3 | 2 | | | | 6 |
| | P1, Image 4: | 1 | 1 | 1 | | | | 3 |
| | P1, Image 5: | 1 | 2 | 1 | | | | 4 |
| | P1, Image 6: | 0 | 1 | 1 | | | | 2 |
| | | | | | | | | |
| | P2, Image 1: | 2 | 2 | 2 | | | | 6 |
| | P2, Image 2: | 2 | 2 | 2 | | | | 6 |
| | P2, Image 3: | 2 | 3 | 3 | | | | 8 |
| | P2, Image 4: | 1 | 2 | 1 | | | | 4 |
| | P2, Image 5: | 3 | 3 | 3 | | | | 9 |
| | P2, Image 6: | 0 | 1 | 1 | | | | 2 |
| | | | | | | | | |
| | P3, Image 1: | 1 | 1 | 2 | | | | 4 |
| | P3, Image 2: | 2 | 2 | 2 | | | | 6 |
| | P3, Image 3: | 0 | 2 | 3 | | | | 5 |
| | P3, Image 4: | 2 | 2 | 1 | | | | 5 |
| | P3, Image 5: | 3 | 2 | 3 | | | | 8 |
| | P3, Image 6: | 1 | 1 | 1 | | | | 3 |

*Note.* Answers from the committee members are displayed. Individual values for each question were recorded and unweighted category sums are shown. P1= evaluator 1, P2= evaluator 2, P3= evaluator 3