Emotional Design for Digital Games for Learning:

The Affective Quality of Expression, Color, Shape, and Dimensionality of Game Characters

Jan L. Plass*, Bruce D. Homer**, Andrew MacNamara*, Teresa Ober**,

Maya C. Rose**, Shashank Pawar*, Chris M. Hovey*, & Alvaro Olsen*

* New York University ** The Graduate Center, CUNY

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Abstract

What is the affective quality of specific design features of game characters? The Integrative Model of Emotion in Game-based Learning (EmoGBL) describes common mechanisms of how emotion and learning processes interact to foster specific learning outcomes. In the present paper, we asked how color, shape, expression, and dimensionality of game characters induce emotions in digital games for learning. We investigated learners' perception of the affective quality of these four different visual design features for adults and adolescents using a forced choice paradigm (studies 1-3) as well as the PANAS-X and qualitative measures (study 4). Participants were shown a series of game characters and were asked to report their emotional response. Results show the relative contribution of the four visual attributes on players' perception of affective quality, with the visual design features of expression and dimensionality having the strongest effect, color a medium-sized effect, and shape a small to medium-sized effect.

Emotional Design for Digital Games for Learning:

The Effect of Expression, Color, Shape, and Dimensionality on the Affective Quality of Game Characters

How can characters in games for learning be designed to induce specific emotions in learners? In particular, which visual design features of game characters have the strongest effects on learners' emotional arousal levels–their color, shape, expression, or dimensionality? Digital games have in the past decade received increased attention by researchers and by educators because of their perceived potential as educational interventions. Often the reason for the interest in using digital games as learning environments is their ability to motivate students to engage in activities that are relevant for learning. However, the potential impact of games goes far beyond their ability to motivate learners (Plass, Homer, & Kinzer, 2015). Also of importance is the ability of games to induce emotions in learners, as research has shown that inducing some emotions can enhance learning outcomes in digital learning environments (Mayer & Estrella, 2014; Loderer, Pekrun, & Plass, 2018; Plass & Kaplan, 2016; Um, Plass, Homer, & Hayward, 2006).

The effect of emotions on learning has long been recognized (Zeidner, 1998), and has recently been described by a number of theories and frameworks that model different aspects of the learning process. The integrative framework of achievement emotions describes the reciprocal relationship between emotions, their effects on learning outcomes, and their antecedents (Pekrun, 2000). Theories describing cognitive processes of multimedia learning have begun to incorporate affective processes and their relation to cognitive processing (Moreno & Mayer, 2007; Plass & Kaplan, 2016). In the context of digital games, the integrative model of emotion in game-based learning describes the mechanisms by which emotional design affects emotions, and how these emotions affect learning in games (Loderer, et al., 2018b).

Whereas the body of literature on the relation of emotion and learning is growing (Mayer & Estrella, 2014; Loderer at al., 2018b; Plass & Kaplan, 2016), less is known about emotional design methods in games. Even though digital games offer a broad range of design elements that affect players' emotions, little systematic research exists on which specific design features of game-based learning environments can induce emotions. The present research therefore aims to contribute to our understanding of emotional design in games for learning. Our focus is on the affective quality of game characters, a central element in many digital games, where we investigated four visual different features of game characters and how they affected players' emotions.

Theoretical Background

Emotion and Affective Quality

For the purpose of this paper, we base our definition of emotions on Russell's (2003) comprehensive conceptualization of emotions. According to his dimensional model, core affect is defined as a "neurophysiological state that is consciously accessible as a simple, nonreflective feeling" (p. 147) and is comprised of two basic dimensions: pleasure, experienced as pleasant vs. unpleasant affect, and arousal, experienced as activation vs. deactivation (see Figure 1).

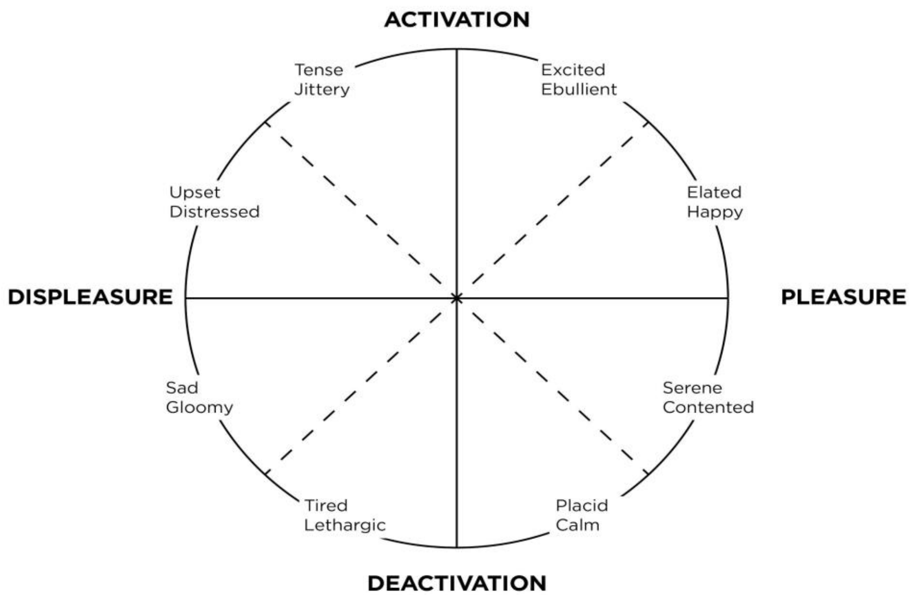

Figure 1. Core Affect as described by Russell (2003)

An emotional episode, then, is the perception of *affective quality* and *attributed affect*. Affective quality, the ability of an object to cause change in core affect, is described by the same two dimensions as core affect, i.e., pleasure and arousal. Attributed affect occurs when an individual psychologically combines core affect with a particular object, meaning that the object is perceived as the cause of the experienced affect (Russell, 2003). In the context of this paper, the objects under investigation are game characters, and we are seeking to determine how visual design factors determine a game character's affective quality. Figure 2 shows three examples of a game character used in our study. These examples differ along one design factor, their facial expression, which is sad (left), neutral (middle), or happy (right).

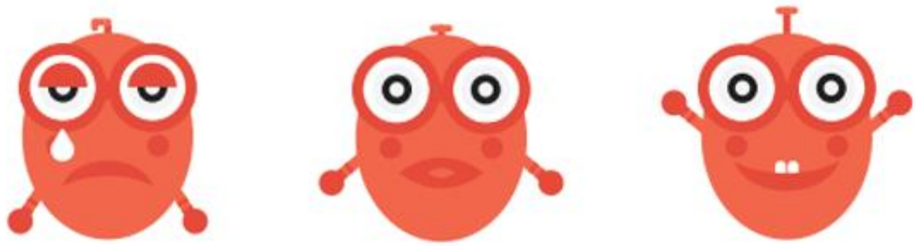

Figure 2. Three expressions of a game character

Understanding the effect of this and other design factors on the affective quality of game characters is of relevance for learning and instruction as research has shown that emotions affect cognition and learning, as we will discuss below.

Emotion, Cognition, and Learning

While a full review of the relation of emotion and learning is beyond the scope of this paper, we highlight some of the key research findings and theories that show the importance of considering emotion as an integral part of learning, cognition and instruction.

Emotion has found to have an effect on cognition on many levels, including basic cognitive mechanisms such as memory, attention and perception (Derryberry & Tucker, 1994; Isen, Daubman, & Nowicki, 1987; Isen, Shalker, Clark, & Karp, 1978; Izard, 1993, 2007; Lewis, 2005; Tucker, 2007). Emotions have also been found to provide effective retrieval cues for long-term memory (Isen, Daubman, & Nowicki, 1987; Isen, Shalker, Clark, & Karp, 1978). Other research has shown that positive emotions support information processing and communication and enhance creative problem solving, decision-making, and similar higher level cognitive activities (Erez & Isen, 2002; Konradt, Filip, & Hoffman, 2003). Thus, emotions have the capacity to affect the cognitive processes that underlie learning itself.

Emotions are ubiquitous in learning (Pekrun & Stephens, 2010), and their effects on learning processes and outcomes have been investigated empirically on the effect of anxiety on academic performance (Poropat, 2009; Poropat, 2014; Seipp, 1991), with studies on test anxiety occurring dating back to the 1930s (Zeidner, 1998). Contemporary approaches connecting emotion and learning include theories such as the *Control-Value Theory of Achievement Emotion* (CVT, Pekrun, 2000). This theory is an integrative framework that describes the antecedents and effects of emotions experienced by learners, suggesting that positive achievement emotions, such as enjoyment, facilitate learning by giving the learner a sense of autonomy and by establishing the intrinsic value of the learning material (Pekrun, 2006; Pekrun & Stephens, 2010). Cognitive theories, such as Mayers (2001) *Cognitive Theory of Multimedia Learning* (CTML), were first expanded into the *Cognitive-Affective Learning Theory with Media* by incorporating affective and motivational components in the processes of selecting, organizing, and integrating of visual, verbal information (CATLM, Moreno & Mayer, 2007). More recently, CTML has been further expanded into the *Integrated Cognitive-Affective Theory of Learning with Media* (ICALM, Plass & Kaplan, 2016), which proposes separate but related channels of emotional processing and cognitive processing, resulting in the construction of integrated cognitive-affective mental models. The ICALM approach to learning suggests that learning from multimedia materials involves affective processes that make demand on cognitive resources, as well as cognitive processes that result in the experience of affect. These theoretical developments have been incorporated in a model that specifically describes the relation of emotion and learning in games, which we will discuss next.

Integrative Model of Emotion in Game-based Learning (EmoGBL)

The recently proposed Integrative Model of Emotion in Game-based Learning (EmoGBL) aims to capture the diversity of emotions involved in learning with games and describes common mechanisms of how emotion and learning processes interact to foster specific learning outcomes (Loderer, et al., 2018b). The model is grounded in the control-value theory of achievement emotions (CVT, Pekrun, 2006; Pekrun & Perry, 2014) and incorporates results from research on emotion in learning with intelligent tutoring systems (Graesser, D'Mello, & Strain, 2014; Muis, Pekrun, et al., 2015; McNamara, Jackson, & Graesser, 2000) and from research on emotion in multimedia learning (ICALM, Plass & Kaplan, 2016).

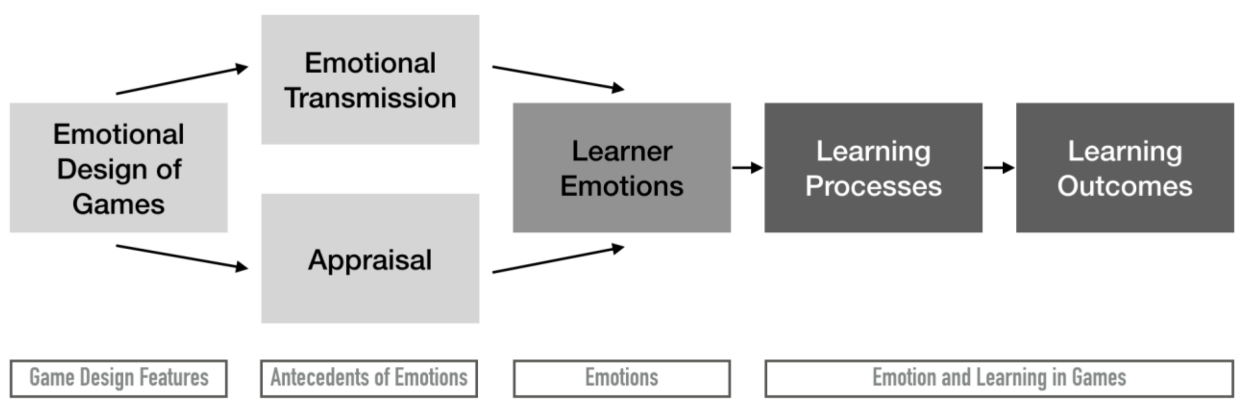

Figure 3. Simplified version of Integrative Model of Emotion in Game-based Learning (EmoGBL)

Figure 3 shows a simplified version of this model for the purpose of the present studies. The full, much more comprehensive model is described by Loderer et al. (2018b).

The core of EmoGBL follows the structure provided by CVT, showing how the emotional design of games, emotional transmission, and appraisals (light shaded boxes) are antecedents of emotions experienced by a learner (medium shaded box), which have an effect on learning processes and, consequently, on outcomes in learning with games (dark shaded boxes). We will first discuss how emotions can influence learning processes and learning outcomes in game-based learning and, when applicable, digital learning environments, and then turn to the antecedents of these emotions. While not all of the studies cited below were conducted using digital games, the environments they used share many of the features of game-based learning.

The Effect of Emotions on Learning in Games

The EmoGBL model follows the CVT by describing four cognitive and motivational mechanisms that are affected by emotion and that, in turn, have an effect on learning outcomes (Loderer et al., 2018b). These processes include the allocation of attention, memory storage and retrieval, and problem solving, as discussed previously, as well as motivational tendencies and behavior (Barrett, Lewis, & Haviland-Jones, 2016).

Motivational processes are affected differently based on valence and arousal of the experienced emotions. Positive activating emotions, such as pride, have been found to increase motivation to learn, whereas negative deactivating emotions, such as boredom and frustration, can undermine motivation (Loderer, Pekrun, & Lester, 2018a). Studies investigating the effect of emotions on cognitive load in game-like multimedia learning environments found that positive emotion induced via the visual design of the learning materials can reduce self-reported cognitive load (Um et al., 2012) and sustain attentional focus on the learning material (Park, Knörzer, Plass, & Brünken, 2015), but certain kinds of positive emotions, induced via autobiographical recall, have also been found to have deleterious effects on learning (Knörzer, Brünken, & Park, 2016). Studies on the effects of emotion on learning strategies in games found that learners who experienced enjoyment and curiosity in the game *Crystal Island* engaged in more effective problem-solving strategies than learners who experienced frustration or boredom (Sabourin & Lester, 2014). And finally, research on the relation of emotion and self-regulation found that positive activating emotion, in addition to promoting more flexibly strategy use as discussed above, also relates positively to learners' self-regulation, whereas negative, deactivating emotions have the opposite effect (Artino & Jones, 2012; Muis, Psaradellis, et al., 2015; Pekrun et al., 2002).

The connection of emotion, learning processes, and learning outcomes in EmoGBL is supported by meta-analyses such as the one by Loderer et al., 2018a, which found significant positive relations of emotions, such as enjoyment and curiosity, with outcomes in a range of digital learning environments, including games. On the other hand, negative deactivating emotions, such as boredom, have been found detrimental to learning (Tze et al., 2016). Examples of recent studies on the relation of emotion and learning include the investigation of multimedia learning environments in which visual design elements were manipulated in order to induce different emotions during learning. Results showed that materials using warm colors and round shapes induced more positive emotions and resulted in greater comprehension of a science topic and greater transfer compared to materials using neutral colors and square shapes, which did not show the same induction of positive emotions and resulted in less learning (Um et al., 2012). These findings, which largely focused on the valence component of emotion, have since been replicated by other studies (Mayer & Estrella, 2014; Plass et al., 2014). Another type of study focused on the arousal component, investigating whether the level of emotional arousal in playing a game to train cognitive skills had an effect on outcomes. Emotion arousal was experimentally manipulated by using different designs of game characters, which induced high emotional arousal (both positive and negative) on one version of the game, and low arousal in another. Results showed higher gains in the cognitive skill using the high arousal version of the game compared to the low arousal version, especially for older learners and for learners with lower prior levels of the cognitive skill (Rose, Ober, MacNamara, Olsen, Homer, & Plass, 2018).

In summary, there has been empirical support for the effect of emotion on learning processes and outcomes, both in general learning environments and increasingly also in digital games. However, often the observed emotions were a result of learning within a single environment rather than manipulated experimentally. The systematic study of the effect of emotion on learning would be benefitted by more experimental studies in which different variants of the game elicit different emotions. We believe that for experimental design purposes and for learning environment design purposes, a deeper understanding of the antecedents of emotions is useful. This is especially the case in the context of digital games, where many game features induce emotions by design.

Antecedents of Emotions

The EmoGBL model describes proximal and distal antecedents of emotions in game-based learning. Proximal antecedents can either involve appraisals of the self and of the situation, or emotional transmission from real-life peers, virtual peers, teachers, or other game features.

Appraisal processes are described based on appraisal theories that suggest that the emotions we experience are a function of the perception of our circumstances (Ellsworth & Scherer, 2003). They may give rise to different types of emotions, including achievement motivations, which are based on our perception of the controllability and value of learning activities and corresponding outcomes (Pekrun, 2006), and epistemic emotions, which are a result of cognitive incongruity during learning that may result from unexpected or contradictory information (Millis et al., 2011). Other types of emotions include social emotions, which can arise in competitive or collaborative learning activities in games (Plass et al., 2013), topic emotions, which relate to our values of the specific topic in a learning game (Loderer et al., 2018b), aesthetic emotions, which relate to the pleasantness, controllability, and novelty of the design of a game (Silva, 2005), and technology emotions, which are emotions experienced in response to the perceived controllability of the game (Butz et al., 2015).

Emotional transmission is a mechanism that describes our affective attunement to sensory input (such as visuals our sound) as well as emotions observed in others (Loderer et al., 2018b) through entrainment, contagion, or empathy (Scherer and Coutinho, 2013). Entrainment describes the synchronizing of one learner's moves with that of another learner or with the actions within the game (such as the beat of the sound track) during game play, which may be especially relevant for the arousal of aesthetic emotions (Scherer & Coutinho, 2013). Emotional contagion is the result of the unconscious mimicry of expressive cues by others, including virtual agents or characters in a game (Krämer et al., 2013). Empathy can give rise to emotions in collaborative or competitive games in response to emotions expressed by others, such as frustration (Järvenoja & Järvelä, 2005).

In addition to these two types of proximal antecedents of emotions in game-based learning, appraisal and emotion contagion, the EmoGBL model also describes distal antecedents. These include individual differences, such as achievement goals and beliefs, as well as the emotional design of the game-based learning environment (Loderer et al., 2018b). While the discussion of individual differences is beyond the scope of this paper, we will describe emotional design in the following section.

Emotional Design in Games for Learning

Emotional design describes the use of a range of design features of digital learning environments with the goal to elicit emotions in order to enhance learning or cognitive skills development (Plass & Kaplan, 2016). Emotional design for digital games describes how different designs of specific game features can lead to different emotions. These game features include virtually all of the key design elements of games, such as the game mechanics, the visual/aesthetic design, the narrative, the sound design, and the incentive system design (Plass et al., 2015; Plass, Perlin, & Nordlinger, 2010). The EmoGBL model suggests mechanisms for how these design features can affect learners' emotions – through appraisals, emotional transmission, and interaction with individual differences, such as beliefs. Researchers and game designers are also interested in how video games can impact player emotion, as well as how emotion can be measured in games (Anolli, Mantovani, Confalonieri, Ascolese, & Peveri, 2010; Callejas-Cuervo, Martínez-Tejada, & Alarcón-Aldana, 2017).

One area of special interest to game designers and researchers are game characters, as they are ubiquitous in games and provides a broad range of emotional design opportunities. The design of game characters has been documented mostly from practical and theoretical perspectives (Isbister, 2006; Isbister, 2016; Perlin, 1997), but only a few studies have investigated them empirically (Plass et al., 2009). In one study, researchers showed that players are more likely to cooperate with a virtual person in a game when their facial expressions showed a range of emotions, and when they perceived the character to be more human-like compared to a character without expression of emotions (de Melo, Zheng, & Gratch, 2009). Baylor (2011) identified the expression of virtual agents, which are not unlike game characters, as one of their most important design elements, but called for additional research on the specific of the design of these characters. This need for further research becomes evident with a later study on the effect of smiling expressions of agents that found that the perception of a smile as disingenuous actually gave rise to negative emotions in learners (Liew, Zin, Sahari, & Tan, 2016). Because of the dearth of studies focusing on the effect of specific design features of game characters, the present study was undertaken to investigate affective quality of four design features of game characters.

In the studies by Um et al. (2012), Mayer and Estrella (2014), and Plass et al., (2014), two easily-modified design features were identified, namely the shape and color of game characters. Another design feature, expression, comes from the mostly anthropomorphic function of game characters, which is facilitated by including facial features (Baylor, 2011). A fourth design feature, dimensionality, was selected because of the increasing popularity of 3D environments such as virtual reality, for which the emotional impact of dimensionality seems to be an open question (Rooney & Hennessy 2013). In the research presented in this paper we were therefore interested in the use of these four visual attributes for the emotional design of game characters: shape, color, expression, and dimensionality. We briefly describe each attribute and its theoretical foundation below.

Visual Shape

The shape of visual elements that game characters or other screen elements are comprised of describes whether they are round, square, or resemble other geometric shapes. Human faces with round features, large eyes, small noses, and short chins are perceived as baby-like and evoke baby-like personality attributes such as innocence, honesty, and helplessness (Berry & McArthur, 1986; Zebrowitz & Montepare, 2008). According to the baby-face bias, non-living objects can also induce this positive affective reaction using some of these attributes (Lorenz & Generale, 1950), an effect found even when used on something as non-human as the front of a motor vehicle (Miesler, Leder, & Herrmann, 2011). This effect is supported by neuroscience research that found a neural substrate for the babyface effect in the amygdala and fusiform face area, both of which show higher BOLD signal change when viewing faces of babies than faces of an adult (control) (Zebrowitz, Luevano, Bronstad, & Aharon, 2007). Studies by Um et al. (2012) and Plass et al. (2014) have shown that this baby-face bias can also be utilized in multimedia learning environments to induce positive emotions and, consequently, to enhance comprehension of a science topic and transfer of knowledge. For the design of game characters, we therefore similarly expect a positive arousal for round shapes in contrast to shapes with sharp (square) edges.

Color

The use of color has long been shown to be able to generate positive arousal of emotion such as excitement and pleasure (Berlyne, 1970; Tucker, 1987). In particular, warm colors have been found to elicit greater emotional arousal than cold colors (Bellizzi & Hite, 1992; Wolfson & Case, 2000). Higher levels of chroma (saturation) and value (degree of darkness or lightness of the color) have been found to result in feelings such as excitement (Gorn et al., 1997; Thompson et al., 1992). The color green, for example, has been found to evoke hope, growth, and success (Lichtenfeld, Elliot, Maier, & Pekrun, 2012). In some cultures and contexts, the color red may signal danger or, in the context of learning, failure, and give rise to negative emotions (Elliot, Maier, Moller, Friedman, & Meinhardt, 2007). In romantic contexts, on the other hand, the color red evokes positive emotion toward females in males (Elliot & Niesta, 2008).

In the multimedia learning study by Um et al. (2012), color was used successfully as one of the design factors to induce positive emotions. The study by Plass et al. (2014) found that warm colors were able to induce positive emotions, especially when combined with round shapes. For the design of game characters, we therefore expect positive arousal for warm colors (orange) compared to neutral colors (grey).

Expression

A design feature that is specific to game characters is that they can have their own facial expressions of emotions, showing positive or negative valence or neutral emotions. These expressions can impact people's emotions through an effect known as contagion (Hatfield et al. 1994), which describes how emotions can be triggered directly by external stimuli.

Emotional contagion, one of the emotion transmission mechanisms describes in EmoGBL, constitutes a largely unconscious process that is driven by observation and automatic mimicry of expressive cues of others (Loderer et al., 2018b; Scherer & Coutinho, 2013). As discussed above, such contagion can be experienced with human collaborators (Järvenoja & Järvelä, 2005) and with virtual agents (D'Mello & Graesser, 2012; McQuiggan & Lester, 2007). Research has found that the appearance of virtual agents, which bear many similarities with game characters, can also affect people's attitudes, motivations, and beliefs, making them one of the most important design features (Baylor, 2009). Research in computer graphics has begun to investigate how to design specific facial expressions (Perlin, 1997; Burleson et al., 2004), but their impact in the context of games for learning has not yet been sufficiently studied.

For the design of game characters, we expect high positive and negative arousal for characters with strong positive (i.e., happy) or negative (i.e., sad) facial expressions, compared to characters with neutral expressions. Based on Baylor (2009) we further expect these effects on emotion to be stronger than those of the other design features.

Dimensionality

The use of 3D graphics provides an additional opportunity to induce emotion. There is a rich literature on computer graphics methods for the emotional design of 3D characters (Pardew, 2008). The psychological principles underlying an effect of dimensionality include the baby-face bias combined with the effect of anthropomorphism, which has shown people's tendency to attribute unique human characteristics and qualities to nonhuman beings, including inanimate objects (Dehn & van Mulken, 2000; Disalvo &

Gemperle, 2007; Hongpaisanwiwat & Lewis, 2003; Reeves & Nass, 1996). Representing a game character in 3D provides more opportunities to include presence-inducing cues, which we expect to enhance their emotional effect. For the design of game characters, we therefore expect high positive and negative arousal for characters rendered in 3D, compared to characters rendered in 2D.

The Present Studies

Our review highlighted that recent research has established a link between experienced emotions and academic learning outcomes as well as cognitive skills training. In both domains, manipulations of the affective quality of specific elements of the learning environment resulted in enhanced outcomes. In the case of multimedia learning, the use of warm colors and round shapes induced positive emotions that enhanced comprehension and transfer of scientific topics compared to materials with neutral colors and square shapes (Plass et al., 2014; Um et al., 2012). This effect was recently replicated in three experiments by Mayer and Estrella (2014). In the case of cognitive skills training, game characters with warm colors, round shapes, and strong facial expressions resulted in higher gains in executive functions than game characters with neutral colors, square shapes, and neutral facial expressions (Rose et al., 2018), but did not decompose the individual effect of each of these visual attributes on emotion arousal.

Based on these findings, the question emerges, what design features can be used to induce emotions in learners, especially in digital games? We therefore conducted four within-subject design studies in which we investigated the affective quality of visual attributes of games characters, namely shape, color, expression, and dimensionality. Our key question in each study was, *how do variations in visual attributes influence the affect participants attribute to the game characters?*

Study 1: Color, Shape, Expression

Study 1 investigated the perception of the affective quality of game characters for which the visual attributes *color*, *shape*, and *expression* were manipulated. We conducted this study first with an adult population and then with adolescents since both populations use learning games.

Method

Participants and Design

Study 1 participants consisted of 164 adults recruited through MTurk. Participants had a mean age of 35.0 (*SD*=10.0) with 49% being female, 50% being male, and 1% declining to state their gender. The sample consisted of individuals who self-identified as Asian American (7.8%), Black or African American (7.8%), Hispanic American (3.9%), Native American (1.0%), White American (78.4%), and Other (1.0%). Education level of participants varied, with a small portion having only a high school diploma (16.7%), a larger portion having experience taking some college courses (31.4%), a majority having finished college (49.0%), and the remainder having some experience in graduate school (2.9%). Participants reported spending an average time of 7.38 hours per week playing games (range: 0 to 40 hours).

Participants were recruited using the MTurk online platform. In order to ensure that participants were experienced, had a good worker reputation, and were able to read the English instructions, the MTurk qualification system was employed. We required for participants to have previously completed at least 4,999 previous MTurk tasks, and to have their past work submissions approved at least 97% of the time by the task issuer. After setting all these MTurk qualifications, only those workers that qualified were recruited for the study. In addition, in order to assure that all submissions were unique, we allowed each participant to complete the task only once.

The study used a forced choice paradigm in a within-subject design in which participants were asked to respond with their emotional response for pairs of game characters, see next section for details. The task was advertised with the title “Happy or Sad.” Its description stated that “This survey aims to investigate the emotional impressions that video games characters have” and was paired with the keywords “Brain Training games, Cognitive training video games.” The fee advertised for the completion of the thirty-minute task was $4.00 USD. The study was set up as an External Question, a format provided by MTurk to allow task employers to host the study on their own private web server, i.e., the DREAM platform.

Materials and Apparatus

Demographic Survey. A demographic survey was presented online that included items asking for participants’ gender, ethnicity, level of education, and video game play experience.

Emotional Image Comparison Task. The Emotional Image Comparison Task was an online task employing a forced-choice paradigm in which participants were shown a pair of game characters and had to choose the one that best elicited a specified emotion. The game characters were Aliens that were designed for the previously validated cognitive skills training game *All You Can E.T.* (Homer & Plass, 2016a; Parong, Mayer, Fiorella, MacNamara, Plass, & Homer, 2017; Plass & Homer, 2016) with variations for three visual attributes: shape (round or square), color (warm or neutral/grayscale), and expression (sad or happy or neutral); see Figure 4.

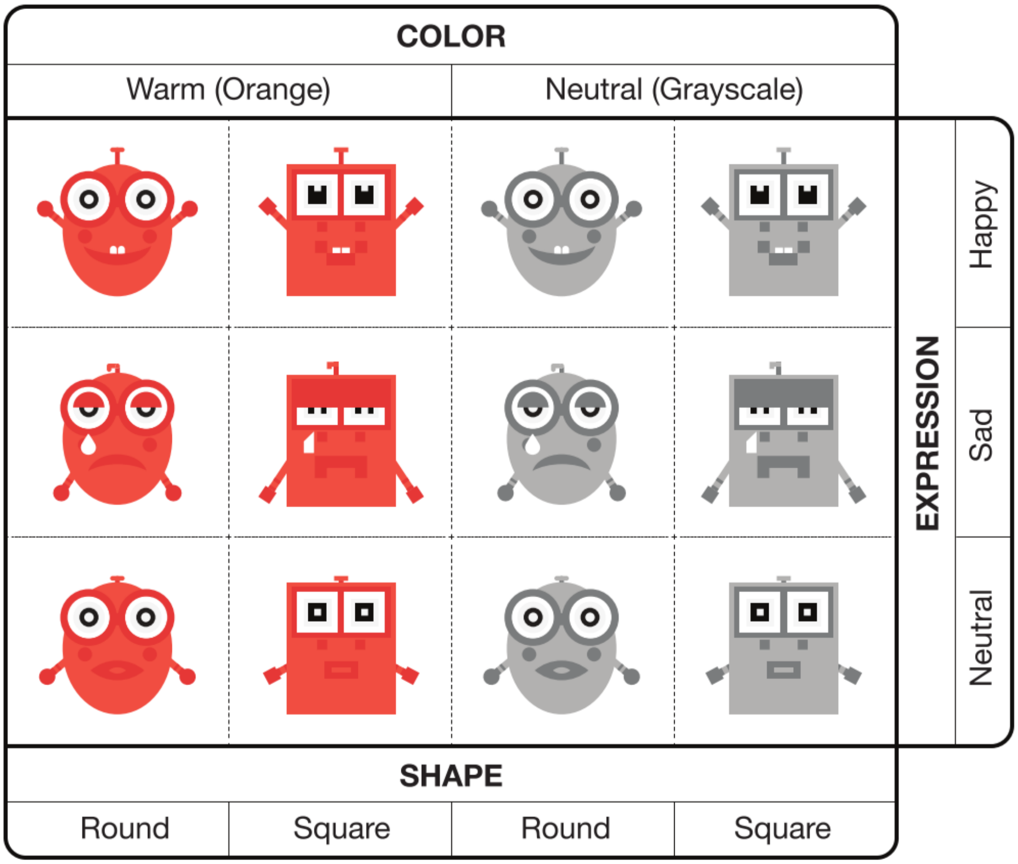

Figure 4. Twelve variants of game characters, varying attributes of shape, color, expression

Using all possible combinations of attributes, a total of 12 alien character images were created for the task, for a total of 66 possible comparison combinations. In three separate blocks of trials, each focusing on a particular emotion, participants were asked to rate which character made them feel *saddest*, which character made them feel *happiest*, or which character made them feel most *neutral*; see Figure 5 for an example. Character pairs within each emotion block were randomized, and the block order was counterbalanced.

Figure 5. Forced choice comparisons of game characters. Instructions: Select the character that makes you saddest

DREAM. The Digital Reference of Experiments and Assessments Manager (DREAM) is an online research management platform that was used to deliver all surveys and the Emotional Image Comparison Task. All data for participant responses was recorded through this online platform. The DREAM research platform is a web-based service developed and maintained by New York University's *Consortium of Research and Evaluation of Advanced Technologies in Education* (CREATE Lab) and has been successfully used in a broad range of prior studies (Homer & Plass, 2016b).

MTurk. Amazon Mechanical Turk (MTurk) is an online platform for connecting workers to digital tasks that require human input. Through this platform, a participant is able to sign up for a fully self-contained online task, work on the task, submit one or more answers, and, once completed, collect a financial reward. A built-in MTurk qualification system allows the issuer of the task to set certain qualifying requirements for participants, such as the number of prior tasks completed, the average quality rating received for these tasks, the participant's English language competency, and their geographic location. Previous research has shown MTurk-based participants to provide experimental data that is as reliable as lab-based research environments (Buhrmester, Kwang, & Gosling, 2011; Hauser & Schwarz, 2016).

Procedure

After accepting the human intelligence task (HIT) in MTurk, participants read and responded to an online consent form. Participants were then given instructions to access the experiment through DREAM, where they completed the demographics survey and the Emotional Image Comparison Task. At the end of these tasks they received a completion code to submit their work in MTurk in order to receive payment.

The Emotional Image Comparison Task began with an instructional page where participants were informed that they would be "presented with 3 sets of 66 pairs of images." Users were instructed to choose the image that best matched the emotion presented at the bottom of the screen by pressing "C" for the left image or "M" for the right image. When a new pair of images were presented, the choice keys were disabled for the first second to prevent accidental choices. If no choice was made after ten seconds, the ability to choose was forfeited and the next pair was presented.

Participants then proceeded through three blocks of forced-choice trials, with each block focused on asking for participant feedback with respect to a single emotion. The order of the target emotions was randomized. At the beginning of a block, participants were shown a message instructing them to "Please select the character that makes you feel HAPPIEST" (or SADDEST, or NEUTRAL) and were presented with all sixty-six possible pair combinations in a randomized order; see Figure 3. The following two blocks provided the same instructions but targeting the remaining emotions. Participants were then given their completion code to access their payment through MTurk.

Results

We first calculated the total number of times each alien game character was selected in the comparison trials by the participant as making them feel saddest, happiest, and neutral. We then created total counts for each of the visual attributes (e.g., color: warm, neutral; shape: round, square; expression: happy, sad, neutral) present in these selected characters for each particular emotion and calculated an average for each attribute. Using these averages, we computed separate within-subject three-way ANOVAs for each of the blocks of target emotions (sad and happy and neutral).

The results of the ANOVA for the block with a happy target emotion indicated main effects of all three factors including color, $F(1,153)=164.63$, $p<.001$, $\eta_p^2=.56$, shape $F(1,153)=21.67$, $p<.001$, $\eta_p^2=.22$, and expression, $F(2,152)=1325.84$, $p<.001$, $\eta_p^2=.96$. Post-hoc pairwise comparisons revealed the effect of color to favor warm (orange) (M=5.94, SD=3.26) over neutral (gray) color (M=4.95, SD=4.94), d = 4.10, the effect of shape to favor round (M=5.62, SD=3.43) over square (M= 5.27, SD=2.96), d = 1.78, and the effect of expression to favor happy (M=8.87, SD=1.39) over neutral (M=5.44, SD=1.47), d = 12.33, and neutral over sad (M=2.03, SD=1.38), d = 3.48. All contrasts mentioned are significant with $p < .0001$.

The ANOVA with the data from the neutral block also indicated good overall fit (R^2_{adj}=.70). This analysis revealed main effects of all three factors including for color, $F(1,153)=97.41$, $p<.001$, $\eta_p^2=.72$, shape, $F(1,153)=166.07$, $p<.001$, $\eta_p^2=.33$, and expression

$F(2,152)=450.58$, $p<.001$, $\eta_p^2=.84$. For this block with a neutral target emotion, the effect of color favored the neutral ($M=5.97$, $SD=2.92$) over the warm colors ($M=4.85$, $SD=3.10$), d = 4.39, the effect of shape favored square ($M=6.00$, $SD=2.90$) over round ($M=4.83$, $SD=3.13$) , d =4.31, and the effect of expression favored the neutral images ($M=8.54$, $SD=1.59$) over the happy images ($M=4.26$, $SD=2.05$) , d = 13.74, and the happy images over the sad images ($M=3.43$, $SD=2.14$) , d = 1.97.

For the block with a sad target emotion, the ANOVA similarly revealed main effects of all three factors including color, $F(1,153)=223.13$, $p<.001$, $\eta_p^2=.33$, shape, $F(1,153)=11.67$, $p<.001$, $\eta_p^2<.01$, expression $F(2,152)=1228.62$, $p<.001$, $\eta_p^2=.84$. The effect of color for the block with a sad target emotion favored the neutral colors ($M=6.16$, $SD=3.01$) over the warm colored characters ($M=4.74$, $SD=3.23$), d = 5.58. The effect of shape favored the round ($M=5.57$, $SD=3.53$) over the square images ($M=5.33$, $SD=2.85$) , d = 1.43. The effect of expression favored the sad ($M=8.83$, $SD=1.50$) over the neutral images ($M=5.21$, $SD=1.57$) , d = 12.84, and the neutral over the happy images ($M=2.31$, $SD=1.66$) , d = 9.75.

In relation to the research question, which sought to examine how variations in visual features of a game character influence participants' attribution of affect, these findings suggest that adult participants consider expression, color, and shape when experiencing the game characters as either happy or sad. The responses to happy as target emotion show that warm colors, round shapes, and a happy expression were associated with this emotion. For sad as target emotion, neutral colors, sad expressions, and, interestingly, round shapes were the associated design features for these adult participants.

Study 2: Color, Shape, Expression

Study 2 aimed to replicate findings from study 1 with adolescents. We were interested in this age-group due to the prevalent use of gaming among adolescents as well as due the positive learning outcomes that were associated with games for learning for this age group.

Method

Participants and Design

Study 2 participants consisted of middle school and high school students (N=47) recruited from a large urban public school system. The average age of the participants was 12.3 (SD=1.8). The sample consisted of an approximately equal number of males (49%) and females (49%), with a small number who declined to state their gender (2%). The design of study 2 was identical to study 1.

Materials and Apparatus

Study 2 was identical to Study 1, with three exceptions. Unlike study 1, which was administered to participants recruited online through MTurk, Study 2 participants completed the study in-person. The demographic survey was modified to add questions pertaining to children and remove questions pertaining to adults, such as grade level instead of highest level of education attained. The Emotional Image Comparison Task was modified to remove the neutral block of trials, as a pilot test of the materials had revealed that middle school students found it very difficult to rate neutral feelings and that the overall procedure, involving 3 blocks, was too long.

Procedure

In separate visits by multiple schools, participants arrived at the research lab accompanied by their teachers. Permission forms were collected from the parents of each student and from the principal of each school prior to students' arrival. Participants were given general introductions to research and what their participation would involve. This study was one of several studies in which students participated during their visit.

Students were seated at computers with the DREAM website open in a Firefox browser window. Researchers then entered the access code to begin the study in DREAM. Students were responded to a consent form provided online via DREAM. For students who were under 13 years of age, oral consent was administered by a researcher. Students then completed the demographic survey, and next the Emotional Image Comparison Task. While the Emotional Image Comparison Task in Study 2 was comprised of two emotion blocks (happy and sad) rather than the three used in Study 1 (happy and sad and neutral), the task instructions and pair presentational style remained the same as in Study 1. Research assistants answered questions as needed, ensuring study adherence and resolving any issues. Once all studies for the lab visit were completed, students were debriefed.

Results

As in the analysis for study 1, we first calculated a total across all images for each of the two blocks (happy and sad) and conducted separate within-subject three-way ANOVAs for each of the two blocks.

An ANOVA conducted on the data collected during the blocks with a happy target emotion revealed markedly similar findings than in Study 1, with main effects of each of two of features, namely color, $F(1,36)=97.70$, $p<.001$, $\eta_p{}^2=.63$, and expression

$F(2,36)=392.70$, $p<.001$, $\eta_p^2=.84$. The effect of shape was not significant for this block, $F(1,36)=.19$, $p=.66$. Pairwise comparisons of the main effects revealed a significant preference for warm colored ($M=6.23$, $SD=3.42$) over neutral grayscale ($M=4.81$, $SD=3.24$) images with respect to color, $d = 1.73$, a preference for images with the happy ($M=8.81$, $SD=2.37$) over the neutral ($M=5.46$, $SD=2.15$) expression, $d = 5.00$, and a preference for the images with a neutral over a sad ($M=2.28$, $SD=1.78$) expression, $d = 2.53$. All contrasts were significant with a p-value of less than .001.

An ANOVA conducted on the data collected during the blocks with a sad target emotion ($R^2_{adj}=.83$) also revealed main effects for the feature of color, $F(1,36)=418.70$, $p<.001$, $\eta_p^2=.33$, and expression $F(2,36)=2803.40$, $p<.001$, $\eta_p^2=.84$, as well as shape $F(1,36)=27.5$, $p<.001$, $\eta_p^2<.01$. Pairwise comparisons revealed the main effect of color favored neutral gray ($M=6.25$, $SD=3.31$) over warm colored ($M=4.72$, $SD=3.32$) characters for the sad target emotion block, $d = 1.73$, and square ($M=5.68$, $SD=2.94$) over the round ($M=5.29$, $SD=3.73$) characters, $d = 1.61$. The pairwise comparisons for expression revealed that the characters with a sad expression ($M=9.06$, $SD=2.54$) were favored over the characters with a neutral expression ($M=5.17$, $SD=2.04$), $d = 3.70$, and the characters with a neutral expression were favored over the characters with the happy expression ($M=2.22$, $SD=1.84$), $d = 4.69$.

These findings suggest that adolescent participants similarly consider expression and color when assessing compared with adult participants. The target emotion happy was associated with warm colors and happy expressions of the game characters. Interestingly, differences in the shape of the characters appeared to be less strongly associated with variation in responses in trials with a happy target emotion. The target emotion sad was associated with neutral colors, square shapes, and sad expressions of the game characters.

Summary: Study 1 and Study 2

Studies 1 and 2 were conducted to investigate the affective quality of game characters for an adult population and for adolescents. Adolescents were included because they are a primary audience for digital games, but since game-based learning is increasingly also used with adults (Homer & Plass, 2016a; Rose et al., 2018), we included this population as well. Inspecting the effect sizes for the impact of color, shape, and expression in Studies 1 and 2, we found large to very large effects for color and expression. Expression had the largest effect size (between .84 and .96), followed by color (between .33 and .72). For shape, we found small to medium size effects (less than or equal to .33). In fact, the effect for shape, although statistically significant for the induction of happiness and sadness in study 1, did not impact sadness in Study 2.

Study 3: Color, Dimensionality, Expression

Given the findings from Studies 1 and 2, which had shown that the effect for the visual shape attribute was often small, and in some cases negligible, we removed this attribute in Study 3 and replaced it with the attribute dimensionality. Study 3 therefore investigated the perception of the affective quality of game characters for which the visual attributes color, dimensionality, and expression were manipulated, compared to color, shape and expression in studies 1 and 2.

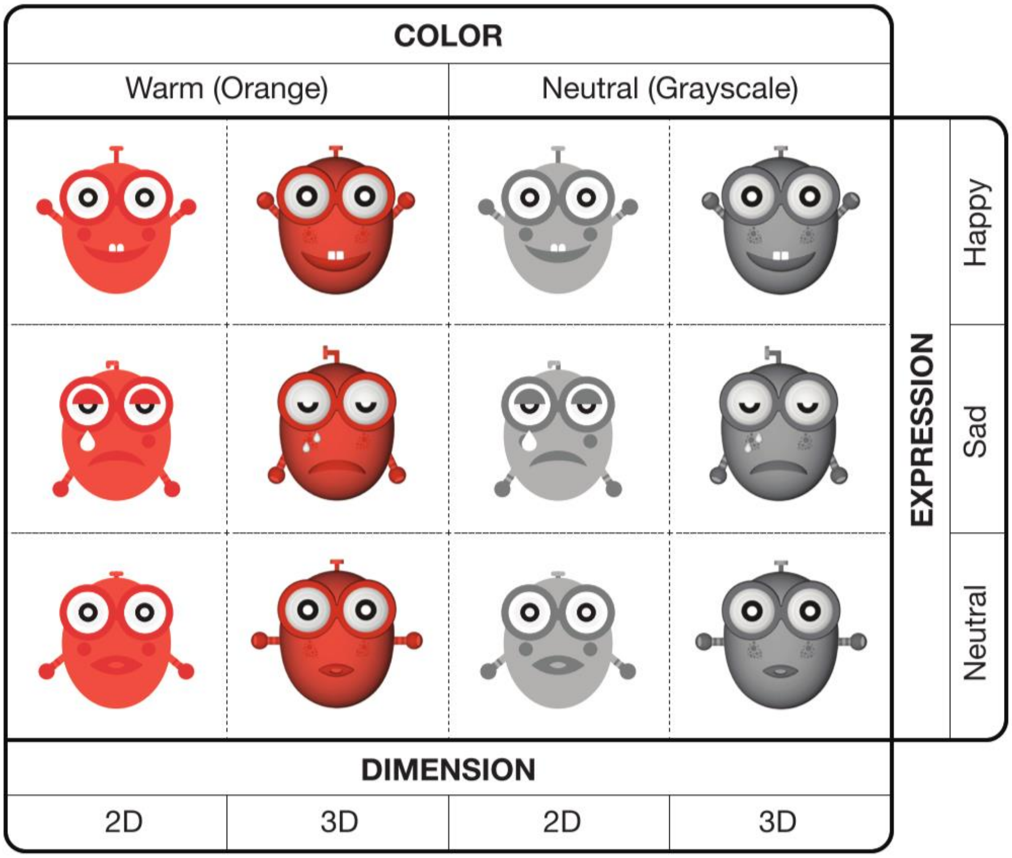

Figure 6. *Twelve variants of game characters, varying attributes of color, dimensionality, expression*

Method

Participants and Design

Approximately 292 middle school and high school students from a large urban public school system were recruited to complete the study in-person in early 2017. Participants ranged between 12 to 19 years of age, with a mean age of 14.1 (*SD*=1.74). Within the sample, 52% identified as female, 48% identified as male, and 1 individual declined to state. The design of this study was identical to that of study 2.

Materials and Apparatus

Study 3 was identical to Study 2, with the exception of the visual attribute of shape (round or square) for characters being replaced the attribute of dimensionality (2D or 3D), resulting in the use of a new set of game characters to be used in the Emotional Image Comparison Task. As in study 2, the neutral block of the comparison task was not included. Shading effects were used to create the appearance of 3D; see Figure 6.

Procedure

The procedure in Study 3 was the same as in Study 2.

Results

We computed total counts for each image as in Studies 1 and 2, described above, and then calculated averages for each attribute for the rating of each emotion. Separate within-subject three-way ANOVAs were conducted for each block; one with a happy target emotion, and one with a sad target emotion.

An ANOVA revealed a significant main effect of color and expression for the block with a happy target emotion. The warm color images (M=6.42, SD=3.51) were significantly more likely to be chosen as happy than neutral grayscale characters (M=4.59, SD=3.10), $F(1,290)=695.5$ ($p<.001$), $\eta_p^2=.66$, $d = 4.61$. The characters with a happy expression (M=8.62, SD=2.63) was significantly more likely to be rated as happy than the characters with a neutral expression (M=5.70, SD=2.09), $F(2,289)=2845.9$ ($p<.001$), $\eta_p^2=.87$, $d = 7.82$. The characters with the neutral expression was, in turn, significantly more likely to be rated as happy than the characters with the sad expression (M=2.21, SD=1.86), $d = 10.80$. There did not appear to be a main effect of dimensionality, $F(1,290)=.004$, $p=.95$, $\eta_p^2<.001$.

For the block with the sad target emotion, an ANOVA revealed a main effect of color, expression, and dimensionality. With respect to the feature of color, the neutral grayscale characters (M=6.34, SD=3.30) were significantly more likely to be rated as more sad than warm colored characters (M=4.52, SD=3.36), $F(1,290)=651.06$, $p<.001$, $\eta_p^2=.64$, d = 4.75. In terms of expression, the characters with the sad expression (M=8.73, SD=2.60) were significantly more likely to be rated as sad than the characters with the neutral expression (M=5.17, SD=2.19), d = 10.84. The characters with the neutral expression were significantly more likely to be rated as more sad than the characters with the happy expression (M=2.40, SD=2.01), $F(2,289)=2626.7$, $p<.001$, $\eta_p^2=.86$, d = 7.64. With respect to the feature of dimensionality, the 3D characters (M=5.54, SD=3.53) were significantly more likely to be rated as more sad than 2D images (M=5.32, SD=3.37), $F(1,280)=9.236$, $p<.05$, $\eta_p^2=.05$, d = 1.04.

Summary

We were interested in examining how variations in visual attributes of a game character influence participants' attributions to certain emotions. Study 3 largely confirmed the effects for color and expression found in Studies 1 and 2. However, the most significant finding from this study is that dimensionality only showed a very small effect for the target emotion sad, and no effect for the target emotion happy. This may be a result of the fact that even though the images of the characters were rendered in 3D using shading, they were presented on a 2D screen. We therefore conducted a fourth study, using an immersive VR environment to present the 3D characters.

Study 4: 2D, Immersive 3D

Study 3 compared the emotional impact of 2D versus 3D characters; however, both types of dimensionality were viewed on a 2D screen without gameplay. Study 4 therefore aimed contextualize characters within gameplay, and to compare the emotional impact of 2D game characters presented on a computer screen with that of 3D game characters presented in an immersive 3D VR environment. Because this comparison involved two different systems, it did not readily allow for the use of the forced choice paradigm. We therefore used a think-aloud protocol, in which we recorded unprompted utterances about the emotional effect of the 2D versus 3D game characters, combined with an emotion self-report survey, the PANAS-X.

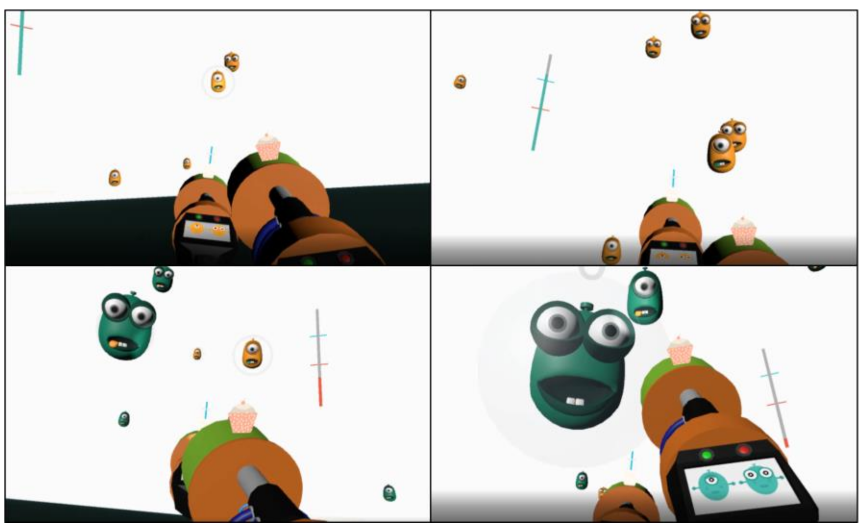

Figure 7. Screen shots from the immersive VR Game, showing aliens at the distance (top) and close-up (bottom)

Method

Participants

Students (*N*=41) were recruited from middle and high schools from a large urban public school system in the northeastern United States (mean age=13.78 years (*SD*=1.87); 51% female; 49% male). These participants were randomly selected from a similar population of students as those who took part in study 2 and 3. The study used think-aloud protocols and surveys to assess participants' emotions in a within-subject design.

Materials and Apparatus

Cognitive Skills Training Games. 2D and Immersive 3D versions of the cognitive skills training game *All You Can E.T.*, developed by our research group, were used. In this game, players feed incoming aliens different types of food. The players must follow the feeding rules, which describe food preferences of different types of aliens (e.g. one-eyed aliens want cupcakes and two-eyed aliens want milkshakes). The game challenges players with frequently changing feeding rules and poses the goal of feeding correct food to as many aliens as possible. The 2D version of the game was played on a computer using a mouse and keyboard and requires players to feed aliens either cupcakes or milkshakes as they descended down the screen, with a specific feeding rule being given to the player before each round began In the 3D version, players performed the same task as the 2D version butused a VR Headset (HTC Vive) to look around in the 3D environment and two handheld VR controllers to launch food towards approaching aliens. see Figure 7.

Surveys. To measure emotional responses, each participant completed two surveys consisting of items from the PANAS-X (Watson & Clark, 1999). Participants were asked in the modified PANAS-X survey to "indicate to what extent [they] felt each of the emotions" for both games. The prompted emotions included those generally related to experiences of positive, negative, and other emotions as categorized by the PANAS-X. The PANAS-X was chosen for its strong construct validity, with self-report convergent correlations of .9-.95 (n=5,000+) for both positive and negative emotion prompts, experienced anywhere from the current moment, the past month, or in general. They rated each prompted emotion on a 5-point Likert-type scale with a response of 1 indicating that the prompted emotion was being felt "very slightly or not at all" and a response of 5 indicating that it was being felt "extremely." The items were selected based on their relevance to gameplay.

A think-aloud protocol was used to capture in-game emotional utterances of players. The protocol was implemented by two researchers, an experimenter and an observer. The experimenter was responsible for guiding participants through the experiment and prompting them to verbalize their thoughts, while the observer was responsible for noting down emotional utterances from the participants. Before the experiment, participants were trained to think-out-loud by the experimenter while playing a simple board-game. During the training, an experimenter modeled think-aloud behavior by verbalizing their actions and gameplay strategies. The participant then followed to do the same. The experimenters were trained to exclude emotional utterances during the training phase to avoid priming participants to follow the same behavior. Before the beginning of the experiment, a coding protocol was established between the experimenters using sample observer notes. Here, the experimenters agreed on keywords and utterance traits indicating emotional reactions. For analysis, the frequencies of such emotional utterances were derived from the observer notes and used as a measure of emotional arousal of players during gameplay.

Procedure

Each participant first completed the modified PANAS-X survey reporting their emotional state before gameplay. Participants then went through a short think-aloud training session in which they learned to verbalize their thoughts as they occurred, without editorializing, and were then instructed to think-aloud during gameplay sessions. After the training session, participants played the 2D and the immersive 3D VR version of the cognitive skills training game for 5 minutes each. The order of games was counterbalanced between participants to avoid a recency effect in the reported emotional states. Participant's verbal utterances regarding their emotional state were captured by a trained observer during both gameplay sessions. After playing both games, participants completed the modified PANAS-X survey, reporting their emotional states for each mode of play.

Results

Initial analyses were conducted to determine if age, sex or presentation order had any effect on the main dependent variables. Age was not significantly correlated with either number of utterance or PANAS-X totals for 2D or 3D VR. Similarly, number of utterance and PANAS-X totals for both 2D and 3D VR did not differ significantly by sex. Therefore, neither age nor sex was included in subsequent analyses. There was a significant main effect for order of game play. Participants who played the 2D version first had significantly higher PANAS-X means for 3D VR (M = 2.76, SD = .62) than participants who played the 3D version first (M = 2.40, SD = .40), $t(39) = 2.21$, $p = .03$. Therefore, task order was included as a covariate in subsequent analyses.

Separate repeated-measures ANCOVAs were then conducted with PANAS-X and number of verbal utterances as dependent variables. For both analyses, type of game play (2D versus 3D VR) was included as a within-subject independent variable, with order as a between-subjects variable. For number of utterances, there was a significant effect of type of game play, F (1, 39) = 61.14, $p < .001$, $\eta_p^2 = .61$. Unprompted, verbal utterances were significantly more frequent for 3D VR gameplay (M = 8.07, SD = 4.13) than 2D (M = 3.12, SD = 2.53), $t(40) = 7.89$, $p < .001$, d = 1.23. Neither task order nor the interaction between order and type of game play was significant.

For PANAS-X, analysis revealed a significant effect of type of game play, F (1, 39) = 19.19, $p < .001$, $\eta_p^2 = .33$. Emotional arousal was significantly greater for 3D VR game play (M = 2.58, SD = .55) than 2D (M = 2.26, SD = .69), d = .69.

PANAS-X survey data was further examined using the responses of prompts for *positive affect* (items = happy, joyful, excited, enthusiastic, energetic, daring, and alert), *negative affect* (items = afraid, scared, disgusted, nervous, angry, hostile, and sad), and *other affect* (items = strong, fearless, attentive, calm, relaxed, and surprised). All prompts for positive and negative affect were significantly different between conditions, which was consistent with the convergent correlations of the instrument, and were therefore compiled into mean positive and mean negative affect scores for further analysis. Of the *other affect* prompts, only "surprised" was significantly different (p<.001) between modes of play, with VR eliciting more surprise (m=3.41, sd=1.35) than 2D (m=2.45, sd=1.45); a mean *other affect* was computed for the remainder of the analysis to be consistent with the *positive* and *negative* composite scores. A repeated measures ANCOVA was conducted with type of game play (2D versus 3D VR) and emotion (positive affect, negative affect, or other affect) as within-subject variables, and order as a between-subjects variable. There was a significant effect of medium, F (1, 39) = 19.19, p < .001, η_p^2 = .33, indicating significant differences in affect ratings between the two modes of gameplay. There was also a significant effect of emotions, F (1, 78) = 65.87, p < .001, η_p^2 = .63.

Pairwise comparisons for positive affect indicated that participants rated significantly higher positive-emotion arousal in VR than in 2D; F(1,40) = 13.39, p = .001, d = .37. Negative-emotion arousal was also rated significantly higher in VR than in 2D; F(1,40) = 24.51, p < .001, d = .84. The means of other affect prompts were not significantly different between modes of gameplay.

Players' utterances revealed specific aspects of the immersive VR environment that may have induced the high levels of arousals reported above. These include presence, game character movement, and game character anthropomorphizing. As an indication of *presence* inducing emotion, players of the VR game made statements such as, "makes you feel like you're in here," and "I got a sense of danger in that game [VR version] that I don't get in this one [2D version]." *Game character movement* seemed to have induced emotion as indicated by statements such as "they are attacking me," and "oh, they are coming from everywhere". Finally, *game character anthropomorphizing* appeared to have induced emotion, which is indicated by players talking to characters, saying "Come closer, I dare you," or "Come here you piece of s#it".

Summary

Study 4 provides initial evidence for the effect of 2D versus immersive 3D game characters. Due to the different systems used to present the stimuli, the forced choice paradigm from Studies 1–3 could not be used, and effect sizes can therefore not be compared directly. However, the effects we found were large effects, suggesting a strong affective quality of 3D immersive game characters. Furthermore, analyses of utterances during the think aloud protocols indicated that players experienced more emotions during the immersive 3D game play, and suggest that features such as presence, game character movement, and game character anthropomorphizing help produce greater affective response.

Discussion

The goal of this research was to investigate the affective quality of game characters that were designed by manipulating four visual attributes, color, shape, expression, and dimensionality, and to compare the size of their effects on players' experienced emotions. The goal of this research on the affective quality of specific design features in games for learning was to add to the EmoGBL model by providing more insights into emotional design, one of the distal antecedents of learner emotions described in this model. This research was also inspired by recent research results indicating that emotional design can be used to enhance learning outcomes in game-based environments, both for comprehension and transfer of scientific knowledge (Mayer & Estrella, 2014; Plass et al., 2014; Um et al., 2012), and for cognitive skills development, particularly the training of executive functions (Rose et al., 2017). What these studies revealed is the need for systematic research investigating the affective quality of specific design features that can provide guidance to the designers of games for learning.

An investigation of the affective quality of game characters requires the selection of features to be included, as well as decisions about their operationalization. Based on previous studies and theoretical contributions which we describe in the literature review, we selected color, shape, expression, and dimensionality as design features we manipulated for the game characters. Color was varied between orange and grey, shape between round and square, expression between happy, sad, and neutral, and dimensionality between 2D and 3D representations. We also selected two specific target emotions for the Emotional Image Comparison Task, happy and sad. These choices were made based on the use of game characters in the All You Can E.T. game (Homer & Plass, 2016a; Plass & Homer, 2016) from which we appropriated them. In this game, the characters are happy when they receive the right food or drink, and sad when they receive the wrong food or drink. This makes the choice of emotion more ecologically valid, but it limits some of our conclusions since happy is a positive activating emotion, and sad a negative deactivating emotion, which does not allow for conclusions about differential effects of valence and activation.

The results of four empirical studies with participants ranging in age from approximately 12 years to adulthood showed that *expression* has a large effect, *color* has a medium sized effect, and *shape* has a small to medium effect; see Table 1. These findings are in line with Baylor (2009) who suggested that expression is one of the most important design features of game characters. It is possible, albeit not a conclusion our data can support empirically, that the design factor expression inducing emotion via emotion contagion, and that this mechanism results in stronger effects than design factors shape and color, which may be a result of appraisal processes related to aesthetic emotions–two different mechanisms of affecting emotions described in the EmoGBL model.

Table 1. *Comparison of Effect Sizes found for visual game character attributes color, shape, expression, and dimensionality*

Visual Attribute	Levels	Effect Sizes
Color	Warm (orange) vs. neutral (grey)	$.33 < \eta_p^2 < .72$*
Shape	Round vs. square	$\eta_p^2 \leq .33$*
Expression	Happy vs. neutral vs. sad	$.84 < \eta_p^2 < .96$*
Dimensionality	2D, 3D (on-screen)	$\eta_p^2 \leq .05$*
Dimensionality	2D, immersive 3D (VR)	$.69 < d < 1.23$**

* Effects based on Emotional Image Comparison Task

** Effects based on PANAS-X scores and think-aloud method

Furthermore, we found that using 3D visual representations of game characters induces stronger affective responses compared to 2D characters, see Table 1. We found a small effect even when we compared 2D versus 3D characters on screen-based computer games, but the effect of *dimensionality* was especially strong when comparing 2D screen-based characters to 3D characters in immersive VR game environments. The effect found for dimensionality in VR environments cannot be directly compared with the other effects, however, since the design of study 4 different significantly from studies 1-3.

This set of studies extends findings from previous research in which the effects of color and shape on emotion and learning have been investigated (Mayer & Estrella, 2014; Plass et al., 2014; Plass & Kaplan, 2016; Um et al., 2011). This research also extends previous work that developed procedural methods to design corresponding game characters (Perlin, 1997). The additional insights provided by the current research allow for the decomposition of the effects of the four visual design attributes and provide a comparison of the size of the effect of each design attribute on emotional arousal (Table 1).

Limitations

As is the case with any empirical research, the present study has limitations that reduces the generalizability of our findings. One limitation relates to the measures used for emotion, which relied on self-reports. There is indication that self-reports may be less reliable than behavioral measures (Leutner & Plass, 1998), and researchers suggest using a combination of observational measures and self-reports to assess emotion (Baker, D'Mello, Rodrigo, & Graesser, 2010). As self-reports can have inherent problems of validity, further research should replicate our findings using other measures. Additionally, these self-reports differ between Studies 1-3 and Study 4. In the first three studies, we employed a forced-choice paradigm. This method, in which participants reported their emotions related to 66 pairs of game characters, may have introduced study-related emotions such as boredom, which may have led to an underestimation of the positive emotions, and overestimation of negative emotions we found. However, this possibility had to be balanced against the need to have each learner complete all 66 comparisons due to the within-subject nature of this study. Another limitation was that the 3D VR game experience used in Study 4's did not lend itself to use the same forced choice paradigm as in studies 1-3, which makes a direct comparison of the emotional response difficult. Finally, while this research has the goal of determining the features for the design of game character that are antecedents of emotions in a learning context, the design of the study did not allow us to include learning tasks. Our findings therefore contribute to the part of the EmoGBL model that describes antecedents of emotions in learning, and future research should incorporate learning tasks and measurements of learning to verify the link of emotional design choices ultimately leading to the enhancement of learning.

Implications and Conclusion

The present work has both theoretical and practical implications. On the theoretical side, our research provides empirical evidence for how the emotional design of game characters can serve as antecedents of emotions, and thereby makes a contribution to the EmoGBL model proposed by Loderer et al. (2018b). This model describes antecedents of emotions experienced in an academic context, as well as their effect on learning processes and outcomes in games. Loderer at al. (2018b) had identified insights into the affective quality of specific design features of games as one of the areas in need of research. Our results provide initial insights for four specific visual attributes on emotional arousal: color, shape, dimensionality, and expression, and provides comparisons of the size of their corresponding effects on emotion arousal. It also provided preliminary insights into specific attributes of immersive VR environments that affect emotions, namely the attributes of presence, game character movement, and game character anthropomorphizing. This is of theoretical significance since previous research had established that emotional design can be used to enhance academic learning outcomes (Mayer & Estrella, 2014; Plass & Kaplan, 2016; Um et al., 2012).

On the practical side, these results provide guidance for the designers of games, particularly games for learning and games for cognitive skills development, with much needed guidance on specific visual design attributes of game characters that can be used to induce emotions in players that facilitate learning, or to induce high emotional arousal in order to facilitate cognitive skills training. This is significant because the use of design elements such as game characters provides an effective method for inducing emotion in games without having to modify the learning content or the learning mechanics.

Future research should investigate the contribution of additional visual attributes, as well as of auditory attributes (music, sound), game mechanics, and other design elements, and thereby add to the growing list of methods for emotional design for learning.

Acknowledgments

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