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Resto Quest – A Serious Game on the Restorative Effects of Immersive Virtual Environments

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Abstract. Mostly, restorative environments, like parks and forests, are only thought of in the real world. However, one can wonder whether their restorative effects translate to a virtual world; and whether the environment itself makes any difference. In order to assess the possible translation of restorative properties from the real world to a virtual setting, we developed *Resto Quest*, a single-player, first-person exploration game, designed to investigate the possible restorative effects of both natural and urban virtual environments. *Resto Quest* is playable on a normal personal computer, and its main game play loop consists of exploring the environment, locating in it a task to accomplish, and completing a simple minigame. After completion of each minigame, a positive change in the scenery takes place. Evaluation of *Resto Quest* has shown that players found its game mechanics relaxing, and that the minigames offer balanced difficulty between two interchangeable environments.

Keywords: Restorative Environments · Attention Restoration Theory · Serious Games · Virtual environments

1 Introduction

Mental stress and fatigue can stem from a variety of sources, and most people are affected by some kind of mental stress or fatigue throughout the day. One can reduce stress by participating in certain activities, such as yoga [30], or placing oneself in a restorative environment. Restorative environments are studied within the research area of environmental psychology. Environments are considered restorative when they provide positive influence on cognitive capacities, experience of stress and mental fatigue, and positive affect of an individual [1,9]. While restorative environments can vary for different individuals, a majority indicates that natural environments are considered restorative [14,27,35].

Travelling to natural environments is not always an option for everyone, due to such factors as money, time, or the lack of knowledge. A possible solution could

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be to develop a virtual environment that mimics the corresponding real world natural environment. Such a virtual environment, e.g. in the form of a digital serious game, could prove beneficial, as it would make restorative environments more accessible to the public at large. Moreover, research has shown that gaming can de-stress individuals [22]. However, while a serious game can provide a safe setting for individuals to play in, it is also possible that its natural elements get inadequately translated from reality into the virtual domain [8]. A good simulation of an environment should convey to players the notion that they 'are taken away' from their current surroundings. Findings from research suggest that natural environments are usually experienced as restorative [11]. In contrast, there has not been much research done on the possible restorative effects of urban environments.

A considerable part of the current studies on restorative environments employ virtual exposure methods such as pictures or videos. Using a video-game as a virtual exposure method offers a different research opportunity. Video-games require from an individual inherently more engagement with the environment than a photo or video. This engagement with the environment increases the opportunity of a restorative experience, as is shown in studies by Duvall [5] and Pasanen et al. [21]. The application opportunities for restorative video-games could also be more prevalent, since it is a popular pastime for large groups in the population. Although there have been some virtual restoring examples proposed [2–4,15,24,38,40], to the best of our knowledge, there has been no *serious game* proposed to research the restorative properties of interactive virtual environments, including the comparison of restorative differences of disparate virtual environments.

In this paper, we use exploration to assess how restorative properties can be well translated from the real world into different virtual environments. For this, we designed and developed the serious game *Resto Quest*, aimed at supporting research on the restorative effects of such virtual environments. For psychological comparative research, game environments can be considered balanced when they are fully similar on key characteristics, and the same game mechanics can be equally applied to either of them. We can then say that these environments are interchangeable.

In its current form, *Resto Quest* offers comparable gameplay within two very different virtual environments: one is a natural world, and the other an urban world. In this paper, we describe the main game design aspects of *Resto Quest*, its basic game mechanics, as well as our comparative evaluation of its virtual environments. Actual use of *Resto Quest* in a clinical setting is currently underway, and will be reported elsewhere.

2 Related Work

Prior research has been done in the fields of restorative environments, psychology regarding human attention, and use of virtual worlds. This research supports the underlying design choices of *Resto Quest*.

2.1 Theories on Attention Restoration

A person's attention capacity is important because many daily activities require sustained cognitive demand. Such activities are stressful and will eventually lead to a decrease in performance. Stress can also be a triggering or aggravating factor for many diseases and pathological conditions [39].

In cognitive psychology, focusing on a task that requires effort is called *voluntary attention*. One cause of attention fatigue is the activity of focusing on a specific task or stimulus with minimal motivational draw, while suppressing distractions which seem more interesting [12]. This fatigue causes a person's actions to be delayed, perception to be impaired, plan making abilities to decrease and irritability to increase.

In contrast to voluntary attention, which requires effort, there is *involuntary attention*, defined as attention that is not elicited by conscious decisions, but by certain outside events that are either intriguing or important stimuli. Fan et al. [6] clearly distinguish between voluntary attention and involuntary attention. More importantly, it has been shown that when involuntary attention is triggered, voluntary attention capacities can recover [12,31].

2.2 Natural Environment Theories

Involuntary attention is attention captured by intriguing stimuli, as e.g. those elements in natural environments, which are fascinating to humans. There are multiple theories that imply that exposure to nature enhances psychological well-being. For this research, three theories were considered: the Biophilia hypothesis, Attention Restoration Theory (ART), and Stress Reduction Theory (SRT).

The Biophilia hypothesis [13] states that humans have an innate need to affiliate with other living things, because of the humans' close relation with nature throughout evolution. Lin et al. [16] explores this and shows that even trees that are unconsciously noticed in an urban environment may restore the individual.

The Attention Restoration Theory [11] claims that urban living taxes attentional capacities and leads to mental fatigue. In contrast to urban environments, natural environments are suggested to contain elements that are inherently fascinating. ART states that for an environment to be restorative, e.g. natural environments, it needs four attributes: (1) it has to encourage involuntary attention. (2) the person experiencing the environment must have a feeling of *being away*. (3) the environment must be adequately rich to make up a whole other world. (4) the environment must meet the characteristics and the goals of the person.

The Stress Reduction Theory [18] states that exposure to natural environments with water, vegetation, and other elements that accompanied human evolution produce a response characterised as decreased physiological arousal, decreased negative affect, and increased positive affect.

All three theories highlight the impact of the natural environment on the human well-being, but research has also been done on urban environments. Ulrich et al. [33] and Reetz et al. [23] compare psychological effects of urban environments against that of natural environments, in which nature consistently

performed better than the urban scenes. Ulrich et al. [33] additionally show that the complexity of an environment, the number of perceived elements and their dissimilarity, is less important than the content.

2.3 Restoration Through Leisure Activities

Not all activities are equivalent in restorative properties. Rupp et al. [25] show that playing games and reading are both more restorative than doing nothing. They distinguish between affective restoration (feeling better) and cognitive restoration (performing better), and show that playing games causes affective restoration.

An experience does not need to be complex to carry restorative properties. Valtchanov et al. [34] show that a person can benefit from the restorative properties of an environment just by looking at images of that environment using an VR headset.

Casual games have more benefits than just the possible restorative property. Whitbourne et al. [37] look at adult players ranging from 18 to 80 years old who casually play the popular free online game, *Bejeweled Blitz*. All players show an improvement in memory, in quicker perception, in recognising patterns, as well as a clever resourcefulness and a boost in confidence.

2.4 Challenges of Using Virtual Worlds in Game Design

A crowded environment can induce anxiety in a person, therefore it is important to be aware of the number of humans in the environment. In theory, the fewer humans, the more restorative it becomes [36], but this does not mean that the environment should feel lonely [19].

The geography of an environment also affects the restorative properties. Schebella et al. [26] show that a hilly environment is more restorative than one that is flat. This corresponds with the notion that natural environments could be more restorative than urban environments, since hills are often more perceptible in natural environments.

Ulrich et al. [33] discuss the colours and patterns that are often found in the different environments. Nature consists largely of blue and green colours, while urban environments contain more grey, black, and white colours.

Much research has been done on methods to generate virtual worlds [29], both natural [10,20] and urban [28,32], so the creation of a virtual environment can be largely facilitated by employing a variety of procedural methods. In any case, when developing a virtual world for a serious game, one should always take into account its purpose, to keep a good balance among gameplay, meaning, and realism [8].

3 Game Design

Resto Quest is a 3D first-person exploration game in which the player can explore one of two virtual environments: urban and natural. The two environments are interchangeable by design, featuring similar game mechanics, story, and goals,

Fig. 1. Main game loop, iterating between exploration and each minigame.

in order to compare their psychological effects, as done by Ulricht et al. [33] and Reetz et al. [23].

Another essential design feature of *Resto Quest* is that it presents a set of low-cognitive-load minigames that simply keep you busy and relaxed while in the environment. In this way, researchers using *Resto Quest* can more easily focus on the relation between restorative elements in real life and in the particular virtual environment of the game.

3.1 Game Synopsis

Resto Quest is an exploration game with interchangeable environments, in which the player is encouraged to walk around, searching for minigames. In both environments, the minigames will only differ in theme, the gameplay will be basically the same. At the game introduction, players are told they are either a park ranger preparing for the next camping season, in the natural environment, or the vice mayor preparing for the upcoming town festival, in the urban environment. The inclusion of this overarching story line helps to integrate the different minigames, as well as keeping the player's engagement, immersion, and motivation throughout the game, instead of relying just on players' curiosity to explore its environment.

3.2 Main Game Loop

The game starts with a brief introduction to the environment, after which the player iterates between exploring the environment while looking for the next task on their task list, and playing the respective minigame; see Fig. 1. After completing each minigame, the task is ticked off the list, and the environment will

Table 1. The five minigames: description and finish condition.

Minigame name	Activity	Finish Condition
Stacking blocks	Stack 10–15 objects	Stable for 10 s
Matching colours	Match object with right colour	10 times correct match
Connect the dots	Connect two dots without crossing	Complete 3 levels
Sweeping	Scrap the top layer to reveal text	Top layer is removed
Scavenger hunt	Collect items throughout the environment	All items collected

undergo some visible positive (rewarding) change. When all tasks are completed, the player transitions into the epilogue. The intended playtime of *Resto Quest* is around 15 min.

3.3 Key Game Mechanics and Minigames

Resto Quest comprises several game features. In the first place, basic navigation allows the player to explore the environment. Moreover, other features and game mechanics, such as the task list, minigames and the corresponding score, and rewards, contribute to the gameplay and immersion of the player.

3.3.1 Exploration

Navigation. As exploration of the environment is key in *Resto Quest*, it is necessary to be able to see the whole environment around the player. As usual in first-person games, players can look around using their mouse, and move using the directional keys. This gives them full control on motion and on where to look, reinforcing their immersion in the environment.

Directions. While exploration is encouraged in *Resto Quest*, players could possibly become frustrated when they cannot find a minigame location. Therefore, hints, such as signs or descriptions, are occasionally given, in order to help players locate their pending tasks.

3.3.2 Tasks and Minigames

Task List. When a minigame is completed, the task associated to it is ticked off the list. The use of a task list is consistent with the low-cognitive requirement desired for *Resto Quest*: the player does not have to remember which tasks are already completed nor which still have to be done.

Minigames. Currently, there are five different minigames in *Resto Quest*, of which a short generic description is provided in Table 1. Most of the minigames are based on games that parents play with their young children [7]. Again, the

choice for these infant-themed games ties in with the desire for low-cognitive-load activities. While each minigame mechanics stays consistent between the urban and natural environments, their assets and story differ slightly to keep consistency with the respective main story-line, as described in Subsect. 3.1. Table 2 summarises the stories of the minigames in both environments.

Rewards. Upon completion of a minigame, the player receives a reward consisting of a visible change in the current scenery, e.g. when the player sweeps away dirt, ground will show up beneath. This is a permanent change to the environment, and it is meant to give a sense of satisfaction to the player.

Table 2. Stories associated to the minigames.

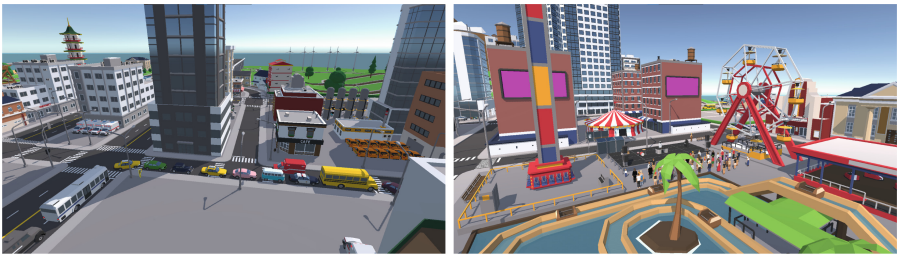
Mingame	Urban environment	Natural environment
Stacking blocks	Help the builders near the music stage with building the Ferris wheel	Help the camp by stacking firewood near the log cabins.
Matching colours	Help the valet service near the stadium	You have to help the butterflies reach the correct flowers in order for them to pollinate the other flowers. You can most likely find them at the big flower patch along the pathways.
Connect the dots	More electricity is needed for the party, please use the electricity box near the airport to rewire it	The fountain does not work, please try to find the issue and fix it. It can be found near the pathways.
Sweeping	There has been an oil spill near the refinery and at the church, please sweep it up	There are loads of leaves on the pathways, please sweep them up when you find them.
Scavenger hunt	Send 5 invitations to the party. The mailboxes are scattered around the city	Help the animals by finding them food; maybe you should start with the deer near the log cabins

3.4 Game Style

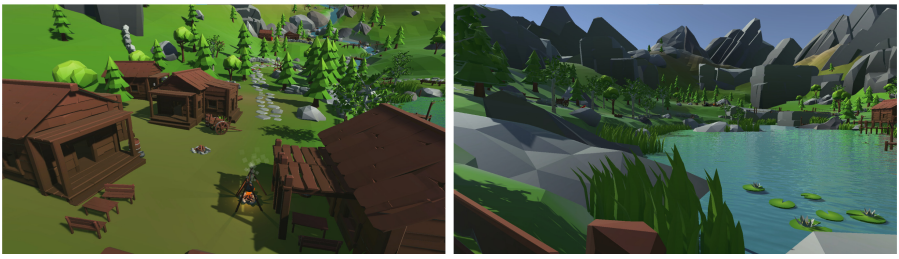
The game uses a low-poly art style, due to its non-distractive nature, as well as to the small effort required to make it look good. The low-poly art style is also low on hardware requirements, so most computers should be able to run *Resto Quest* without issues. The low-poly art assets used for the urban[1] and natural[2] environments can be found in the Unity Asset Store.

The ambience for both environments was desired to be neither stressful nor scary. The time of day is 3–4PM, which is a fitting time since both stories take

[1] https://assetstore.unity.com/packages/3d/props/low-poly-ultimate-pack-54733.
[2] https://assetstore.unity.com/packages/3d/environments/landscapes/lowpoly-style-ultra-pack-108275.



(a) Urban environment



(b) Natural environment

Fig. 2. Graphics style of *Resto Quest*. (Color figure online)

place during work time. This allows for some daylight and a good general visibility. *Resto Quest* uses only sounds that are expected on the respective environments, so that they are not distracting and only serve the purpose of increasing immersion. In the natural environment, these are mostly animal, water, and tree noises, while the urban environment mostly has people talking and cars in the background, such that ART [11], the Biophilia Hypothesis [13], and SRT [18] can apply. In both environments, there are some creatures or humans, enough to make sure that neither the player will feel lonely, which can cause stress, nor the environment will be too crowded [19,36]. The natural environment also has hills, in contrast to the urban environment, to align with restorative effects hills can provide [26]. The colour scheme of both environments has been chosen according to Ulrich et al. [33]: largely blue and green for natural environment and overall grey, black and white colours in the urban environment.

Figure 2 gives a good impression of the graphics style of *Resto Quest*. A short trailer with more footage on the game can be found elsewhere[3].

4 Evaluation

This evaluation is a preliminary exploration before full psychological research takes place. In order to properly evaluate *Resto Quest* and assess whether it is fit

[3] https://surfdrive.surf.nl/files/index.php/s/NfsmsNKViE4aJlx/download.

to be used for such research on the restorative effects of virtual environments, the gameplay should be equivalent in all regards, except for the actual environment. This would mean that the restorative aspects of the visual elements of the virtual environments can be separately evaluated. Furthermore, it is important that the various game elements are well perceived as such by the players, as intended by design.

4.1 Method

The participants played one of the environments, after which they answered the questionnaire in Table 3. To measure the time spent exploring the environment, a logging system was implemented that keeps track of: total playtime, time spent per task, and amount of clicks per minigame. These values are used to calculate an exploration rate as a ratio between time spent exploring the environment and time spent in minigames. These metrics contribute to answering whether *Resto Quest* is suitable for experimental research and, particularly, whether the environments are interchangeable.

Table 3. Interview protocol used.

Nr	Question	Question type
1	What is your age?	Open question
2	Do you game more than 10 h a week?	Closed question
3	On a scale from 1 to 5, how well were the game elements a translation from reality? (Feel free to further elaborate on your answer)	Likert scale Open question
4	Did you feel relaxed after playing this game? Why (not)?	Closed question Open question
5	What elements in the game could be changed to improve your experience?	Open question

The selection of the participants (n = 12) was done by asking acquaintances to play the game in one of the environments (urban and natural). For both environments one older, non-gamer person played the game. Urban and natural environments were equally distributed among the other participants, by our assignment, rather than by their choice. Most participants were students, with ages in the range 20–27.

4.2 Results

The average realism grade given (question 3) was 4.3 for the urban environment, and 3.9 for the natural environment, yielding an overall realism grade of 4.1.

With regard to relaxation effect (question 4), 50% of players in the urban environment report experiencing relaxation, and this figure went up to 66% for the natural environment. Overall, more than half of the players report they were in a relaxed mood after the game.

The logged data, summarised in the charts of Fig. 3, reveals that the exploration rate is higher for the natural environment than for the urban environment. Moreover, the average total playtime for the urban environment is slightly higher but has a much lower spreading.

Regarding the duration of the various minigames, except for the Matching game, their playtime is, on average, balanced between the two environments; see the charts in Fig. 4. All charts displayed feature the same error bars, which use the exclusive median, including inner and outlier points (Table 4).

Table 4. Participant answers to questions 1 and 2 from the interview in Table 3. ('Gamer' was defined as 'participant plays more than 10 h a week')

ID	Age	Gamer?	Environment
1	24	no	urban
2	23	no	natural
3	21	no	urban
4	21	yes	natural
5	27	no	natural
6	57	no	urban
7	20	no	urban
8	23	no	natural
9	23	no	urban
10	49	yes	urban
11	25	yes	urban
12	55	no	natural

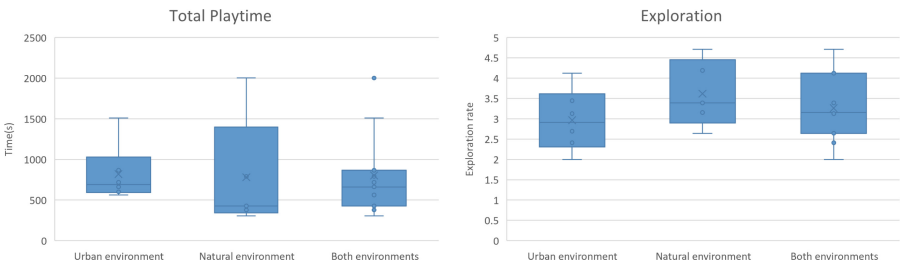


Fig. 3. Total playtime (in seconds) and exploration rate.

4.3 Discussion

From the results above we can conclude that the two environments in *Resto Quest* are perceived as relaxing by over 50% of the participants.

The playtime logged data depicted in Fig. 3 shows small differences between the minigames in the urban and natural environments. The data shows that, on average, players have a slightly higher average playtime in the urban environment compared to the natural environment. However, there is a much larger variance in the total playtime of participants in the natural environment than in the urban environment. We therefore conclude that participants did spend more time exploring the natural environment, while they seemed to move on quicker to the tasks in the urban environment.

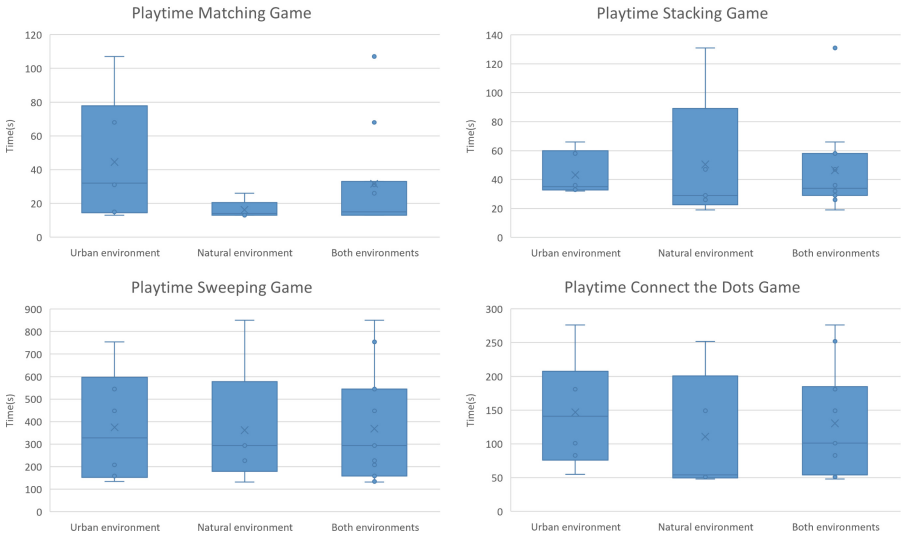


Fig. 4. Playtime (in seconds) for each of the minigames.

The average exploration rate was higher in the natural environment. A reason for that could be the irregular placement of its minigames, making it harder to figure out where to go next. In contrast, the grid layout of the city and its clear roads, might be making the navigation more intuitive.

Regarding the playtime data per minigame, in Fig. 4, we found out that the longer playtime for the Matching game in the urban environment was due to the unfortunate coincidence of one specific asset having white in it, becoming at times less distinguishable. For the rest, the data does not show a significant difference between environments in terms of minigame difficulty or average time taken to complete the game. Overall, the total time and effort taken is much more dependent on the players themselves than on which environment they played.

This is also a good result regarding the interchangeability of these two virtual environments within *Resto Quest*, as similar times indicate similar difficulty.

One limitation of the current sampling method is selection bias: due to non-probability sampling, the researchers chose the subjects and this may involve a certain bias. However, for testing whether the game is fit for psychological research, this evaluation is considered sufficient.

5 Conclusion

Real-world restorative environments are effective, but far from accessible to everyone. Virtual environments are a promising alternative, if only they properly translate the right restorative elements. We presented *Resto Quest*, a first-person exploration game designed to support psychological research on the restorative effects of both natural and urban virtual environments.

By design, the main game loop of *Resto Quest* casually leads the player to explore the environment, looking for tasks to accomplish towards an overarching goal. Each task involves a low-cognitive load minigame, that gently integrates into the main game story within each virtual environment.

Evaluation of the game mechanics of *Resto Quest* has confirmed its suitability and potential for experimental deployment by experienced psychologists. Research is currently underway, on the restorative effects of various virtual environments, including those in *Resto Quest*.

From the direct feedback received, we identified several directions for improving *Resto Quest*. Particularly the urban environment could be improved in terms of immersion and experience (e.g. accessible places, spread of objects). Moreover, most minigames could be made somewhat more challenging, possibly featuring some adaptive difficulty adjustment mechanism [17]. Finally, the graphics, textures, and animations could as well be enhanced, for improved realism.

References

1. Berto, R.: Exposure to restorative environments helps restore attentional capacity. J. Environ. Psychol. **25**(3), 249–259 (2005). https://doi.org/10.1016/j.jenvp.2005.07.001
2. Björling, E.A., Sonney, J., Rodriguez, S., Carr, N., Zade, H., Moon, S.H.: Exploring the effect of a nature-based virtual reality environment on stress in adolescents. Front. Virtual Reality **3** (2022). https://doi.org/10.3389/frvir.2022.831026. https://www.frontiersin.org/article/10.3389/frvir.2022.831026
3. Browning, M.H.E.M., Saeidi-Rizi, F., McAnirlin, O., Yoon, H., Pei, Y.: The role of methodological choices in the effects of experimental exposure to simulated natural landscapes on human health and cognitive performance: a systematic review. Environ. Behav. **53**(7), 687–731 (2021). https://doi.org/10.1177/0013916520906481
4. Depledge, M.H., Stone, R.J., Bird, W.J.: Can natural and virtual environments be used to promote improved human health and wellbeing? Environ. Sci. Technol. **45**(11), 4660–4665 (2011). https://doi.org/10.1021/es103907m. pMID: 21504154

5. Duvall, J.: Using engagement-based strategies to alter perceptions of the walking environment. Environ. Behav. **45**(3), 303–322 (2011). https://doi.org/10.1177/0013916511423808
6. Fan, J., McCandliss, B.D., Fossella, J., Flombaum, J.I., Posner, M.I.: The activation of attentional networks. Neuroimage **26**(2), 471–479 (2005). https://doi.org/10.1016/j.neuroimage.2005.02.004
7. Guyton, G.: Using toys to support infant-toddler learning and development. Young Child. **66**, 50 (2011)
8. Harteveld, C., Guimarães, R., Mayer, I.S., Bidarra, R.: Balancing play, meaning and reality: the design philosophy of LEVEE PATROLLER. Simul. Gaming **41**(3), 316–340 (2009). https://doi.org/10.1177/1046878108331237
9. Herzog, T.R., Black, A.M., Fountaine, K.A., Knotts, D.J.: Reflection and attentional recovery as distinctive benefits of restorative environments. J. Environ. Psychol. **17**(2), 165–170 (1997). https://doi.org/10.1006/jevp.1997.0051
10. Huijser, R., Dobbe, J., Bronsvoort, W.F., Bidarra, R.: Procedural natural systems for game level design. In: 2010 Brazilian Symposium on Games and Digital Entertainment (SBGAMES), pp. 189–198. IEEE (2010)
11. Kaplan, R., Kaplan, S.: The experience of nature: a psychological perspective. CUP Archive (1989)
12. Kaplan, S.: The restorative benefits of nature: toward an integrative framework. J. Environ. Psychol. **15**(3), 169–182 (1995). https://doi.org/10.1016/0272-4944(95)90001-2
13. Kellert, S.R., Wilson, E.O.: The biophilia hypothesis. Bull. Sci. Technol. Soc. **15**(1), 52–53 (1995). https://doi.org/10.1177/027046769501500125
14. Korpela, K., Staats, H.: The restorative qualities of being alone with nature, pp. 351–367. Wiley (2013). Chapter 20. https://doi.org/10.1002/9781118427378.ch20
15. Li, H., et al.: Effect of a virtual reality-based restorative environment on the emotional and cognitive recovery of individuals with mild-to-moderate anxiety and depression. Int. J. Environ. Res. Public Health **18**(17), 9053 (2021). https://doi.org/10.3390/ijerph18179053
16. Lin, Y.H., Tsai, C.C., Sullivan, W.C., Chang, P.J., Chang, C.Y.: Does awareness effect the restorative function and perception of street trees? Front. Psychol. **5** (2014). https://doi.org/10.3389/fpsyg.2014.00906
17. Lopes, R., Bidarra, R.: Adaptivity challenges in games and simulations: a survey. IEEE Trans. Comput. Intell. AI Games **3**(2), 85–99 (2011)
18. McMahan, E.A., Estes, D.: The effect of contact with natural environments on positive and negative affect: a meta-analysis. J. Posit. Psychol. **10**(6), 507–519 (2015). https://doi.org/10.1080/17439760.2014.994224
19. Nordh, H., Alalouch, C., Hartig, T.: Assessing restorative components of small urban parks using conjoint methodology. Urban For. Urban Greening **10**(2), 95–103 (2011). https://doi.org/10.1016/j.ufug.2010.12.003
20. Onrust, B., Bidarra, R., Rooseboom, R., van de Koppel, J.: Ecologically-sound procedural generation of natural environments. Int. J. Comput. Games Technol. **2017**, 7057141 (2017)
21. Pasanen, T.P., Neuvonen, M., Korpela, K.M.: The psychology of recent nature visits: (how) are motives and attentional focus related to post-visit restorative experiences, creativity, and emotional well-being? Environ. Behav. **50**(8), 913–944 (2017). https://doi.org/10.1177/0013916517720261
22. Pine, R., Fleming, T., McCallum, S., Sutcliffe, K.: The effects of casual videogames on anxiety, depression, stress, and low mood: a systematic review. Games Health J. **9**(4), 255–264 (2020). https://doi.org/10.1089/g4h.2019.0132

23. Reetz, A., Valtchanov, D., Barnett-Cowan, M., Hancock, M., Wallace, J.R.: Nature vs. stress. Proc. ACM Hum.-Comput. Interact. **5**(CHI PLAY), 1–13 (2021). https://doi.org/10.1145/3474674
24. Rockstroh, C., Blum, J., Hardt, V., Göritz, A.S.: Design and evaluation of a virtual restorative walk with room-scale virtual reality and impossible spaces. Front. Virtual Reality **1** (2020). https://doi.org/10.3389/frvir.2020.598282. https://www.frontiersin.org/article/10.3389/frvir.2020.598282
25. Rupp, M.A., Sweetman, R., Sosa, A.E., Smither, J.A., McConnell, D.S.: Searching for affective and cognitive restoration: examining the restorative effects of casual video game play. Hum. Factors J. Hum. Factors Ergon. Soc. **59**(7), 1096–1107 (2017). https://doi.org/10.1177/0018720817715360
26. Schebella, M.F., Weber, D., Lindsey, K., Daniels, C.B.: For the love of nature: exploring the importance of species diversity and micro-variables associated with favorite outdoor places. Front. Psychol. **8** (2017). https://doi.org/10.3389/fpsyg.2017.02094
27. Scopelliti, M., Carrus, G., Bonaiuto, M.: Is it really nature that restores people? A comparison with historical sites with high restorative potential. Front. Psychol. **9**, 2742 (2019). https://doi.org/10.3389/fpsyg.2018.02742
28. Silva, P.B., Eisemann, E., Bidarra, R., Coelho, A.: Procedural content graphs for urban modeling. Int. J. Comput. Games Technol. **2015**, 808904 (2015)
29. Smelik, R.M., Tutenel, T., Bidarra, R., Benes, B.: A survey on procedural modelling for virtual worlds. Comput. Graph. Forum **33**(6), 31–50 (2014)
30. Smith, C., Hancock, H., Blake-Mortimer, J., Eckert, K.: A randomised comparative trial of yoga and relaxation to reduce stress and anxiety. Complement. Ther. Med. **15**(2), 77–83 (2007). https://doi.org/10.1016/j.ctim.2006.05.001
31. Staats, H.: Restorative Environments. Oxford University Press, Oxford (2012). https://doi.org/10.1093/oxfordhb/9780199733026.013.0024
32. Taal, F., Bidarra, R.: Procedural generation of traffic signs. In: Eurographics Workshop on Urban Data Modelling and Visualisation. Eurographics (2016)
33. Ulrich, R.S.: Natural versus urban scenes: some psychophysiological effects. Environ. Behav. **13**(5), 523–556 (1981). https://doi.org/10.1177/0013916581135001
34. Valtchanov, D., Barton, K.R., Ellard, C.: Restorative effects of virtual nature settings. Cyberpsychol. Behav. Soc. Netw. **13**(5), 503–512 (2010). https://doi.org/10.1089/cyber.2009.0308
35. Van den Berg, A.E., Joye, Y., Koole, S.L.: Why viewing nature is more fascinating and restorative than viewing buildings: a closer look at perceived complexity. Urban For. Urban Greening **20**, 397–401 (2016). https://doi.org/10.1016/j.ufug.2016.10.011
36. Wang, X., Rodiek, S., Chengzhao, W., Chen, Y., Li, Y.: Stress recovery and restorative effects of viewing different urban park scenes in Shanghai, China. Urban For. Urban Greening **15**, 112–122 (2016). https://doi.org/10.1016/j.ufug.2015.12.003
37. Whitbourne, S.K., Ellenberg, S., Akimoto, K.: Reasons for playing casual video games and perceived benefits among adults 18 to 80 years old. Cyberpsychol. Behav. Soc. Netw. **16**(12), 892–897 (2013). https://doi.org/10.1089/cyber.2012.0705
38. White, M.P., et al.: A prescription for 'nature' - the potential of using virtual nature in therapeutics. Neuropsychiatr. Dis. Treat. **14**, 3001–3013 (2018). https://doi.org/10.2147/ndt.s179038

39. Yaribeygi, H., Panahi, Y., Sahraei, H., Johnston, T.P., Sahebkar, A.: The impact of stress on body function: a review. EXCLI J. **16**, 1057 (2017). ISSN: 1611-2156. https://doi.org/10.17179/EXCLI2017-480
40. Yu, C.P., Lee, H.Y., Lu, W.H., Huang, Y.C., Browning, M.H.: Restorative effects of virtual natural settings on middle-aged and elderly adults. Urban For. Urban Greening **56**, 126863 (2020). https://doi.org/10.1016/j.ufug.2020.126863. https://www.sciencedirect.com/science/article/pii/S1618866720306804