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Joyful Adventures and Frightening Places–Designing Emotion-Inducing Virtual Environments

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Virtual environments (VEs) can evoke and support emotions, as experienced when playing emotionally arousing games. We theoretically approach the design of fear and joy evoking VEs based on a literature review of empirical studies on virtual and real environments as well as video games' reviews and content analyses. We define the *design space* and identify central design elements that evoke specific positive and negative emotions. Based on that, we derive and present *guidelines* for emotion-inducing VE design with respect to *design themes*, *colors and textures*, and *lighting configurations*. To validate our guidelines in two user studies, we 1) expose participants to 360° videos of VEs designed following the individual guidelines and 2) immerse them in a neutral, positive and negative emotion-inducing VEs combining all respective guidelines in Virtual Reality. The results support our theoretically derived guidelines by revealing significant differences in terms of fear and joy induction.

Keywords: virtual reality, virtual environments, immersion, emotions, design

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1 INTRODUCTION

Computer games and simulations in general enable users to experience intriguing virtual environments (VEs), e.g., huge real world buildings, vast natural landscapes, or completely fictional worlds (Perry and DeMaria, 2009; McGonigal, 2011). Exploring and interacting with these VEs can lead to gaming immersion (Jennett et al., 2008) resulting in players completely directing their attention to the gaming action. In such a state of gaming immersion, the virtual environment is perceived as *real* and players feel present in the VE. They become the game character, adopt their body and attribute virtual events to themselves (Perron, 2004; Endress et al., 2016). Loosing track of the virtuality (Lee, 2004), we tend to think and behave as if the situation was real (Slater, 2003). In such a situation, we follow action tendencies related to emotions (Perron, 2004). According to Plutchik (2001) an "*emotion is a complex chain of loosely connected events that begins with a stimulus and includes feelings, psychological changes, impulses to action and specific, goal directed behavior*." The emotion-inducing effect of digital media can be amplified when using immersive Virtual Reality (VR) (Pallavicini et al., 2018). Research demonstrates that VR is an effective emotion-induction medium, e.g., when exploring either a positive or negative park (Riva et al., 2007), and may serve as an ideal expressive medium for emotional challenge in computer games (Peng et al., 2020). While most VR applications fulfill a distinct purpose, such as education, therapy, and entertainment, they all simulate VEs in which users experience the actual content. Thus, the emotions evoked by a given VE can have an impact on the overall effectiveness of a VR application.

Several applications already take advantage of this phenomenon by manipulating the VE design to maximize the desired effect (Birbaumer and Schmidt, 2010; Oberdörfer et al., 2021, 2022). Exergames and applications of therapy and rehabilitation let users travel from their homes and hospital rooms to beautiful VEs like sunny beaches or colorful meadows to increase their motivation to perform the desired exercises (Hamzeheinejad et al., 2019; Kern et al., 2019). Similarly, adventure games use warm and kind environments to evoke certain degrees of escapism (Chan, 2020). In contrast to these positive examples, other applications like horror games rely on gloomy and frightening locations (Perron, 2012; Prohászková, 2012). Given that the induction of fear is the most important aspect of horror games, the right VE is able to maximize those emotions (Tajeran, 2012).

These two directions of VE design open up a rather large design space. This design space is not only relevant to computer games, but also to any other situation that exposes users to VEs. Researchers and developers need to be aware of the various possibilities and effects of VE design to support, create and potentially even avoid unwanted emotional stimuli. For instance, VR training applications helping children to overcome anxieties before a medical examination (Liszio et al., 2020) should not contain fear-inducing aspects. To enable well-targeted designs, a comprehensive and theoretically grounded set of design guidelines is needed.

Contribution

In this paper we examine previous research on virtual and real environments, such as work places and computer games, to define the emotion-inducing *design space* of VEs. We further identify central aspects of VE design that evoke emotions, i.e., *design themes*, *colors and textures*, and *lighting*. Based on our results, we derive and present design guidelines for well-targeted VE design for inducing positive, i.e., joy (*positive VEs*) or negative, i.e., fear (*negative VEs*) emotions. When discussing negative VE design, we investigate the emotion fear solely; when discussing positive VE design, we investigate the emotion joy.

Finally, we validate the guidelines in two user studies. The first study investigates each guideline individually while the second study exposes participants in VR to three versions of a virtual replicate of one of our labs: 1) an unchanged emotionally neutral office (neutral VE), 2) a positive VE following all guidelines for joy-inducing VE design, and 3) a negative VE accounting for all guidelines for fear-inducing VE design. The results support our theoretical assumptions.

2 THEORETICAL BACKGROUND

Having a long tradition of presenting emotionally-charged contexts, computer games and their VEs can generate both positive and negative feelings (Mitchell, 2012; Granic et al., 2014; Jones et al., 2014). Hence computer games are ideal for the dissemination of design guidelines for emotion-inducing VEs. This work focuses on the *adventure* genre and its sub-genre of *survival horror* games, which will be described in the following.

2.1 The Adventure and the Survival Horror Genre

The adventure genre encompasses story-driven games, in which players experience interactive stories about fictional characters (Whalen, 2004; Adams, 2014). Compared to other genres, its entertainment value strongly depends on the games' settings and VEs due to its focus on exploration (Dillon, 2004; Adams, 2014). With the start of graphic adventures in the 1980's, the users' engagement in games such as the *Monkey Island* series (LucasArts, 1990) was driven by their visual appearance. Later on, higher levels of engrossment (Dillon, 2004) were achieved with more realistic looking and details graphics, such as in the landmark adventure game *Myst* (Cyan Worlds, 1993; Dickey, 2006; Mitchell, 2012). Independent from their style, typical adventure games as the ones mentioned above offer players journeys through interactive VEs, turning away from violence and death and offering a welcoming atmosphere (Dillon, 2004; Wolf, 2011).

In stark contrast to this, the sub-genre of survival horror also originates from the adventure genre (Whalen, 2004; Perron, 2012). Survival horror games provide stories about lone protagonists stranded in maze-like landscapes with limited ammunition who must face monsters and solve riddles to survive (Kirkland, 2005, 2011; Pruett, 2010; Roux-Girard, 2011; Adams, 2014). For instance, the protagonist is trapped in a hostile environment, like the city *Silent Hill* (SH) in the eponymous series (Konami, 1999), and the player's main goal is to escape from there. The environments reflect and set the stage for possible story goals, such as revealing mysterious secrets and horrible incidents of the past as well as the search for missing family members, lovers or friends overshadowed by topics like incest and child abuse or similar unsettling childhood memories, murder or insanity (Perron, 2004, 2012; Kirkland, 2010b, 2011, 2015). Also, the environmental design is intended to induce a sense of isolation and powerlessness in the user (Steinmetz, 2018).

2.2 Emotions and Video Games

Emotions arising as action tendencies are determined by the individual appraisal of a situation (Plutchik, 1982; Ekman et al., 1985; Ellsworth and Smith, 1988). They have evolutionary importance since they prepare the organism and cause appropriate reactions. For example, interest manifests in paying attention while fear triggers fight or flight reactions (Perron, 2005a, 2004). Emotions vary in their intensity (Plutchik, 1982) as well as valence and arousal (Russell, 1980). Therefore, relevant gameplay emotions can be subdivided into multiple levels of intensity to underline and support the games' unfolding narratives and emerging events.

Regarding the survival horror genre, the *Defensive Behavior System* (Fanselow, 1994) can be used to classify fear-induction stages of players (Garner and Grimshaw, 2011) with all stages being defined by high arousal and negative valence (Russell, 1980). The Defensive Behavior System describes the behavior of rats which were exposed to a predator in a closed environment. It can be used together with Plutchik's *Wheel of Emotions* (Plutchik, 1982) to classify the most important negative emotions. For example, in a so-called *Pre-Encounter* phase, a rat enters an enemy's territory knowing there could be a threat, but uncertain about the specifics (Fanselow, 1994; Vachiratamporn et al., 2013). The respective emotion is apprehension. When players enter the VE of a horror game and immerse into its atmosphere, attention is heightened and sensitivity to potential threats increases (Tajeran, 2012). In the *Post-Encounter* phase, the rat becomes aware of the predator. Similarly, players are sensitized to recognize cues of imminent dangers such as enemies lurking in dark spaces. Given such a concrete (well-specified) fear, the player must decide on an appropriate avoidance behavior (Plutchik, 1982; Fanselow, 1994; Vachiratamporn et al., 2013). Lastly, in the phase of the *Circa-Strike*, e.g. when a rat is finally confronted with a predator (Fanselow, 1994), or, respectively, when the player meets the opponent, the being trembles in terror, instinct takes over and unreflected reactions follow in quick succession (Birbaumer and Schmidt, 2010; Lynch and Martins, 2015; Lin et al., 2017).

In contrast, games from the adventure genre aim to evoke joy or other related positive emotions (Edge, 2018; Chan, 2020) scoring high on valence (Russell, 1980). Again, three levels of positive emotions can be derived from Plutchik (1982)'s *Wheel of Emotions*. Serenity, the state of inner peace (Gerber, 1986; Kreitzer et al., 2009), forms the first level of positive emotions (Plutchik, 1982). It differs from the next higher level of joy with respect to arousal. While serenity is characterized by low arousal, joy involves high levels of arousal (Clark et al., 1984). Joy is object-orientated and depends on effort and time (Ellsworth and Smith, 1988; Plutchik, 2001; Watkins et al., 2018), e.g. players feel joy when receiving an in-game object they have been longing for. Accordingly, the situation is appraised as pleasant (Ellsworth and Smith, 1988). Regarding action tendencies, joy evokes the desire to communicate one's success to others, e.g. by celebrating, thus it creates strong social connections (Watkins et al., 2018). Ecstasy is the most intense positive feeling (Plutchik, 1982). Like joy, it is also oriented towards specific events (Strongman and Kemp, 1991).

Even awareness of virtuality cannot suppress these innate survival instincts (Baird, 2000).

2.3 Central Aspects of VE Design

With respect to immersive VR, research demonstrates a higher degree of presence in emotionally charged versions of a park in comparison to neutral version (Riva et al., 2007). In this way, presence is considered as a mediating variable between the media experience and the induced emotions. A recent study of Jicol et al. (2021) investigated the formation of felt emotional intensity and agency evoked by the VE design as well as the influence of these two aspects on the formation of presence. The study revealed that presence is mostly influenced by emotional intensity and less by emotional valence (Jicol et al., 2021). Also, only the predominant emotion in a VE increased presence (Jicol et al., 2021). Presence describes the subjective sensation of being in a real place, i.e., accepting the VE as the current location, despite physically being in a different environment (Slater, 2009). In this way, presence represents the perceived realness and plausibility of the virtual experience (Skarbez et al., 2017). The feeling of presence increases when a higher *technical immersion* is provided. Technical immersion is "the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding, and vivid illusion of reality to the senses of a human participant" (Slater and Wilbur, 1997). Hence, when aiming for a high degree of presence, research indicates that high emotional intensity is beneficial. For instance, the environment's design can be manipulated to further intensify these emotions (Bradley et al., 2005; Tajeran, 2012).

Regarding a video game's visual appearance, several dimensions conflate and each dimension can be utilized to increase the desired feeling. Inspired by Windleharth et al. (2016)'s classification, this paper focuses on the manipulation of *design themes* or so-called visual motifs as well as visual looks and styles, created by the use of *colors and textures* and *light*, to maximize emotions. While motifs emphasize the games' themes, "colors are associated with certain qualities which enables them to evoke specific feelings of individuals" (Roohi and Forouzandeh, 2019). Adding textures, perceived color emotions vary (Lucassen et al., 2011). Lastly, light not only fulfills functional aspects, such as making the VE perceivable and drawing the players' attention to game-relevant objects, but also performs emotion-inducing tasks (El-Nasr, 2006; Knez and Niedenthal, 2008).

3 GUIDELINE DEDUCTION

Our guideline deduction was based on a literature review. For finding grounding principles and deriving design guidelines, we started with the examination of video games belonging either to the genre of adventure or survival horror games. In order to draw conclusions related to emotional impact, we collected reviews of these games published in professional multimedia journals such as *EDGE* as well as scientific content analyses. If applicable, we further inspected video games of other genres to infer additional approaches of VE design. We enhanced this review by taking literature on movies from related genres into account. Also, we looked at previous research stemming from other directions, such as city planning and interior as well as workspace design. Since these research areas deal with the design and emotional effects of surrounding physical environments, the findings should also be applicable to VEs.

Utilizing the described approach, we searched for literature with the help of the databases *Google Scholar*, *APA PsychInfo*, *ACM Digital Library*, *IEEE Xplore* and *PSYNDEX* using keyword combinations such as "horror game, fear", "adventure game, joy", or " (virtual) environment, positive/negative emotion". Doing so, 175 literature elements were collected. We started by sorting out literature mainly focusing on games' stories (n = 14), players' point of view (n = 7), user interfaces (n = 6), sound design (n = 25), jumpscares (n = 6), character or enemy design (n = 11), controls and game mechanics (n = 5), and style-referring without mentioning emotions (n = 4). Thus, 58 literature elements on general environmental design, 23 items on illumination, 15 texts on colors, and six articles dealing with weather were include in the literature review. In sum, we analyzed 62 literature elements on environments eliciting negative emotions, whereas 47 literature items used to derive guidelines for positive emotion induction with some texts containing information for both positive and negative VEs. We summarized our findings in point-form and aligned them with the relevant emotional effect. Subsequently, we traced similarities among our findings to unify and to align them with the central design aspects, i.e., design theme, color and textures, and lighting. Finally, we extracted the key aspects and summarized them in concrete design guidelines. Design guidelines for positive VEs are indicated with GL_{pos}, whereas GL_{neg} denotes guidelines for negative VEs.

4 GUIDELINES FOR NEGATIVE ENVIRONMENT DESIGN

In the following, we present 12 guidelines for negative VEs derived from the literature particularly dealing with horror media. For example, locations presented in horror games often narrate stories about what happened before the player arrived. They tell stories-within-stories or represent the protagonist's inner world (Kirkland, 2009, 2011, 2015, 2016; Perron, 2012; Kohlmaier and Mandelc, 2014; Steinmetz, 2018).

4.1 Design Themes

The most common themes of survival horror games are vengeance, confinement, punishment, and religion (Steinmetz, 2018). Horror games' VEs are able to represent all of these themes by turning everyday places like hotels, restaurants, schools and hospitals into abandoned nightmarish worlds with omnipresent signs of violence and potential dangers (Kirkland, 2010a; Perron, 2012). The following discussion of our results and the presentation of the guidelines demonstrates how everyday places can be turned into gloomy locations.

The games of the *Silent Hill* series (Konami, 1999) demonstrate how players can be imprisoned by the environmental design–even right from the start of the game in the *Pre-Encounter* phase (Fanselow, 1994). Roads, that should lead out of town, are either destroyed or blocked by barricades or deep gorges. Similarly, protagonists can be trapped in haunted houses with sealed windows and doors. This entrapment induces feelings of isolation and uncertainty which in turn lead to anxiety (Kohlmaier and Mandelc, 2014; Steinmetz, 2018). Related to this, self-propelling wheelchairs and hospital beds symbolize captivity in one's own body, as shown in *Silent Hill 4: The Room* (Konami, 2004; Kirkland, 2010a; Steinmetz, 2018). These deliberations lead to our first guideline, $GL_{neg}1$:

$GL_{neg}1$: Highlight Boundaries of the VE to Cause Feelings of Confinement

Horror game VEs show residues of violence, e.g. with dead human bodies crucified on walls or floors covered with puddles of blood (Köhne, 2008; Perron, 2012). Otherwise, blood trails can guide the player through the environment (Jellicoe, 2010; Perron, 2012). This omnipresence of death and human vulnerability in the scope of punishment and vengeance evokes disgust, suspense and fear. Players are confronted with the precarity of their identity, their bodies' corruptibility and the materiality of death (Steinmetz, 2018). Violence does not have to be directly shown; the atmosphere and visual effects of past aggression generate unnerving and demoralizing feelings without contact to actual threats, demonstrated in games like *Amnesia: The Dark Descent* (FrictionalGames, 2010), *Anna* (Dreampainters, 2012) and *Silent Hill* (Konami, 1999) demonstrate (Jellicoe, 2010; Kohlmaier and Mandelc, 2014).

$GL_{neg}2$: Use signs of passed violent acts to evoke fear

Even dismembered manikins are used to emphasize violent incidents (Kirkland, 2010a). Besides human-sized manikins, several kinds of dolls, especially toy and voodoo dolls, are popular props in horror games. For instance, *Resident Evil 5* (Capcom, 2009) uses them to represent African voodoo spiritualism and religion (Lindsay, 2009). When eventually dolls or manikins start moving, the horror is maximized since motion increases the creepiness (Mori et al., 2012). Unforeseen movements in the form of poltergeist-actions, borrowed from horror movies like *Paranormal Activity* (Peli, 2007), can be used for jump-scares (Leitner, 2017) to produce short *Circa-Strike* phases (Fanselow, 1994).

These moments can already be prepped in the *Pre-Encounter* phase (Fanselow, 1994) by the uncanny feeling arising from inconspicuous changes in the environment, which confuse players and induce anxiety. Following the example of the movie *The Picture of Dorian Gray* (Berman and Lewin, 1945), paintings and portraits at the wall can transform when players look in the opposite direction, as realized in the indie-title *Devotion* (Leitner, 2017; RedCandleGames, 2019).

$GL_{neg}3$: Use motion and alternation where it is not suspected

4.2 Colors and Textures

Predominated by dark colors, the coloration of survival horror games is rather monotonous since emotional status is higher in colored settings, but should be low and desaturated in horror games (Küller et al., 2006; Kohlmaier and Mandelc, 2014; Cho et al., 2018). Nevertheless, developers make use of selected colors to evoke negative feelings in players. The most important color in survival horror games is red. Rusted furniture, coppery light and most significantly the omnipresent trails of blood (see $GL_{neg}2$) are used to create a disgusting environment (Köhne, 2008; Perron, 2012; Kohlmaier and Mandelc, 2014; Kirkland, 2016).

$GL_{neg}4$: Predominantly *use dark colors in the environment.*
$GL_{neg}5$: Reddish highlights should be added.

Also, the surface quality of objects can induce emotions. Smooth and polished textures like metal and stone appear cold (Callahan, 1999). Additionally, rust, dirt and filth can be added to metal structures to elicit emotions like fear and disgust (Kirkland, 2010a, 2016; Steinmetz, 2018).

$GL_{neg}6$: Apply smooth textures together with *rust and filth.*

4.3 Lighting

Either spotlights, ambient lighting or area light can be used in a VE (Callahan, 1999). Regarding ambient lighting and area lights, the illumination of the whole virtual scene ranges from *low-key lighting* up to *high-key lighting*, where low-key strategies produce barely lit environments that leave a lot to the players' imagination (Callahan, 1999; Niedenthal, 2007). Dark environments are typical for horror games since the lack of visual information causes the phylogenetically relevant human fear of the dark (Grillon et al., 1997; Perron, 2005b; Niedenthal, 2007, 2009). Due to the diurnal cycle humans feel vulnerable at night (Grillon et al., 1997, 1999; Mühlberger et al., 2008; Toet et al., 2009; Tajeran, 2012; Lynch and Martins, 2015). In alignment with the *Defensive Behavior System* (Fanselow, 1994), the VE's illumination could be separated into three stages. Starting with a fully lit scene, anxiety is present because of the environment's appearance. Over time, lights fade out and suspense arises. In the end, darkness dominates the VE which induces fear in the players. Horror movies, e.g., *REC* (Balagueró and Plaza, 2007) also make use of this technique (Leitner, 2017).

GL_{neg}7: Adjust illumination to the currently induced emotional state with vanishing light intensifying the negative emotions.

Although low-key lighting is appropriate for survival horror games, functional aspects must be fulfilled to make a game playable, otherwise players will be frustrated (El-Nasr, 2006; McEachern, 2010). For this, bluish light is used to softly illuminate the scenes. For instance, the developers of *Alan Wake* (RemedyEntertainment, 2010) combined night blue light with fog to create a cold and gloomy VE (McEachern, 2010). Alternatively, neutral, ergo greyish light can look cold and sad and therefore also add to the emotional challenge (Callahan, 1999; El-Nasr, 2006). Studies show that participants are less relaxed and pleased in a cool-lightened room compared to a room with warm lighting (Baron et al., 1992). While bluish lighting signals night and dawn, light is turning reddish in the morning and until dusk (Callahan, 1999). *Resident Evil 4* (Capcom, 2005) is using this technique to create a whole day and night circle in the game (Niedenthal, 2009).

GL_{neg}8: Implement *low-key lighting using soft blue, grey, or red colored light depending on the time of day.*
GL_{neg}9: Warm light *adds tension while cold light reduces pleasantness.*

In combination with GL_{neg}5, a brightly colored light can increase the negative emotional effect of the VE. A highly saturated warm, ergo reddish light inside a VE with a predominantly low, ergo bluish light temperature causes an imbalance in the overall light temperature of the scene. This strains the human eye because it has to compensate the red with cyan. The eye is fatigued and tension arises (Knez, 1995; El-Nasr, 2006). Beside that, red is associated with anger and aggression, fire, blood, and violence. Examples of red light usage are demonstrated in *F.E.A.R.: First Encounter Assault Recon* (VivendiGames, 2005) and *Doom 3* (idSoftware, 2004) (El-Nasr, 2006).

GL_{neg}10: Use unbalanced light temperatures.

Interactive lighting can be added to a static scene illumination at all stages of the game. Examples like *Amnesia: The Dark Descent* (FrictionalGames, 2010), *Silent Hill* (Konami, 1999), *Sweet Home* (Capcom, 1989) and *Alone in the Dark* (Infogrames, 1992) use player-directed light in the form of flashlights, lamps, or lanterns (El-Nasr, 2006; Niedenthal, 2007; Kirkland, 2010a; Jellicoe, 2010; Perron, 2012). These allow players to examine the environment and search for specific items. Also, interactive player light adds comfort to the gameplay and contrast to the scene. Contrast in turn adds tension and can produce scary plays of light and shadow with distorted silhouettes on floors and walls (Perron, 2005b; El-Nasr, 2006; Niedenthal, 2007).

Another form of dynamic light are stroboscopic effects. In fully dark scenes, strobe lights can be used to provide spatial orientation to the players. Since only short moments of full illumination are offered, players have to use static images to navigate through the environment under pressure. Besides games like *Doom 3* (idSoftware, 2004) of *Haunted House* (Atari, 1982), horror movies, e.g., *Shutter* (Pisanthanakun and Wongpoom, 2004) use this technique to induce fear in the players (El-Nasr, 2006; Perron, 2012; Leitner, 2017).

GL_{neg}11: Offer players interactive or dynamic light to navigate through the VE.

Finally, illumination is affected by weather influences. In the *Silent Hill* series (Konami, 1999), the use of fog, snow and rain is a filmic convention. What once was a compromise between technical possibilities and the game's look has now become an obligatory approach in survival horror games, e.g. *Alan Wake* (McEachern, 2010; RemedyEntertainment, 2010). Fog limits the players' view as well as their orientation and therefore evokes feelings of isolation (see GL_{neg}1) as well as uncertainty right from the beginning of the game (Murphy, 2008; McEachern, 2010; Rautzenberg, 2010; Kohlmaier and Mandelc, 2014; Steinmetz, 2018).

GL_{neg}12: Apply weather influences to limit the players' *view.*

5 GUIDELINES FOR POSITIVE ENVIRONMENT DESIGN

In the following, we present 12 guidelines for positive VEs derived from the literature particularly dealing with adventure games and positive real places. Positive VEs offer a welcoming atmosphere to the users (Wolf, 2011). When entering such an environment, users should start to feel relaxed and experience the desire to stay or to explore the scenery.

5.1 Design Themes

Similarly to survival horror games, adventure games and generally positive environments are based on everyday places, e.g., *urban* or *natural* areas. The VEs are open spaces that avoid restricting the player. This induces a feeling of freedom, e.g., the colossal environement of *The Legend of Zelda: Breath of the Wild* (Nintendo, 2017) gives "room to breathe" (Edge, 2017) allowing for free exploration. When designing urban terrains, the size of the area leads to different requirements. While large cities evoke a positive feeling when featuring large and wide roads, smaller towns benefit from small and curved streets (Botkin, 1997). However, it is also important to add various types of vegetation "to create an atmosphere of lushness, green and shade" (Botkin, 1997). Aside from adding man-made parks, this could be done by integrating informal greenspace, i.e., wild and spontaneous natural spots inside of urban spaces (Rupprecht et al., 2015). Informal greenspaces could be street and railway verge, vacant lots or watersides.

$GL_{pos}1$: Avoid restricting *a player's movement.*
$GL_{pos}2$: Adjust the general architecture of a settlement to its size.
$GL_{pos}3$: Combine urban environments with natural spots to create a positive atmosphere.

In contrast to urban spaces, natural environments mostly feature wild vegetation and few man-made elements, e.g. applied in *Lost Ember* (Mooneye Studios, 2019) or *A Short Hike* (Staats et al., 1997; Edge, 2017; Adamgryu, 2019; Schilling, 2020). MacKerron and Mourato (2013) showed in their study that people prefer to be in regions of 1) marine and coastal, 2) mountains, moors, heathland, 3) woodland, 4) semi-natural grassland (regions are ordered by their degree of positive impact). While players of *The Legend of Zelda: Breath of the Wild* (Nintendo, 2017) are pleased by these regions (Edge, 2017), research shows positive emotions of elderly people when virtually going on a virtual walk in coastal as well as forested regions (Graf et al., 2020). The desire for an access to nature already comes into play when considering workspaces or hospitals. Providing window views of nature leads to a reduced stress, better health status and higher job satisfaction (Ulrich, 2001). Similarly, plants, landscape views and homely elements like furniture inside hospital rooms lead to an improved well-being and recovery of patients (Dijkstra et al., 2006; Dinis et al., 2013). Research already shows that VEs featuring natural elements lead to reduced stress and anxiety as well as a better recovery (Yin et al., 2020).

$GL_{pos}4$: Immerse the player in natural environments
$GL_{pos}5$: In man-made environments, add greenery and natural objects

The existence of aesthetically pleasing and nonthreatening objects induces joy. For instance, a childlike appeal is not only applicable for characters but can also be transferred to the design of objects in an environment (Marcus, 2015; Nittono, 2016). Such an integration of rounded and face-like shapes generates a charming and delightful scene (Plass et al., 2014; Rossi et al., 2014; Nittono, 2016). Also, situations are appraised as pleasant by the absence of threats. The omission of virtual deaths, as done in *Monkey Island* (LucasArts, 1990–2010) and *Myst* (Cyan Worlds, 1993), preserves this pleasantness (Dillon, 2004).

$GL_{pos}6$: Use rounded shapes to create aesthetically pleasing VEs.
$GL_{pos}7$: Design VEs conveying *safety.*

5.2 Colors and Textures

Distinguishing between achromatic and chromatic colors, large differences in valence ratings occur, in which the latter are perceived more positive than black, grey, and white (Wilms and Oberfeld, 2018). Applying this finding to environments, more colorful rooms induce a higher positive emotional status (Küller et al., 2006). Although emotions associated to colors are highly individual depending on one's preferences and experiences (Kaya and Epps, 2004), general statements on emotions related to particular colors can be made. Overall, warm colors, as those used in the game *Moss* (Polyarc, 2018), elicit arousal and excitement but are also perceived as inviting (Bellizi and Hite, 1992; Um et al., 2012; Kennedy, 2014; Edge, 2018). Yellow induces joy and optimistic expectations (Valdez and Mehrabian, 1994; Kennedy, 2014). Regarding cold-toned colors, vibrant colors, i.e., blue and green, are categorized most pleasant (Valdez and Mehrabian, 1994), e.g., light shining through ice or water. While blue and green evoke relaxing feelings, green also creates comfort (Kaya and Epps, 2004; Kennedy, 2014; Roohi and Forouzandeh, 2019). However, independent of color shade, bright or pastel colors are associated with childlike appeal and thus induce joy (Marcus, 2015; Keating et al., 2017). Adventure games such as *King's Quest I: Quest for the Crown* (Sierra Entertainment, 1983) and *Arise: A Simple Story* (Piccolo Studio S.L., 2019) make great use of bright colors to generate charming environments (Karhulahti, 2011; Edge, 2020). Adding high saturation to the colors adds even more pleasure (Valdez and Mehrabian, 1994).

$GL_{pos}8$: Use bright or pastel colors to create aesthetically pleasing VEs
$GL_{pos}9$: Yellow induces joy, whereas green evokes *relaxation and comfort*

Not only colors, but also surface textures of objects in the environment can induce positive feelings. Soft and fuzzy objects create warm experiences (Callahan, 1999), and therefore support feelings of serenity and joy in VEs. Beside that, high graphical fidelity leads to greater enjoyment of a virtual scene (Gerling et al., 2013).

$GL_{pos}10$: Use soft textures with high fidelity.

5.3 Lighting

In line with the phylogenetical context discussed in $GL_{neg}7$, daytime VEs are appraised as significantly more pleasant than nighttime VEs are (Toet et al., 2009). Also, aside from snow, sunlight was the only weather phenomenon perceived as positive (MacKerron and Mourato, 2013). The computer game *Abzu* (Giant Squid, 2016) indicates the importance of adding

FIGURE 1 | Comparison of the neutral office (center) to the ultimate negative (left) and the ultimate positive (right) VEs.

sunlight to VEs (Edge, 2016). Here, the game's lighting engine gives the underwater world a magical appearance that positively affects a player's emotion to a great extent. Access to sunlight also is an important aspect of hospital rooms to improve recovery (Dijkstra et al., 2006; Dinis et al., 2013).

> GL$_{pos}$11: Create illuminated daytime *scenes by predominantly using sunlight.*

Sticking to highly illuminated environments, warm reddish light is appraised as pleasant which evokes positive feelings such as enthusiasm and joy (Baron et al., 1992; Knez, 1995; Knez and Niedenthal, 2008). In the context of gaming performance, players performed better and faster when exposed to pleasant warm-toned light compared to cool lighting (Knez and Niedenthal, 2008). Regarding low illuminated environments, cool-temperatured light is preferred (Knez, 1995). Using multiple light-tones in one scene, they can be balanced to avoid uncomfortable feelings in users, e.g. by value with a small high contrast area counterbalanced by a large area of low contrast. This avoids straining the human eye as intended with GL$_{neg}$10. Similarly, lighting color can be balanced by saturation (Callahan, 1999).

> GL$_{pos}$12: Use warm light tones *and balance them.*

6 IMPLEMENTATION

Our theoretical analysis resulted in the proposal of twelve positive as well as twelve negative design guidelines. Using either one of these guidelines to change a given VE should lead to the adjusted VE eliciting more positive or negative emotions, respectively. To validate our theoretical assumption, we exposed users to VEs fulfilling either a single or every guideline of a positive or negative design. We used an office environment as the basis. It represents a rather neutral everyday place allowing for a baseline measurement. In particular, we used a virtual replicate of one of our labs. The office is an empty room featuring two adjacent windows, white walls, beige floor, concrete ceiling, and a closed door as displayed in **Figure 1** center. We added virtual elements to this VE in accordance with our proposed guidelines as shown in **Figures 2**,**3**. Finally, besides focussing on individual guidelines, we also created a positive and negative version of the VE following all non-contradicting respective guidelines at once as displayed in **Figure 1** left and right. We refer to these two ultimate VEs as $GL_{pos}U$ and $GL_{neg}U$. **Table 1** provides a summary of our design decisions.

6.1 Special Design Considerations

The provision of freedom as proposed by GL$_{pos}$1 is problematic because it would require additional VEs besides the office environment. This, however, could confound the measurements as the design of the secondary VE potentially influences a user's emotions. This may already be the case as a user is able to peek through the open door of the office into an adjacent room. Hence, as the lab's door provides a metaphor for an unrestricted VE, we decided to assess the effectiveness of GL$_{pos}$1 by comparing the measurements of the restricted VE as proposed by GL$_{neg}$1 to the neutral version of the office.

To investigate the effects of GL$_{neg}$9, we designed two different versions of the VE that only differ in the hue of the light. This allows for an evaluation whether the warm light adds tension and cold light reduces pleasantness. Similarly, to comprehensively inspect GL$_{pos}$8, we created two versions of the VE. The first VE features bright colors whereas the second VE predominantly uses pastel colors.

6.2 Technology

We developed the demonstrator for the VE design guidelines with the game engine Unity (Unity, 2021) in version 2020.1.10f1. Targeting the HTC Vive Pro (HTC Corporation, 2011), we used the Steam VR plugin (Valve Coorperation, 2015) in version 1.20. This allowed users to navigate through the VEs and control the direction of the flashlight in GL$_{neg}$11.

7 STUDY I: VALIDATION USING 360° VIDEOS

We conducted our experiment during the COVID-19 pandemic. To protect the participants and the experimenters, we decided to split the validation process into two separate studies. Instead of taking place in VR and hence in our labs, Study I exposed the participants to 360° videos of the neutral and either the positive or negative emotion-inducing versions of the office VE. Subsequently, Study II aimed at the inspection of the guidelines in VR. Here, we reduced the selection of VEs to the neutral and ultimate versions, only. According to our guidelines, we expect lower joy and higher fear for negative VEs (H1) and

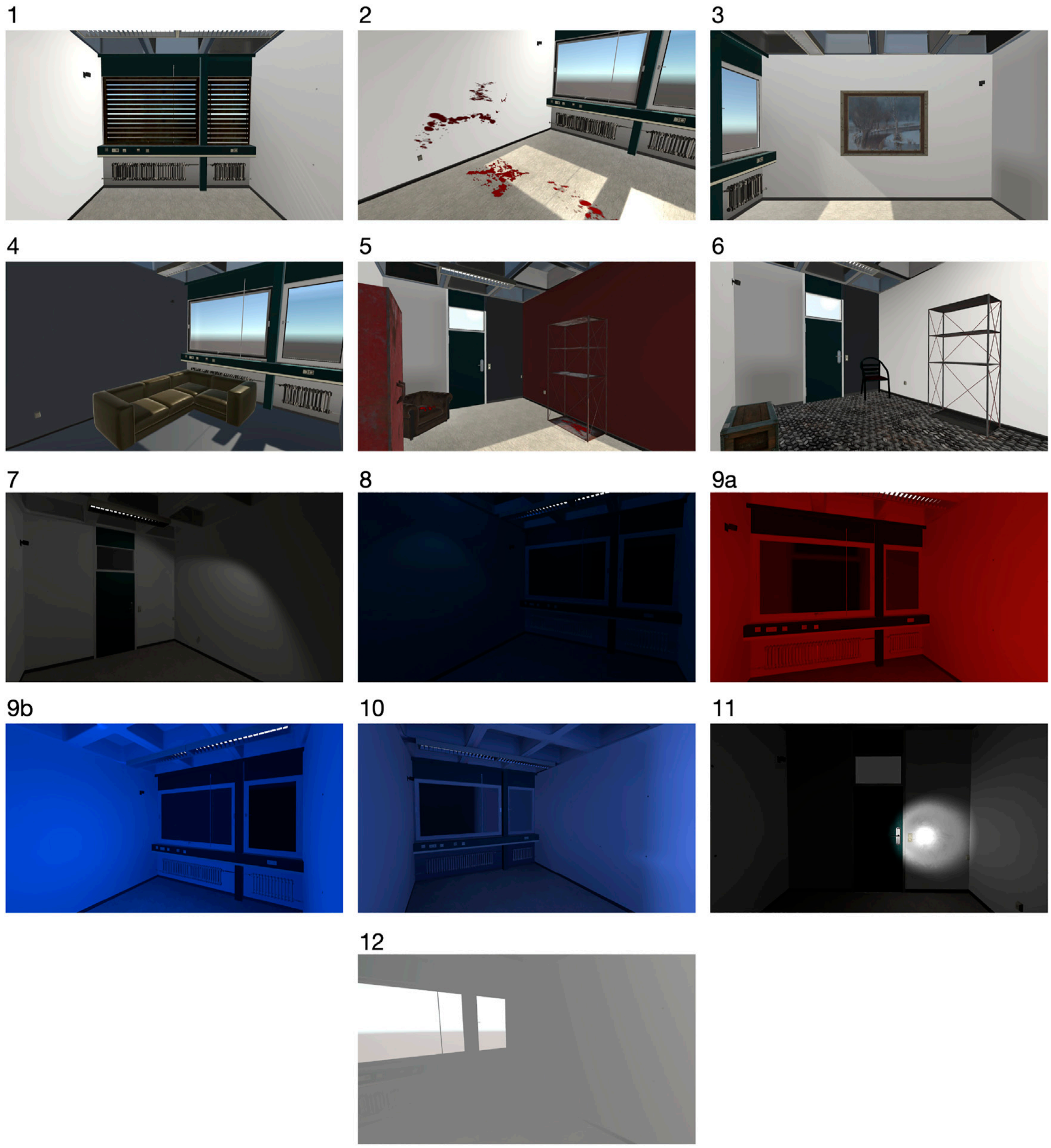

FIGURE 2 | Overview of our implementation of all negative design guidelines.

higher joy and lower fear for positive VEs (H2) since the targeted emotions are contradicting in terms of valence as discussed in **subsection 2.2**.

The institutional review board of Human-Computer Media at the University of Würzburg approved our ethics proposals (Study 1: #17052021, Study 2: #11082021) for these studies.

7.1 Method

To protect our participants and experimenters, we conducted Study I online using a self-hosted *LimeSurvey* (LimeSurvey GmbH, 2021) questionnaire system. We recorded a 1-min long 360° video of each VE and uploaded the videos to *YouTube*. Subsequently, we embedded the videos in our *LimeSurvey* questionnaire and displayed them alongside our question inventories assessing the perceived *Fear* and *Joy*. The 360° feature of *YouTube* enabled the participants to visually explore the VEs using either the gyrosensors of their smartphones in the case of an *Android* device or by changing the perspective by drag gestures using either the finger or mouse depending on the device. For optimal experience, we recommended using *Android* devices and viewing the videos in fullscreen mode. Fullscreen mode was also recommended for all other platforms. To prevent potentially distracted persons from missing the start of a video, participants

FIGURE 3 | Overview of our implementation of all positive design guidelines.

were able to start and stop videos using the *YouTube* controls. After watching a video, the participants were asked to report their perceived *Fear* and *Joy*. Thus, only post-measurements were collected. The evoked emotions were measured using two scales from the *PANAS-X* questionnaire (Watson and Clark, 1994; Röcke and Grühn, 2003, German version). While *Joy* was operationalized using the *Joviality* scale including eight items such as "happy" or "cheerful", *Fear* was measured with the respective *Fear* scale including six items such as "scared" or "jittery". All items were answered on a 5-point Likert scale (1 - "very slightly or not at all", 2 - "a little", 3 - "moderately", 4 - "quite a bit", 5 - "extremely"). No other emotions were assessed. Afterwards, participants continued to the next video.

After giving informed consent, the participants were randomly assigned to either the positive or the negative condition and watched the videos of the respective VEs in randomized order. Both conditions also included the neutral version as a baseline measurement. Therefore, participants in the positive VE condition watched 14 videos of the adapted VE, whereas participants in the negative VE condition watched 14 videos of the manipulated VE. At the end of the study, we also asked them for demographic information and the device used for watching the videos. Participation in the study took about 25–30 min. We

TABLE 1 | Overview of the changes to the office environment in accordance to the proposed guidelines.

GL	Virtual Element
Negative	
1	Rusted bars block the windows and the door is blocked with a brick wall
2	The floor and the walls feature blood stains and puddles of blood
3	A frame hangs on one of the wall and randomly changes between two different paintings
4	The walls as well as the floor are colored in dark grey and a dark brown leather couch was added
5	Besides a dark leather armchair with blood stains, the room features a rusty rack with blood stains as well as a rusty and red cabinet. Also, one wall is colored in dark red
6	The room features furniture made out of metal, i.e., a chair, a wooden box with metal elements as well as a metal rack, and a rusty metal floor
7	The skybox is black and the only light inside the VE is a grey spotlight
8	The skybox is black and the light provided in the VE has a soft blue hue
9	The first version (a) of the VE provides red light whereas the second version (b) provides blue light. The skybox is black
10	The skybox is black and the lights vary between different shades of blue
11	The skybox is black and the only light in the VE comes from a flashlight controlled by the user
12	The room features dense fog drastically limiting the view distance
U	The room has a dark red and black wall. The door as well as the windows are blocked and fog reduces the viewing distance. The walls, the metal floor and leather armchair show bloodstains. A metal rack stands next to the blocked exit and a frame on the black wall randomly shows different pictures. The room is illuminated by dark red light
Positive	
1	Neutral office VE compared to $GL_{neg}1$
2	A large city environment with big houses and large roads is visible from the window
3	A city environment featuring trees and other greenery is visible from the window
4	The office features plants, trees, and flowers. The skybox shows a natural environment
5	The office features a wooden shelf as well as decorative flowers and is embedded in a green and open city environment
6	The room features rounded furniture like a lamp, sofa, clock, table and colored circles on one of the walls
7	A comfortable bed with soft pillows inside of the room indicates a very safe place
8	The first version (a) of the VE provides a brown wall, green sofa, purple carpet, a white table with a red-blossomed flower, and a black and white picture inside a green frame. The second version (b) features red as well as blue pastel-colored walls and bright furniture
9	The office features a yellow wall, green sofa, brown carpet, a red-blossomed plant on a white table, a green plant, and a black and white picture inside a green frame
10	The VE features a grey sofa with a green pillow, grey armchair, and grey carpet. The windows feature green curtains. All elements use a fabric texture
11	The VE features light grey sofa as well as carpet, low orange light and a sunset skybox
12	The VE features light grey sofa as well as carpet and is illuminated by warm orange light
U	The VE features a red pastel-colored wall with colorful circles and a black and white picture inside a yellow frame. The opposite wall is colored in bright yellow. A nature-based skybox is visible behind the windows which feature green curtains. The room also contains a light grey sofa with a green pillow, a light grey carpet, white shelf as well as lamp, and several green plants. The room is illuminated by warm orange light

recruited our participants from students enrolled at the University of Würzburg using an online-recruitment system. The participants received credits mandatory for obtaining their final degree and were informed about the study.

7.2 Participants

In total, 85 persons participated in the study. Their mean age was 22.46 years (SD = 4.78, ranging from 19 to 61 years). While 29 participants self-indicated as male (age: M = 23.76, SD = 7.45, ranging from 20 to 61 years), 56 of them self-reported being female (age: M = 21.79, SD = 2.47, ranging from 19 to 34 years). Being randomly assigned to one of the two conditions, 46 participants (16 male, 30 female; age: M = 23.17, SD = 6.24, ranging from 20 to 61 years) received the negative VEs, whereas 39 participants (13 male, 26 female; age: M = 21.61, SD = 1.76, ranging from 19 to 27 years) saw the positive VEs. Male and female participants differed significantly regarding age ($p_{Shapiro} < 0.001$, $p_{Levene} = 0.155$, $U = 1087.00$, $p = 0.01$, $r_s = 0.34$). However, age did not significantly differ between the conditions ($p_{Shapiro-Wilk} < 0.01$, $p_{Levene} = 0.103$, $U = 1048.00$, $p = 0.176$). Similarly, no significant relationship of gender and condition was indicated (χ^2 (1) = 0.02, p = 0.888, ϕ = 0.02).

Most of the participants (n = 59) completed the study on an *Android* device as suggested, 22 persons worked on a laptop or desktop PC, and only four people used an *Apple* device which restricted the usability of the 360° videos. Calculating t-tests for comparison, no significant differences between *Apple* users (n = 3) and other participants were detected in terms of emotions induced by the negative VEs (ps > 0.05). Only one participant in the positive VE condition used an *Apple* device thus no comparison could be calculated. However, we expect a similar lack of effects as within the positive VE condition. Therefore, *Apple* users were not excluded from the analysis.

7.3 Results

To evaluate the effectiveness of emotion induction using our guidelines derived from literature and games pairwise

TABLE 2 | Study I: Descriptive statistics and test values.

	Fear						Joy					
	M	*SD*	p_{sw}[a]	Statistic[b]	*p*	Effect Size[c]	*M*	*SD*	p_{sw}[a]	Statistic[b]	*p*	Effect Size[c]
Neutral NC	1.49	0.61	–	–	–	–	1.56	0.62	–	–	–	–
GLneg1	1.94	0.83	0.074	–5.28	< 0.001***	0.778	1.38	0.65	< 0.001***	699.00	< 0.001***	0.624
GLneg2	3.04	1.26	0.154	–9.74	< 0.001***	1.436	1.26	0.40	< 0.001***	733.50	< 0.001***	0.625
GLneg3	1.66	0.81	0.113	–1.16	0.125	0.171	1.76	0.79	0.002**	342.00	0.944	0.277
GLneg4	1.35	0.53	0.022*	326.50	0.881	0.237	1.66	0.70	0.003**	357.00	0.920	0.245
GLneg5	2.83	1.15	0.249	–8.40	< 0.001***	1.239	1.25	0.43	< 0.001***	735.00	< 0.001***	0.707
GLneg6	1.39	0.56	0.145	0.81	0.788	0.119	1.67	0.87	0.011*	419.00	0.745	0.114
GLneg7	2.67	1.17	0.619	–7.19	< 0.001***	1.061	1.16	0.25	< 0.001***	780.00	< 0.001***	0.812
GLneg8	2.80	1.25	0.705	–7.27	< 0.001***	1.072	1.27	0.41	0.002**	699.00	< 0.001***	0.624
GLneg9a	2.37	1.05	0.168	–6.08	< 0.001***	0.896	1.37	0.50	< 0.001***	608.00	0.011*	0.412
GLneg9b	1.63	0.74	0.133	–1.15	0.128	0.170	1.48	0.60	0.003**	484.00	0.162	0.180
GLneg10	2.00	1.02	0.095	–3.60	< 0.001***	0.530	1.45	0.67	< 0.001***	606.50	0.027*	0.343
GLneg11	3.47	1.27	0.212	–11.36	< 0.001***	1.675	1.37	0.61	< 0.001***	699.50	< 0.001***	0.549
GLneg12	1.67	0.83	0.047*	260.00	0.186	0.184	1.45	0.74	0.009**	539.50	0.080	0.253
GLnegU	3.07	1.24	0.334	–8.53	< 0.001***	1.257	1.34	0.51	0.001**	662.50	0.011*	0.401
Neutral PC	1.59	0.74	–	–	–	–	1.78	0.81	–	–	–	–
GLpos2	1.65	0.55	< 0.001***	141.00	0.923	0.305	1.69	0.73	0.001**	245.00	0.728	0.126
GLpos3	1.54	0.52	< 0.001***	167.50	0.452	0.031	1.87	0.90	0.006**	152.50	0.127	0.249
GLpos4	1.33	0.60	0.013*	302.00	0.012*	0.488	3.16	1.04	0.602	–8.07	< 0.001***	1.083
GLpos5	1.15	0.34	< 0.001***	328.00	< 0.001***	0.869	2.92	1.04	0.064	–6.76	< 0.001***	1.083
GLpos6	1.65	0.66	0.119	–0.58	0.719	0.094	2.06	0.83	0.009**	148.00	0.015*	0.439
GLpos7	1.57	0.65	< 0.001***	163.50	0.495	0.006	2.04	0.82	0.006**	112.50	0.020*	0.446
GLpos8a	1.33	0.52	< 0.001***	172.00	0.006**	0.638	1.99	0.70	0.434	–1.89	0.033*	0.302
GLpos8b	1.39	0.48	< 0.001***	268.500	0.069	0.323	2.07	0.79	0.147	–1.80	0.040*	0.288
GLpos9	1.27	0.42	< 0.001***	293.00	0.006**	0.550	2.56	0.91	< 0.001***	54.00	< 0.001***	0.829
GLpos10	1.68	0.76	0.177	–0.822	0.792	0.132	1.80	0.69	0.053	–0.12	0.451	0.020
GLpos11	2.04	1.00	0.047*	123.00	0.996	0.534	2.30	0.93	0.117	–3.06	0.002**	0.490
GLpos12	2.01	0.83	0.054	–2.94	0.997	0.471	1.56	0.63	0.027*	255.00	0.945	0.349
GLposU	1.45	0.61	0.107	0.88	0.192	0.141	2.68	1.08	0.376	–5.267	< 0.001***	0.843

Note. Calculated values from 1 to 5. One-tailed testing.
Neutral *NC = neutral environment in the negative condition. Neutral PC = neutral environment in the positive condition.* p_{sw} = p *from Shapiro-Wilk tests.*
[a]Based *on differences between neutral and guideline-adjusted room.*
[b]Student *distribution except for deviation of normality, then Wilcoxon was used.*
[c]For *the Student t-test, effect size is given by Cohen's* d*. For the Wilcoxon test, effect size is given by the matched rank biserial correlation.*
*p < *0.05.* **p < *0.01.* ***p < *0.001.*

comparisons between rooms designed following the guidelines and the neutral environment were calculated for *Fear* and *Joy*. The analyses were calculated using JASP (JASP Team, 2021) version 0.16 with a significance level of 0.05. First, assumptions were checked using Shapiro-Wilk tests. Depending on the normality of group differences, pairwise comparisons were calculated either using Student's *t*-test or Wilcoxon's rank-sum test for paired samples. Descriptive data and test results are displayed in **Table 2**.

Results concerning guidelines for negative emotion induction (H1) indicated the effectiveness of $GL_{neg}1$, $GL_{neg}2$, $GL_{neg}5$, $GL_{neg}7$, $GL_{neg}8$, $GL_{neg}10$, and $GL_{neg}11$ for increasing *Fear* and decreasing *Joy* due to significant differences in values from the neutral room. $GL_{neg}9$ was only partially confirmed. While for room $GL_{neg}9a$, in which red light was applied, a significant decrease of *Joy* and increase of *Fear* was indicated, $GL_{neg}9b$, referring to the usage of cold light, did not induce the targeted emotion. No significant differences between guideline-adjusted room and neutral room were indicated for $GL_{neg}3$, $GL_{neg}4$, $GL_{neg}6$, and $GL_{neg}12$, neither regarding *Fear* nor *Joy*. However, the combination of our guidelines in room $GL_{neg}U$ again revealed the effectiveness of our derived guidelines resulting in a significant difference of *Fear* and *Joy* values compared to the neutral room.

Concerning our guidelines for positive emotion induction (H2), results confirmed the effectiveness of $GL_{pos}4$, $GL_{pos}5$, $GL_{pos}8a$, and $GL_{pos}9$ for significantly increasing *Joy* and decreasing *Fear*. Furthermore, *Joy* was significantly increased when visually inspecting the rooms designed following the guidelines $GL_{pos}6$, $GL_{pos}7$, $GL_{pos}8b$, and $GL_{pos}11$ compared to the neutral environment. However, *Fear* values for these rooms were not significantly different compared to the neutral room. Similarly, results indicated the effectiveness of combining our guidelines for positive emotion induction due to a significant increase of *Joy* $GL_{pos}U$, but there was no significant decrease of *Fear* compared to the neutral environment.

7.4 Discussion

In Study I, we inspected the guidelines using non-interactive 360° videos embedded in an online survey. The majority of the participants experienced the VEs on an *Android* device and hence benefited from an automatic change of perspective when moving the device. While this might have resulted in the best experience, the small size of the displays most likely did not achieve a surrounding experience. Similarly, despite a larger display size, users of laptops or desktop PC might not have experienced a surrounding illusion. A surrounding illusion is a fundamental requirement of high immersive systems (Slater and Wilbur, 1997). Despite this approach of low immersion and low interactivity, the participants already reported significant effects with respect to fear and joy when inspecting the individual VEs, supporting both H1 and H2. This result is notable. It indicates that our derived guidelines not only cause the desired effects, but also work in low immersion settings providing only a small visual angle on the stimulus. A higher visual angle on a stimuli can enhance the emotional response (Gall and Latoschik, 2020). Hence, by providing a higher immersion, e.g., using VR, these effects might be even enhanced and potentially validate further guidelines. Since the neutral VE significantly differed from $GL_{neg}1$, we assume that $GL_{pos}1$ is effective as it avoids restricting a user.

There are, however, several guidelines that did not evoke the desired effects. The lack of an effect for $GL_{neg}3$ is explainable by the overall prominence and size of the stimulus inside of the VE. The randomly changing picture in the frame might not have been noticeable enough for a 360° video inspection, especially as no element drew the attention of the participants to this asset. Experiencing this in a more surrounding presentation or with a stronger prominence in the VE might already lead to the desired effect. Our implementation of $GL_{neg}4$ might have led to an ambiguous perception of the VE. While dark colors generally might lead to more negative emotions, the choice of the sofa and the grey walls could also be seen as a modern interior design. In this way, participants may not necessarily regard the VE as a negative environment. The lack of an effect for GL_{neg6} could be explained in a similar way. While trying to design a filthy environment, the elements used potentially looked too clean. In this way, the room might again have elicited a modern design concept. Hence, it is important to inspect $GL_{neg}4$ and GL_{neg6} again using different assets. The measurements of $GL_{neg}9b$ are potentially explainable in two ways. It is either possible that the 360° video did not evoke a strong enough atmosphere. A higher level of immersion might remedy this effect. The measurements of the other light-related guidelines contradict this assumption. Another explanation lies in the effect of the cold light. It might have reduced the pleasantness but did not result in the perception of fear which could not be detected by our measures. Finally, the lack of an effect caused by $GL_{neg}12$ might again be due to the 360° video. The participants were not surrounded by the fog which creates a completely different atmosphere affecting the experienced emotions. Using a high immersion setup like VR could result in stronger effects of this guideline.

The perception of $GL_{pos}2$ might be influenced by the participants' static position when watching the 360° video. For clearly taking in the scenery, participants would have needed to look out of the window. Hence, the participants only partly saw the large open street environment added to the office VE. The lack of an effect for $GL_{pos}10$ can be attributed to the same causes. It is likely that the soft textures were not apparent enough when watching the 360° video. It did not allow for an upclose inspection of the assets. Finally, the lack of a statistical difference for $GL_{pos}12$ might be due to a rather high similarity to the neutral room. While the light was more balanced with the environment, it might not have been noticably different compared to the neutral VE.

The guidelines $GL_{pos}6$, $GL_{pos}7$, $GL_{pos}8b$, $GL_{pos}11$, and $GL_{pos}U$ were effective with respect to increasing the experienced joy. However, they did not significantly lower the fear values. In addition, fear values were rather low overall. This could be an effect of the low immersion of embedded videos. By providing a higher immersion and hence a higher visual angle on the stimulus, the emotional effects and hence the differences are intensified. Alternatively, it is possible that negative VE design mainly manipulates perceived fear but not joy, and vice-versa positive VE design mainly targets perceived joy but not fear. This assumption is supported by a recent study investigating the effects of emotions on the formation of presence (Jicol et al., 2021). The study showed that only the predominant emotion in a VE affects presence. The happiness levels in the happy VE predicted presence while the fear levels did not. On the flip-side, the fear levels predicted presence in a fear-inducing VE. This observation of Jicol et al. (2021) is explainable by our results. They indicate that the predominant emotional design mainly affects the targeted emotion and hence only this emotion can have an effect on the formation of presence.

Overall, while successfully validating several of our guidelines, Study I was limited due to the presentation device of the stimulus material used. Instead of providing an interactive and highly immersive experience by using devices offering high technical immersion, the participants only watched 360° videos on flat displays. This led to the validation of powerful guidelines but might not have unmasked effects of less noticeable guidelines. In addition, due to the nature of an online study, we could not control the conditions in terms of surroundings when watching the videos. Participants were also able to watch videos multiple times, stop earlier, or skip them. This potentially affected our measurements. Therefore, future work shall inspect all guidelines again in a more controlled setting, ideally using a high immersion setup.

Despite these limitations, our results indicate that the guidelines listed in **Table 4** cause the desired effects.

8 STUDY II: VALIDATION IN VIRTUAL REALITY

Although only using 360° videos, Study I already revealed several significant effects caused by the individual guidelines and ultimate versions. Since immersion increases presence and hence the perceived realness of the simulation, inspecting the guidelines in VR could lead to even stronger effects. To increase the COVID safety of our experiment, we limited the selection of the VEs to the neutral and ultimate versions, only. Again, we

TABLE 3 | Study II: Descriptive statistics per condition.

	Fear		Joy	
	M	*SD*	*M*	*SD*
Neutral VE	1.37	0.44	1.92	1.09
Negative VE	1.96	0.81	1.71	0.86
Positive VE	1.10	0.23	3.15	0.97

postulate higher fear and lower joy values for negative VEs (H1) and increased values of joy but lower values of fear for positive VEs (H2).

8.1 Method

Following the same approach as in Study I, we investigated emotions induced by ultimate positive or negative VEs by collecting post-measures after exploring each VE. This time using a within-subjects study design, we exposed the participants to one of the three VEs before assessing their perceived *Fear* and *Joy* for the respective VE. We used the same two subscales of the *PANAS-X* (Watson and Clark, 1994; Röcke and Grühn, 2003) as in Study I. Again, no other emotions were assessed. In contrast to Study I, our participants experienced the VEs in VR using the *HTC Vive Pro*. Using room-scale VR, they were allowed to explore each VE for 2 min. We conducted the experiment in the real laboratory we remodeled as our office. After being welcomed, the participants gave informed consent to participate. Subsequently, they experienced the neutral VE first, followed by the emotion-inducing VEs in randomized order and reported their perceived fear and joy. Finally, we asked for demographic information before thanking them for their participation. Participation in the study took about 25–30 min. We recruited our participants from the students enrolled at the University of Würzburg using an online-recruitment system. The participants received credits mandatory for obtaining their final degree and were informed about the study.

The study took place during the COVID-19 pandemic. To ensure for protection and hygiene, we took the following precautions. 1) Each participant was required to disinfect their hands before and after the study, constantly wear a mask, and report whether they stayed in a risk area or show signs of an illness. 2) The experimenter was required to disinfect their hands, constantly wear a mask, and daily report whether they show signs of an illness. 3) The experimenter and the participant were required to keep at least a distance of 1.5 m 4) All surfaces touched and devices used, such as the HMD and keyboard, were to be cleaned with a disinfectant after each experimental trial. 5) The laboratory had to be ventilated for at least 15 min after each experimental trial.

8.2 Participants

Overall, 41 test persons took part in the study. Their age was 25.51 years on average (SD = 11.86, ranging from 18 to 72 years). Fourteen of them self-reported being male, whereas 27 self-indicated as female. Females' mean age was 24.74 years (SD = 11.82, ranging from 18 to 72 years), while the mean age calculated for male participants was 27.00 years (SD = 12.25, ranging from 19 to 68 years). Male and female participants did not differ significantly concerning age ($p_{Shapiro} <$ 0.001, $p_{Levene} = 0.957$, $U = 125.00$, $p = 0.078$).

8.3 Results

The analyses were carried out using SPSS version 28 and a significance level of 0.05. Due to the violation of normal distribution as indicated by a Shapiro Wilk test for both fear and joy (ps < 0.01) non-parametric tests were calculated. Descriptive data are displayed in **Table 3**.

To indicate which of the environments - negative, positive or neutral - most strongly evoked fear, a Friedman test was calculated. Results show a significant difference of fear induction between the three environments (χ^2 (2) = 60.86, $p < 0.001$). For pairwise comparison, alpha-adjusted Dunn-Bonferroni tests were carried out. Participants reported higher values of fear in the negative compared to the positive VE (z = -0.92, $p < 0.001$, r = 0.24) and the neutral VE (z = 1.54, $p < 0.001$, r = 0.14) as well as for neutral VE compared to the positive VE (z = 0.62, p = 0.015, r = 0.10).

An analogue Friedman test was calculated to investigate which environment most effectively induced joy. Our results indicate a significant difference of joy values between the three environments (χ^2 (2) = 50.51, $p < 0.001$). Again, alpha-adjusted Dunn-Bonferroni tests were used for pairwise comparisons showing higher values of joy for the positive compared to the negative VE ($z = -1.31$, $p < 0.001$, $r = 0.20$) as well as the neutral VE ($z = -1.33$, $p < 0.001$, $r = 0.21$). However, no significant difference was indicated between neutral and negative VE ($z = -1.33$, $p = 1.000$, $r = 0.21$).

8.4 Discussion

In Study II, we compared the neutral office environment to the ultimate negative and positive VEs. The participants experienced the VEs in high immersion room-scale VR. This not only resulted in a surrounding experience, but also in the possibility of walking through the VEs and inspecting objects up close. Our measurements support the effects according to our derived guidelines. H1 is accepted while H2 can only be partially accepted due to missing differences in terms of evoked joy between the negative and neutral VE. Nevertheless, our results validate our guidelines for creating VEs either eliciting positive or negative emotions. This outcome can be of importance for researchers and developers. Using our guidelines, VEs can be designed that evoke certain emotions and avoid unwanted effects, e.g., in the case of applications for therapy or training.

The negative VE induced the highest fear which was significant compared to the other two VEs. In contrast to our first study, the $GL_{pos}U$ differed significantly from the neutral VE with regard to the perceived fear. This supports our assumption in the discussion of Study I that a higher immersion might increase the susceptibility to the effects of emotional VE design. This aligns with previous research showing an increased emotional response to audiovisual stimuli when a higher visual angle is provided (Gall and Latoschik, 2020).

The negative VE also yielded the lowest joy rating while the positive VE received the highest ratings. The differences between the VEs were significant except for the comparison between the $GL_{neg}U$ and the neutral VE. This would follow our explanation

TABLE 4 | Overview of the guidelines. Guidelines evoking negative emotional states are aligned with the respective contradicting positive guideline. The asterisk denotes guidelines supported by our studies.

	GL	Positive	GL	Negative
Design theme				
	1*	Avoid restricting a player's movement	1*	Highlight boundaries of the VE to cause feelings of confinement
	2	Adjust the general architecture of a settlement to its size		
	3*	Combine urban environments with natural spots to create a positive atmosphere		
	4*	Immerse the player in natural environments	3	Use motion and alternation where it is not suspected
	5*	In man-made environments, add greenery and natural objects		
	6*	Use rounded shapes to create aesthetically pleasing VEs		
	7*	Design VEs conveying safety	2*	Use signs of passed violent acts to evoke fear
Colors & Textures				
	8*	Use bright or pastel colors to create aesthetically pleasing VEs	4	Predominantly use dark colors in the environment
	9*	Yellow induces joy, whereas green evokes relaxation and comfort	5*	Reddish highlights should be added
	10	Use soft textures with high fidelity	6	Apply smooth textures together with rust and filth
Lighting				
	11*	Create illuminated daytime scenes by predominantly using sunlight	8*	Implement low-key lighting using soft blue, grey, or red colored light depending on the time of day
	12	Use warm light tones and balance them	10	Use unbalanced light temperatures
			7*	Adjust illumination to the currently induced emotional state with vanishing light intensifying the negative emotions
			9*	Warm light adds tension while cold light reduces pleasantness
			11*	Offer players interactive or dynamic light to navigate through the VE.
			12	Apply weather influences to limit the players' view

discussed in **Subsection 7.4**. Positive and negative VE design affects the predominantly targeted emotion but causes only a limited effect on the other emotion. Another explanation for the smaller effect of $GL_{neg}U$ could be the occurrence of a detachment evoked by fear scenarios (Jicol et al., 2021). Despite experiencing levels of fear, the participants might have simultaneously enjoyed that thrilling feeling. Such an enjoyment of thrill seeking could have influenced the overall experience of $GL_{neg}U$ making it fear-inducing but also exciting at the same time.

A potential limitation of Study II lies in the focus on the ultimate VEs instead of a repeated inspection of all individual guidelines. It is possible that some guidelines interacted with each other and hence amplified the effects. While this is a potential limitation, the results of Study I do not indicate such an effect.

Future work shall investigate the effectiveness of our individual guidelines in VR and evaluate our assumption explaining the studies' results.

9 OVERALL DISCUSSION

Our two studies indicate that joyful as well as frightening emotions can be evoked in users when applying the respective guidelines on design themes, colors and textures, and lighting. Many of the derived and validated guidelines contradict each other for induction of positive and negative feelings as shown in **Table 4**. While limited spaces evoke fear, wide-ranged natural areas elicit joy. Similarly, dark and achromatic colors should dominate frightening VEs, whereas bright and high saturated colors are able to induce joy. Last, high-key illumination is perceived joyful, whilst barely lit scenes trigger fear caused by a lack of visual information. Overall, the contradicting guidelines indicate the extremes of the design space. By creating blends between two extremes, eerie VEs of various degrees may be created which should be tested in future studies.

Although many of our proposed guidelines originate from game design, our results of the studies suggest that they are applicable for any situation. In both studies, we did not embed the VEs in a computer game context but purely exposed the participants to these environments. In this way, the participants only explored the VEs without any influence of task performance or storytelling. Since this approach caused the desired results in most cases, we thus assume that our guidelines are effective for any activity, e.g., learning, therapy, gameplay, or research such as user studies. Depending on the desired use-case, our guidelines can provide recommendations for elements that should and should not be included. However, we only tested one implementation of each guideline using the same virtual environment as a basis. This could be a potential limitation as different environment types might alter the perception of the individual guidelines. It is important to repetitively assess the effects of the proposed guidelines to approach a full validation.

10 CONCLUSION

In this article, we conducted an inspection of theoretical and empirical work as well as computer games, i.e., games of the adventure and horror genre, to define the emotional *design space* of VEs. The combined approach further led to an extraction of relevant design principles. Based on our findings, we derived general design guidelines for VEs either inducing joyful or frightening emotions in users.

In two user studies, we inspected the effectiveness of the proposed guidelines using VEs demonstrating each guideline. The first user study exposed users to either all negative or positive VEs as well as an ultimate version using 360° videos. This study validated the majority of the guidelines despite potentially being limited by static 360° videos. Subsequently, we conducted a second study comparing the ultimate VEs to a neutral VE in VR. In this study, the participants could explore the three environments on their own. The results reveal significantly higher fear scores for the negative VE and significantly higher joy scores for the positive VE compared to the neutral VE. This validates our proposed guidelines, but also suggests that they can be effective for any use-case. The presented collection of guidelines can be of high importance for researchers who want to create specific stimuli, for developers of video games, and for developers of applications of therapy and rehabilitation to create especially joyful and engaging environments.

Future work shall inspect all individual guidelines in high immersion VR as this might unmask all emotional effects of each guideline. A second research direction is the investigation of whether positive and negative VEs primarily affect the respective emotion or also control the other emotion.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation, to any qualified researcher.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the Human-Computer-Media Institute, University of Würzburg. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SS and SO contributed equally to the conception of this research. SS and SO designed the user studies. SS analyzed the data. SS and SO wrote the manuscript. SS, SO, ML, BL, and SM contributed to the final version of the manuscript.

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