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"What makes you feel relaxed in nature?": Exploring nature-based stimuli as inspiration for designing relaxing experiences

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Abstract: Nature experiences promote relaxation and wellbeing. To bring these benefits to people with limited access to nature, digital technologies can be used to provide nature experiences. However, we do not yet completely understand which exact qualities of nature and what mechanisms are involved in eliciting relaxation. To close this gap, we conducted a diary exercise (n=25) to explore interactions and qualities that stimulate relaxation in nature. Results revealed a typology comprising three pathways to promote relaxation through nature experiences: relaxation by sensing, thinking, and doing. In addition, 8 sensorial and 6 contextual qualities were identified, and a visual summary was made that can support designers in applying nature-based stimuli to the design of digital nature with relaxing effects.

Keywords: nature experience; nature-based stimuli; wellbeing; relaxation

1. Introduction

Nature experience is beneficial for mental and physical wellbeing (Berman et al., 2012; Bratman, Hamilton, & Daily, 2012; Diette, Lechtzin, Hapoink, Devrotes, & Rubin, 2003; Park & Mattson, 2009; Ulrich, 1984; Ulrich et al., 1991; Velarde, Fry, & Tveit, 2007). 'Nature' in this paper refers to elements of living systems such as plants, sunlight, waterbodies, and natural landscapes (Bratman et al., 2012). Nature experiences take place in various forms involving different types of interactions such as watching the sunset through a window, taking care of plants, or walking in a forest. In one way or the other, in general we enjoy nature experience (Wilson, 1984). Nature experiences make us feel better and help us to become healthier and happier. A growing number of studies shows that nature experience can support relaxation and stress reduction (Ulrich et al., 1991), reduce loneliness (van Houwelingen-Snippe, Allouch, & van Rompay, 2021), regulate moods (Beyer et al., 2014; Brooks, Ottley, Arbuthnott, & Sevigny, 2017; Corazon, Sidenius, Poulsen, & Christo, 2019), enhance immune system functioning (Andersen, Corazon, & Stigsdotter, 2021), and foster recovery of patients (Ulrich, 1984). Given the positive impact of nature experience on

wellbeing, it comes natural for designers to draw on nature for inspiration and for people in general to surround themselves with nature-inspired designs (van Rompay & Ludden, 2016). Because whether we recognize this or not, our environments have a large influence on our wellbeing as our 'silent companions' (Petermans & Cain, 2020).

Advances in technology have transformed our environment. Digital technologies such as an interactive LED wall and virtual reality (VR) have enabled physical environments to provide limitless experiences through rich and varied sensory stimuli. This also opens a door for nature experiences: to become available for a wide range of people regardless of their situational or physical boundaries. For instance, people living in an urban area can now encounter dynamic sea waves on their way to work and feel refreshed (see Figure 1-a) or immerse themselves into a van Gogh's landscape and feel dreamy (see Figure 1-b). People with reduced mobility or patients in a hospital can enjoy a nature scene and feel calmer (see Figure 1-c) or take a virtual walk into mountains to get a sense of being away and relaxation (see Figure 1-d).

Figure 1. Boundless nature experiences enabled by different types of digital technologies (a) anamorphic illusion of nature using a LED facade by d'strict (www.dstrict.com) (b) immersive audio-visual digital art of nature painting, Van Gogh's Starry night, using projection by the Atelier des Lumieres (www.atelier-lumieres.com) (c) realistic virtual nature projection for patients by the Tech4people project (www.utwente.nl) (d) interactive VR nature environment for patients by the DREAMS project (Suvajdzic et al., 2019)*. All images used with permission.*

Especially in the healthcare context, there has been increasing attention for the creation of relaxing environments because of their influence on patients' wellbeing (Bayramzadeh, Ahmadpour, & Aghaei, 2021; Fontana & Pittiglio, 2010; Fredriksen & Ringsberg, 2007). Relaxation in this paper refers to both physical (e.g., muscles, heart rate) and psychological (e.g., free from anxiety) aspects. Taking Thayer's model (Thayer, 2001) consisting of two biopsychological dimensions: energy and tension, we define relaxation as the state with highly recharged energy and absence of tension. This is described as the best mood as people in this optimal state feel confident, optimistic, and strong against adversity (P. M. A. Desmet, 2015; Thayer, 2001). One way to promote relaxation is through positive sensory experiences (Baillon, van Diepen, & Prettyman, 2002; Thayer, 2001). Using digital technology, various means have been developed to facilitate relaxation through nature-based stimuli. These include an atmosphere control system showing, for example, forest-like scenes to support restoration and focus (Zhao, Azaria, & Paradiso, 2017) and a VR display providing patients a virtual nature environment with pleasant stimulation and restorative effects (Gerber, Jeitziner,

Knobel, & Mosimann, 2019). Despite the growing potential of simulated nature environments enabled by technology, which we term 'digital nature', there is limited understanding of what constitutes a positive nature stimulus and how to translate this into actionable insights for designers.

Several theories in environmental psychology have proposed nature qualities that link to positive health effects (Appleton, 1975; Gerber, Jeitziner, Knobel, et al., 2019; Keniger, Gaston, Irvine, & Fuller, 2013; Orians & Heerwagen, 1992; Ulrich et al., 1991; Wilson, 1984). However, these insights do not translate easily to design guidelines which may be a reason why design applications are often limited and simple, for instance, a use of nature image on green walls: direct imitation of nature. Moreover, in comparison with the complexity and the richness of human-nature interactions, the insights currently used in design and technological applications are limited and make use of specific qualities of nature only, which mostly come from attention restoration theory (ART) (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995).

Therefore, to inform the design of digital nature and find more comprehensive and in-depth knowledge of nature qualities inducing relaxation, an exploratory study was carried out. This study sought to answer the following research questions: (1) how do nature experiences induce relaxation? (2) what qualities of nature stimuli induce relaxation?

In this study, theories explaining qualities and mechanisms of nature experiences and relaxation were used to increase our understanding of what qualities are associated with relaxing nature experiences. Next, through an exploratory study, samples of nature stimuli were collected and qualities of nature stimuli related to relaxation were analyzed.

2. Theoretical background

Theories in environmental psychology have explained what makes certain nature stimuli beneficial. Most of these theories are based on evolutionary perspectives and explain that when nature stimuli include cues for survival (protection), reproduction (support resource acquisition), and opportunities for adventure, they elicit positive responses like preference or restoration. These theories include Biophilia theory (Wilson, 1984), prospect-refuge theory (Appleton, 1975), and Savannah hypothesis (Orians & Heerwagen, 1992). Other theories focus on the effects of nature stimuli on affect and cognition. These include Stress recovery theory (Ulrish, 1983), Environmental preference theory (R. Kaplan & Kaplan, 1989, 2011), and Attention restoration theory (ART) (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995). Amongst these theories, especially ART has been actively used in design and technological applications (Crossan & Salmoni, 2021; Gerber, Jeitziner, Simon, et al., 2019; Rosenbaum, Ramirez, & Camino, 2018). ART (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995) explains that nature experiences give us restorative effects by providing relief from mental fatigue.

While these theories provide some explanations of relaxing characteristics of nature and how they work, these are quite abstract and generic constructs that do not easily translate

into design parameters. Recognizing this limitation, Bratman and colleagues (Bratman et al., 2019) proposed a framework consisting of four components: nature features, exposure, experience, and the mental health effect. This framework outlines a wide range of the factors that contribute to positive nature experience in a structured way. However, this framework does not help designers to identify perceptual characteristics and to understand why these elements can have such effects.

In the field of architecture, more diverse forms of nature were investigated. A study of Joye (Joye, 2007) for instance considered the effect of indirect nature experience (e.g., nature-inspired designs) on wellbeing and explained the qualities of natural elements that are often used in biophilic architecture such as fractals which can hold one's attention and induce calm. This approach, where the focus is on the qualities of nature linking to positive effects, is more in line with what we want to achieve in our study because it allows for evidence-based implementation of various forms of nature stimuli to enhance wellbeing.

In summary, studies in environmental psychology provided basic knowledge of which nature qualities bring benefits, and scholars from the different fields have enriched the understanding by proposing various frameworks and approaches. Yet they cover only part of the mechanisms of nature experiences as they focus on matters that are relevant to their fields.

3. Exploratory study

To gain a more comprehensive understanding of how relaxation is induced through nature experiences and what qualities construct these nature experiences, we designed an exploratory study using a diary booklet (Sanders & Stappers, 2012). The booklet consists of diverse exercises to collect relaxing experiences in nature through drawing, creating a mind map, describing in text and taking pictures. The study was approved by our institutional ethics committee.

3.1 Participants

A total of 25 participants (17 women, 8 men) were recruited through a notification during one of the (industrial design engineering) master's courses of the university, and social media (n=14 and n=11) between December 7, 2020 and January 2, 2021. The average age of participants was 28.2 years (Range= 21-39, SD= 5.5). The sample was diverse in terms of cultural background. A total of 9 nationalities were represented, with 17 from European, 5 Asian, 2 South American countries and 1 unknown.

3.2 Procedure

Participants received an information brochure, consent form and a booklet via either post or email. In case of receiving them via email, they were requested to print out the booklet to conduct the exercises as some of them required drawing. The diary consists of four-day exercises. Following are the details of the exercises in the booklet:

- First, participants were asked to create a mind map to elaborate on what they associate relaxation with. A picture showing an example mind map (glass of wine, Saturday morning, etc.) was provided for support.
- Next, participants were asked to collect their relaxing experiences in nature by taking pictures of the moments, and later describing them in the diary reflecting on their memory supported by pictures. To cover diverse types of relaxing experiences, participants were asked to describe the following: most recent, most remarkable, and everyday relaxing experiences in nature. Next to this, to gain complete understanding of the context in each experience, participants were also asked to describe: context (time and place), perceived reason for being relaxed, and experienced sensations based on five senses.
- Finally, participants were asked to draw an ideal nature scene in a scenario in which they were staying in a hotel room with a view. Figure 2 shows an impression of the booklet and each exercise.

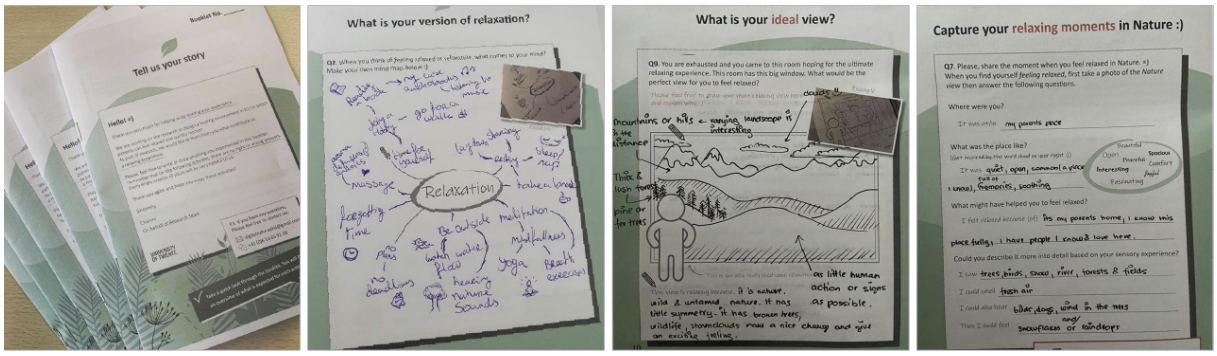

Figure 2. Examples of tasks prompted by the booklet (from left to right: general instruction; mind mapping relaxation; expressing an ideal nature view; describing daily relaxing nature experience)

The exercises took on average 10-15 min per day and in total about an hour. When the exercises were completed, participants were asked to send out the booklet and photos they took via email in either a scan or photo version. For all participants who completed the booklet, a 10-euro worth online gift card was provided as compensation for their time and effort.

3.3 Analysis

A total of 25 completed booklets was received which included 125 individual relaxing experiences combined with 70 photos of the moments taken by participants. All the answers from the booklets received were digitally documented by the first author. Next, a first data analysis was carried out by the first author using a thematic analysis method (Corbin & Strauss, 2014). For the analysis, relaxing experience cards were created. Each card contained one photo or drawing made by participants and their quotes describing the corresponding experience. 125 cards were created, and these were clustered and labeled based on the initial

codes. The initial clusters (see Figure 3) were reviewed in a meeting with all authors and revised until agreement was reached.

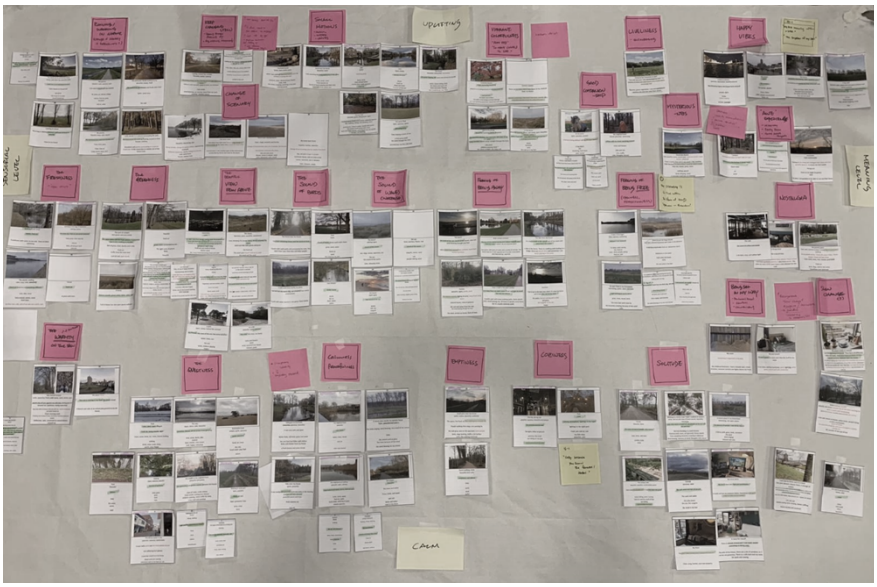

Figure 3. Overview of initial clusters of relaxing nature experiences

The findings consisted of three parts. The first part deals with types of relaxation and how nature stimuli are associated with it. The second part explains which qualities were present in relaxing nature stimuli and how they influenced relaxation. The last part presents how these insights were connected and can be used in design practice by providing a visual summary. The following sections provide more extensive explanation of these findings illustrated with examples and quotes from participants.

4. Relaxation by sensing, thinking, and doing, and the different roles of nature

The analysis revealed a typology of relaxing experiences. The typology consists of 10 different types of relaxing experiences which grouped into three themes: relaxing experiences by sensing, thinking, and doing. Nature plays different roles in each of these types of experiences and different qualities are associated. The overview of 10 relaxing experiences can be found in Figure 4.

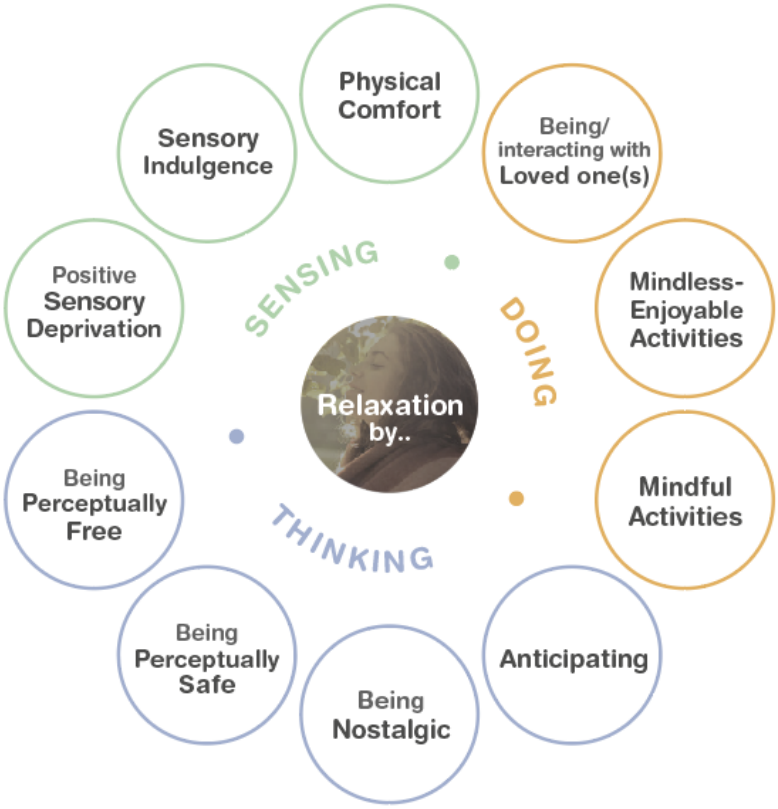

Figure 4. Typology of relaxing experiences

The first theme is relaxation by sensing, which consists of three sub types: **sensory indulgence**, exemplified by listening to music, enjoying a glass of wine, or enjoying a beautiful sunset view; **physical comfort**, including laying down in a comfortable position or lounging in a cozy couch; **positive sensory deprivation**, including closing the eyes or wearing earplugs to reduce or remove sensory stimuli. In this theme, nature provides **pleasant sensory stimulation.** Participants often associated nature elements with various sensory qualities that led them to relaxation. The freshness in nature contributed to a feeling of being recharged: "I felt fresh air and cold wind on my face. It was refreshing" (P20). The greenness of nature found in trees and grass were perceived as soothing: "the huge amount of greenness was soothing to my eyes" (P11). The vibrant nature in colorful flower and trees gave aesthetic delight and uplifted their mood: "trees, colorful flowers, the smell of earth, the sound of rustling leaves, (…) it was enjoyable and relaxing" (P8), "it was fascinating. These very red trees... they are very unique and beautiful" (P4). On the other hand, the serenity and quietness of nature, for instance, a serene lake made them feel calm: "I was at the lake near my house. It was peaceful and quiet as it was early in the morning, and no one was around. I felt calm" (P11).

The second theme is relaxation by thinking, which contains four sub types: **being perceptually free**, described by the state of having space in mind, for instance, because one is off duty after finishing deadlines or being on vacation; **being nostalgic,** in which one thinks of good old memories; **anticipating**, where one looks forward to forthcoming events; and **being**

perceptually safe, when one has peace of mind for instance by being in a familiar place. In this theme, nature induces relaxation by **activating positive thoughts and reflections**. The openness and vastness of the ocean can make one feel free: "(at the seaside) it was very open and spacious. It feels like a real break" (P4), "I got out of work and went to the beach nearby. I liked the big changes in surroundings. Its openness and spaciousness… I felt free" (P25). Recognizing seasonal changes from elements in nature makes one look back on the enjoyable memories from the past seasons or look forward to upcoming holidays: "the trees with almost no leaves reminds me of the time passing by which is joyful and fascinating (…) they remind me that good days (winter holidays) are coming" (P7), "it's relaxing because it (the scene covered with snow) reminds me of the snowy landscape my family used to see from our cabin on the ski slopes when I was younger. We would celebrate Christmas inside" (P4). Lastly, natural places like a forest can give a safe feeling coming from its structural properties: "I felt safe because I was surrounded by trees" (P21).

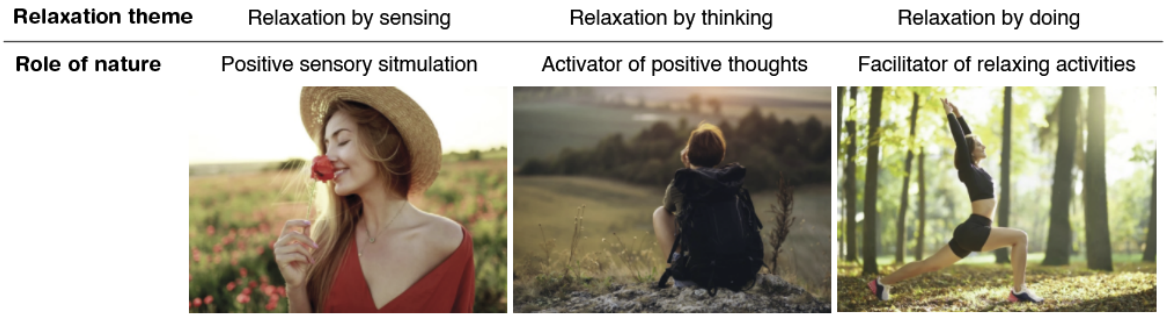

Figure 5. Three different roles of nature associated with three themes of relaxation. All images by Freepik. Used with permission. (www.freepik.com) Note: the images are to provide impression of human-nature interactions per theme and do not mean the nature (e.g., mountains) presented in each image is only limited to the assigned role (e.g., activator of positive thoughts).

The last theme is relaxation by doing, which contains three sub types: **mindful activities** the purpose of which is bringing one's attention to the self and one's feelings in the present moment such as yoga and meditation; **mindless and enjoyable activities** which do not require serious thinking and therefore can diffuse one's attention towards something other than the self or (concerning) thoughts, for instance, physical exercises, creative activities like art projects; **being or interacting with loved ones**, including having a good conversation with a friend, and playing with pets. In this theme, nature provides surroundings or sensory stimuli that **facilitate engagement in these activities**, hence enhancing a relaxing experience. For instance, when meditating, serene nature scenes or calming nature sound can help one to clear mind and focus on the self: "there was only nature around me. I could hear trees squealing, branches creaking in distances. I saw tall trees bending in a small breeze. I could smell pine trees, moss (…) I felt calmness of mind.. I was thinking only about the moment" (P13). When doing exercise, nature provides dynamic views which makes the exercise more enjoyable: "I like cycling around the campus. Watching trees on the road while moving and

changing view, (…) it's peaceful and calming" (P9). When taking a walk with a loved one, nature can act as a positive distraction with whistling leaves or moving clouds, which helps one to be engaged in what he/she/they do(es) without getting bored: "(in a forest) I was talking with my mom and watching around. Seeing trees and moving cloud, hearing whistling leaves. They make the whole experience more enjoyable" (P14).

The overview of the different roles nature play in these three themes of relaxation can be found in Figure 5.

These insights on diverse roles of nature playing in different paths of relaxation *(relaxation by sensing, thinking and doing)* are interesting because they confirm that the effect of nature stimuli can go beyond passive relaxation. This implies that, for instance, aside from designing for reducing situational stress and anxiety, we can support people to generate more positive thoughts and to foster engagement in activities that promote wellbeing through sensory stimuli. It is also notable that diverse qualities of nature (e.g., freshness, greenness, openness, serenity) are associated with different effects of nature (e.g., calming, uplifting, reassuring) that lead to relaxation. In the next section, we investigated these qualities and provided comprehensive analysis.

5. Mechanism and typology of relaxing nature stimuli

We found that the relaxing experiences mostly come from nature (sensory) stimuli but can also be enhanced by contextual factors. For instance, the relaxing experience shared by P5 "I was looking outside (the nature view) from a tall building. I felt safe because I could see everywhere but no one would be able to see me", the fact that P5 was looking at the view from a physically high location contributed to the impression of "seeing without being seen" and made P5 felt safe. If P5 was looking at the same scene but from the ground level, the experience may have come very differently and possibly not as relaxing as it was from the above view. For another example, P3 described, "I was watching snow outside at the window having a cup of tea. It was cozy and relaxing". Here, falling snow contributed to relaxing feeling but the fact that P3 was watching it from a (probably warm) indoor setting may have created a cozy and hence relaxed feeling. As these two examples show, relaxing qualities in nature experience can be distinguished based on whether they are instigated by sensory stimuli of nature (e.g., the nature view, falling snow) or are the resultant of the interplay between stimulus and contextual factors shaping one's experiences (e.g., seeing without being seen by being in a physically high location, looking outside where it is cold while staying in a warm indoor environment). We define the former as sensorial qualities and the later as contextual qualities. It is notable that contextual qualities can regulate the effect of sensorial qualities in a positive or negative way, and in this study, we are focusing on the ideal scenario: contextual qualities amplifying relaxing experiences. Figure 6 illustrates how these two types of qualities in nature construct relaxing experiences.

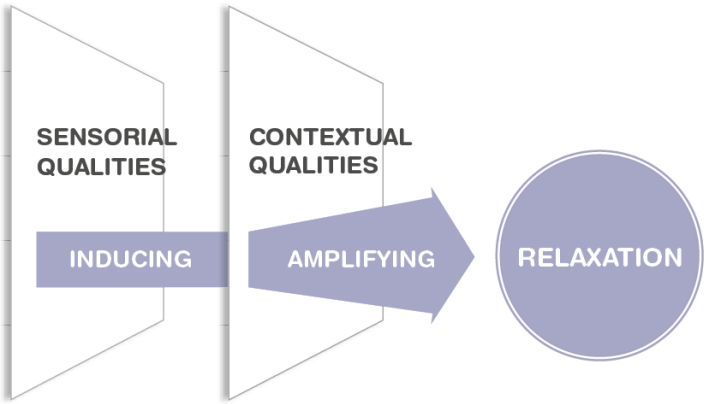

Figure 6. Mechanism of relaxing nature experience

5.1 Eight sensorial qualities

A total of eight sensorial qualities (of nature stimuli) was identified based on the way they lead to relaxation. The explanation of each identified qualities and example quotes are provided in Figure 7.

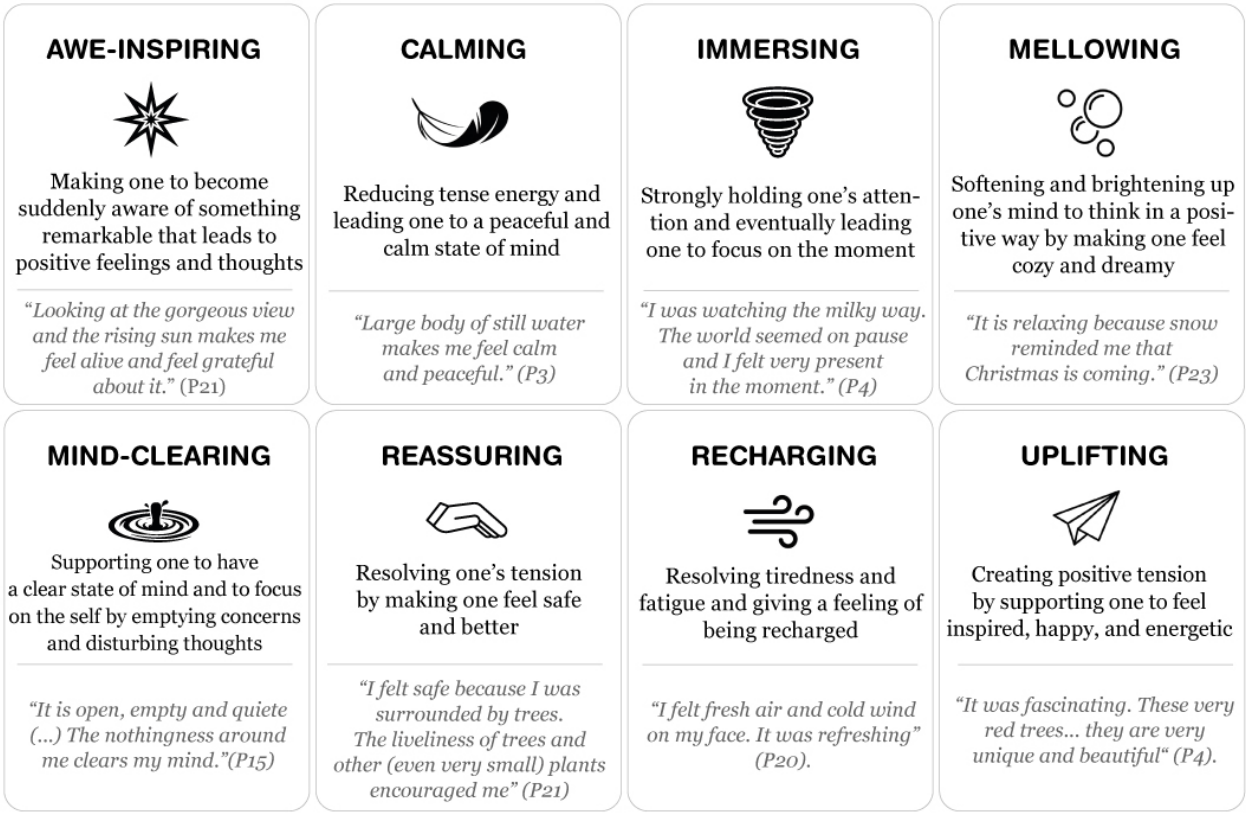

Figure 7. Typology of sensorial qualities of relaxing nature stimuli including quotes from participants. All icons from the Nounproject. Used with permission. (www.thenounproject.com)

Some of identified qualities: calming, immerging, mind-clearing, reassuring, and refreshing are in line with the qualities (sense of being away, soft fascination, and elements of Savannah landscape) found in theories in environmental psychology (R. Kaplan & Kaplan, 1989; S.

Kaplan, 1995; Orians & Heerwagen, 1992). The others (awe-inducing, mellowing, and uplifting) are not directly linked to these theories but are associated with relaxation techniques such as selective attention on positive thoughts and emotions (Jain et al., 2007).

5.2 Six contextual qualities

Contextual qualities refer to factors in the context that can influence one's experiences; these factors could be related to physical condition/ perceptual condition around perceivers, or perceivers themselves. A total of six contextual qualities was identified based on how they can amplify relaxing effects. The explanation of each quality and example quotes are shown in Figure 8.

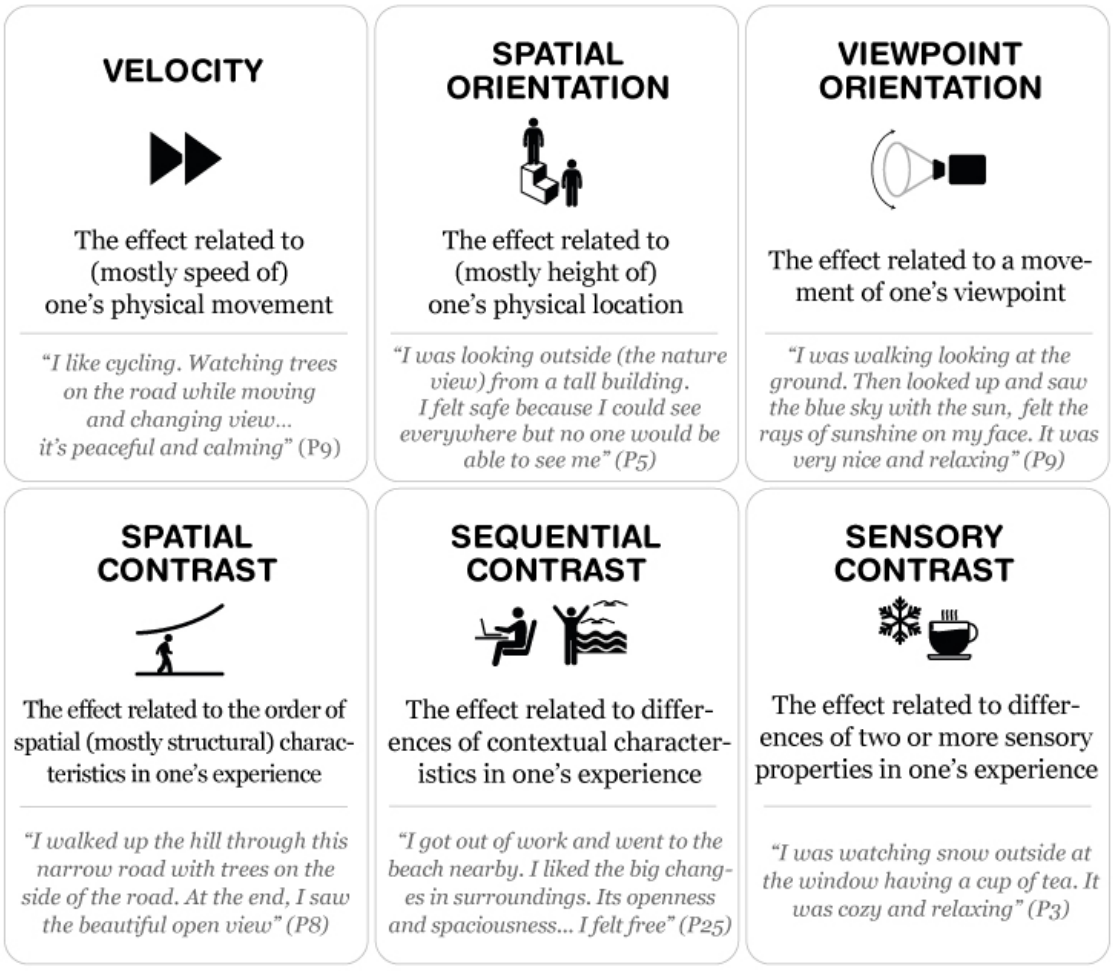

Figure 8. Typology of contextual qualities in relaxing nature experience including quotes from participants. All icons from the Nounproject. Used with permission. (www.thenounproject.com)

One of these qualities, spatial orientation, is in line with the prospect-refuge theory as in the higher one's physical location is, the better chance to obtain visual information for prospect (Appleton, 1975). Other qualities don't directly link to theories in environmental psychology. They do however, share principles in camera techniques from film theories (Baranowski & Hecht, 2018; Bordwell & Thompson, 1993) and environmental storytelling in game and

architecture theories (Carson, 2000, 2004), the aim of which is also to amplify dynamic perceptual effects.

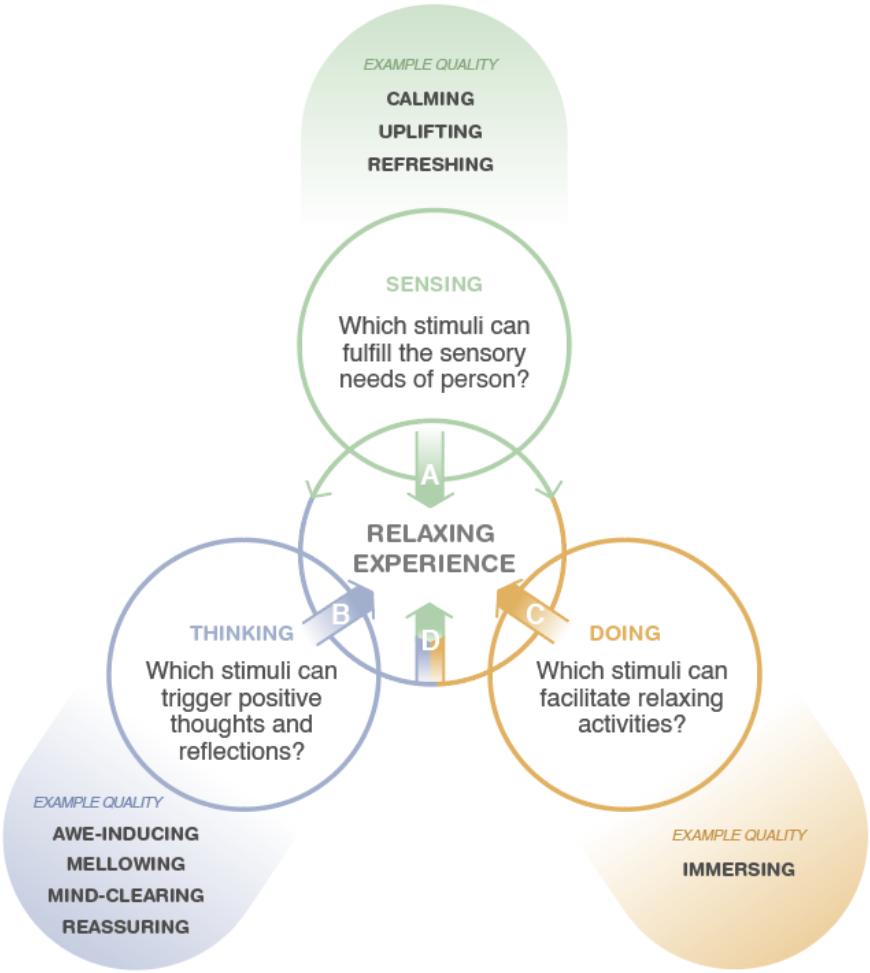

Figure 9. Visual summary of four approaches to design relaxing experiences and related sensory qualities

5.3 Visual summary of relaxing experience through sensory stimuli

We introduced three different ways in which nature experiences lead to relaxation: by sensing, thinking, and doing. In *relaxation by sensing and doing*, human-nature interactions do not necessarily involve any associations or interpretation. On the other hand, in *relaxation by thinking*, nature stimuli can lead to relaxation by influencing one's thoughts and feelings. These different ways of interactions echo the three-experience levels in human-product experiences: pleasurable (visceral), action-oriented (behavioral), and meaningful (symbolic) types of experience (Ludden & van Rompay, 2015; Norman, 2004). Another finding from the analysis was that it is common that nature stimuli from different pathways jointly contribute to relaxation. Such intertwined form of experiences are also often recognized in human-product experiences: one component of experience activating the other and eliciting emotional experience such as a relaxed feeling (P. M. A. Desmet & Hekkert, 2007). The notion of

different types of human-nature interactions helps designers to adapt nature stimuli into their design through various design approaches. The visual summary (feature 9) illustrates four different approaches that designers can consider when designing relaxing experiences inspired by nature-stimuli: fulfilling sensory needs (approach A), stimulating positive thoughts and reflections (approach B), facilitating relaxing activities (approach C), and combining qualities across different approaches (approach D).

Applying the results of our analysis, the visual summary also indicates which sensorial qualities are most involved with each pathway. Contextual qualities were not included in the visual summary because their connection to certain pathway was less distinctive.

6. Discussion and conclusion

In this paper we explored what makes people feel relaxed in nature. We informed designers of digital nature with the intermediate-level knowledge connecting theories and design practice by presenting four different types of insights into relaxation ranging from fundamental level to practical level: (1) a typology of relaxing experiences in nature, (2) a mechanism illustrating that contextual factors can amplify sensorial experiences, (3) a new set of sensorial qualities and contextual qualities related to nature experiences, and (4) a visual summary showing different ways to deliver relaxing experience through sensory stimuli.

To provide an overview of the different paths that lead to relaxation and how nature plays a role, we developed a typology of relaxing experiences. A recent study (P. Desmet & Fokkinga, 2020) introduced three criteria for the soundness of a typology: inclusion, distinction, and equivalence. While the typology of relaxing experiences includes a wide spectrum of possible nature experiences related to relaxation (inclusion), we found that examples related to *relaxation by doing* did not include all activities that are inherently linked to nature such as skiing and climbing. This may be because while these activities can lead to relaxation, their immediate association for most participants is excitement rather than relaxation and therefore they were not perceived as relaxing experiences in this study. All the defined categories in the typology of relaxing experiences are unique and distinctive from each other (distinction) and described in a similar abstract level (equivalence). It was challenging to distinguish some categories as in real life relaxing experiences occur in an interconnected way. For instance, *interacting with loved ones* may be relaxing because it can lead to a feeling of being safe or to nice memories from the past. However, it was considered a separate category as we reasoned that at its core, there is innate longing for interacting with other beings.

The typology of relaxing experience extends the scope of using nature stimuli in technology-mediated design from passive to active relaxation for people. It revealed three ways of relaxation that are motivated by perception, thought, and activity and diverse roles of nature supporting them. Knowing the potentials of nature stimuli in this active form of relaxation– stimulating people to think in a positive way and facilitating their engagement in activities– opens up new opportunities where nature stimuli can intervene. Aside from being exposed to nature stimuli passively, designers could support people to actively pursue relaxation

through digital technologies in environments. Taking an example of patients in hospitals, a VR tour could enable them to virtually visit and explore places where they can feel safe or encouraged. Next to widening the potential of digital nature experience, we also provide a set of 8 sensorial and 6 contextual qualities derived from relaxing nature experiences. Sensorial qualities can support designers to envision a variety of interactions that can lead to relaxing experiences and contextual qualities can inform a designer on how to amplify these experiences. Finally, the visual summary can be used as a high-level guideline for designers to choose an approach and appropriate sensory qualities to design relaxing experiences. For instance, designers who aim to create a relaxing experience by triggering positive thoughts could look into sensory qualities like awe-inspiring or mellowing and based on given examples connected to each of these qualities (see feature 7), explore further possible concrete interaction qualities to adapt into their designs. It is worth noting that, while the study was conducted with the aim to inform the design of digital nature, as many of the insights revolve around interaction values rather than specific nature features, they can also be used to as rich inspiration for other types of design ranging from lighting devices to physical interiors for the built environment.

To our knowledge, this is the first study that investigated nature-based stimuli focusing on their interaction values and provided transitional knowledge including the mechanism and typology.

Interestingly, the identified qualities and interactions leading to relaxation are varied. This also means people need different qualities and interactions to become relaxed at different moments in time. Further work could investigate individual factors that may influence one's relaxing experiences such as one's mood state, relationship with nature, motivation, needs and concerns.

We are living in our environments and consistently interacting with them. Digital technologies allow for the creation of hybrid environments in which physical and digital components can complement each other and create limitless opportunities for wholesome human-nature interactions. As a way to steer such experiences toward human flourishing, this study investigated how to design relaxing sensory stimuli inspired by nature experiences. The insights of our study help designers to appropriately apply nature stimuli for the intended effects so they can cater different sensory and emotional needs of people. We expect these insights will encourage the application of positive design to our environments through various means enabled by technology and support people to actively pursue wellbeing.

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6. References

Andersen, L., Corazon, S. S., & Stigsdotter, U. K. (2021). Nature Exposure and Its Effects on Immune System Functioning : A Systematic Review. *International Journal of Environmental Research and Public Health*, *18*(1416). https://doi.org/10.3390/ijerph18041416

Appleton, J. (1975). *The Experience of Landscape*. New York: John Wiley and Sons.

Baillon, S., van Diepen, E., & Prettyman, R. (2002). Multi-sensory therapy in psychiatric care. *Advances in Psychiatric Treatment*, *8*(6), 444–450. https://doi.org/10.1192/apt.8.6.444

Baranowski, A. M., & Hecht, H. (2018). Effect of Camera Angle on Perception of Trust and Attractiveness. *Empirical Studies of the Arts*, *36*(1), 90–100. https://doi.org/10.1177/0276237417710762

Bayramzadeh, S., Ahmadpour, S., & Aghaei, P. (2021). The relationship between sensory stimuli and the physical environment in complex healthcare settings : A systematic literature review. *Intensive & Critical Care Nursing*, 103111. https://doi.org/10.1016/j.iccn.2021.103111

Berman, M. G., Kross, E., Krpan, K. M., Askren, M. K., Burson, A., Deldin, P. J., … Jonides, J. (2012). Interacting with nature improves cognition and affect for individuals with depression. *Journal of Affective Disorders*, *140*(3), 300–305. https://doi.org/10.1016/j.jad.2012.03.012

Beyer, K. M. M., Kaltenbach, A., Szabo, A., Bogar, S., Nieto, F. J., & Malecki, K. M. (2014). Exposure to Neighborhood Green Space and Mental Health : Evidence from the Survey of the Health of Wisconsin. *International Journal of Environmental Research and Public Health*, *11*, 3453–3472. https://doi.org/10.3390/ijerph110303453

Bordwell, D., & Thompson, K. (1993). *Film art: an introduction* (Fourth edi). New York: McGraw-Hill.

Bratman, G. N., Anderson, C. B., Berman, M. G., Cochran, B., Lindahl, T., Meyer-lindenberg, A., … Daily, G. C. (2019). Nature and mental health : An ecosystem service perspective. *Science Advances*, *5*(7), eaax0903. https://doi.org/10.1126/sciadv.aax0903

Bratman, G. N., Hamilton, J. P., & Daily, G. C. (2012). The impacts of nature experience on human cognitive function and mental health. *Annals of the New York Academy of Sciences*, *1249*, 118–136. https://doi.org/10.1111/j.1749-6632.2011.06400.x

Brooks, A. M., Ottley, K. M., Arbuthnott, K. D., & Sevigny, P. (2017). Nature-related mood effects : Season and type of nature contact. *Journal of Environmental Psychology*, *54*, 91–102. https://doi.org/10.1016/j.jenvp.2017.10.004

Carson, B. D. (2000). Environmental Storytelling : Creating Immersive 3D Worlds Using Lessons Learned from the Theme Park industry. *Gamasutra*. Retrieved from http://www.gamasutra.com/features/20000301/carson_01.htm

Carson, B. D. (2004). Environmental Storytelling , Part II: Bringing Theme Park Environment Design Techniques to the Virtual World. *Gamasutra*. Retrieved from http://www.gamasutra.com/features/20000405/carson_01.htm

Corazon, S. S., Sidenius, U., Poulsen, D. V., & Christo, M. (2019). Psycho-Physiological Stress Recovery in Outdoor Nature-Based Interventions : A Systematic Review of the Past Eight Years of Research. *International Journal of Environmental Research and Public Health*, *16*(1711). https://doi.org/10.3390/ijerph16101711

Corbin, J. M., & Strauss, A. (2014). *Basics of Qualitative Research: Techniques and Procedures for*

Developing Grounded Theory. Sage publications.

Crossan, C., & Salmoni, A. (2021). A Simulated Walk in Nature: Testing Predictions From the Attention Restoration Theory. *Environment and Behavior*, *53*(3), 2777–295. https://doi.org/10.1177/0013916519882775

Desmet, P., & Fokkinga, S. (2020). Beyond Maslow's Pyramid: Introducing a Typology of Thirteen Fundamental Needs for Human-Centered Design. *Multimodal Technologies and Interaction*, *4*(38). https://doi.org/10.3390/mti4030038

Desmet, P. M. A. (2015). Design for Mood : Twenty Activity-Based Opportunities to Design for Mood Regulation. *International Journal of Design*, *9*(2), 1–19.

Desmet, P. M. A., & Hekkert, P. (2007). Framework of product experience. *International Journal of Design*, *1*(1), 57–66.

Diette, G. B., Lechtzin, N., Hapoink, E., Devrotes, A., & Rubin, H. R. (2003). Distraction Therapy With Nature Sights and Sounds Reduces Pain During Flexible Bronchoscopy: a complementary approach to routine analgesia. *Chest*, *123*(3), 941–948. https://doi.org/10.1378/chest.123.3.941

Fontana, C. J., & Pittiglio, L. I. (2010). Sleep Deprivation Among Critical Care Patients. *Crit Care Nurs Q*, *33*(1), 75–81.

Fredriksen, S.-T. D., & Ringsberg, K. C. (2007). Living the situation stress-experiences among intensive care patients. *Intensive and Critical Care Nursing*, *23*(3), 124–131. https://doi.org/10.1016/j.iccn.2006.09.002

Gerber, S. M., Jeitziner, M., Knobel, S. E. J., & Mosimann, U. P. (2019). Perception and Performance on a Virtual Reality Cognitive Stimulation for Use in the Intensive Care Unit : A Non-randomized Trial in Critically Ill Patients. *Frontiers in Medicine*, *6*(December), 1–9. https://doi.org/10.3389/fmed.2019.00287

Gerber, S. M., Jeitziner, M., Simon, D. S., Knobel, S. E. J., Marchal-Crespo, L., Muri, R. M., … Nef, T. (2019). Comparing the Relaxing Effects of Different Virtual Reality Environments in the Intensive Care Unit : Observational Study. In *JMIR Perioperative Medicine* (Vol. 2, p. e15579). https://doi.org/10.2196/15579

Jain, S., Shapiro, S. L., Swanick, S., Roesch, S. C., Mills, P. J., Bell, I., & Schwartz, G. E. R. (2007). A Randomized Controlled Trial of Mindfulness Meditation Versus Relaxation Training: Effects on Distress, Positive States of Mind, Rumination, and Distraction. *Ann Behav Med*, *33*(1), 11–21. https://doi.org/10.1207/s15324796abm3301_2

Joye, Y. (2007). Architectural Lessons From Environmental Psychology: The Case of Biophilic Architecture. *Review of General Psychology*, *11*(4), 305–328. https://doi.org/10.1037/1089-2680.11.4.305

Kaplan, R., & Kaplan, S. (1989). *The experience of nature: a psychological perspective*. Cambridge: Cambridge University Press.

Kaplan, R., & Kaplan, S. (2011). Well-being, Reasonableness, and the Natural Environment. *Health and Well-Being*, *3*(3), 304–321. https://doi.org/10.1111/j.1758-0854.2011.01055.x

Kaplan, S. (1995). The restorative benefits of nature: toward an integrative framework. *Journal of Environ*, *15*, 169–182. https://doi.org/10.1016/0272-4944(95)90001-2

Keniger, L. E., Gaston, K. J., Irvine, K. N., & Fuller, R. A. (2013). What are the benefits of interacting with nature? *International Journal of Environmental Research and Public Health*, *10*, 913–935. https://doi.org/10.3390/ijerph10030913

Ludden, G. D. S., & van Rompay, T. J. L. (2015). How does it feel? Exploring touch on different levels of product experience. *Journal of Engineering Design*, *26*(4–6), 157–168. https://doi.org/10.1080/09544828.2015.1036011

Norman, D. (2004). *Emotional design*. New York, NY: Basic Books.

Orians, G. H., & Heerwagen, J. H. (1992). Evolved responses to landscape. In J. H. Barkow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind: Evolutionary psychology and the generation of culture* (pp. 555–579). Oxford University Press.

Park, S., & Mattson, R. H. (2009). Ornamental Indoor Plants in Hospital Rooms Enhanced Health Outcomes of Patients Recovering from Surgery. *The Journal of Alternative and Complementary Medicine*, *15*(9), 975–980. https://doi.org/10.1089/acm.2009.0075

Petermans, A., & Cain, R. (2020). Setting the scene for design for subjective wellbeing. In *Design for wellbeing* (p. 3). Routledge.

Rosenbaum, M. S., Ramirez, G. C., & Camino, J. R. (2018). A dose of nature and shopping: The restorative potential of biophilic lifestyle center designs. *Journal of Retailing and Consumer Services*, *40*, 66–73. https://doi.org/10.1016/j.jretconser.2017.08.018

Sanders, E. B.-N., & Stappers, P. J. (2012). *Convivial design toolbox: generative research for the front end of design*. Amsterdam: BIS Publishers.

Suvajdzic, M., Bihorac, A., Rashidi, P., Ruppert, M., Williams, S., Ozrazgat-Baslanti, T., … Appelbaum, J. (2019). Developing a Patient-Centered Virtual Reality Healthcare System To Prevent the Onset of Delirium in ICU Patients. In *2019 IEEE 7th International Conference on Serious Games and Applications for Health*. Digital Worlds Institute, University of Florida, Gainesville, FL, United States. https://doi.org/10.1109/SeGAH.2019.8882442

Thayer, R. E. (2001). *Calm Energy*. New York: Oxford University Press.

Ulrich, R. S. (1984). View through a Window May Influence Recovery from Surgery. *Science*, *224*(4647), 420–421.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environment. *Journal of Environmental Psychology*, *11*, 201–230. https://doi.org/10.1016/S0272-4944(05)80184-7

Ulrish, R. S. (1983). Aesthetic and Affective Response to Natural Environment. In I. Altman & J. F. Wohlwill (Eds.), *Behaviour and the Natural Environment. Human Behavior and Envirnment (Advances in Theory and Research)*. Boston, MA: Springer.

van Houwelingen-Snippe, J., Allouch, S. Ben, & van Rompay, T. J. L. (2021). Virtual Reality Representations of Nature to Improve Well‑Being amongst Older Adults: a Rapid Review. *Journal of Technology in Behavioral Science*, *1*, 464–485. https://doi.org/10.1007/s41347-021-00195-6

van Rompay, T. J. L., & Ludden, G. D. S. (2016). Creating Novel Encounters with Nature: Approaches and Design Explorations. In P. Lloyd & E. Bohemia (Eds.), *Future Focused Thinking - DRS International Conference 2016, 27 - 30 June*. Brighton, United Kingdom. https://doi.org/10.21606/drs.2016.308

Velarde, M. D., Fry, G., & Tveit, M. (2007). Health effects of viewing landscapes – Landscape types in environmental psychology. *Urban Forestry & Urban Greening*, *6*, 199–212. https://doi.org/10.1016/j.ufug.2007.07.001

Wilson, E. O. (1984). *Biophilia*. Cambridge: Harvard University Press. https://doi.org/doi:10.4159/9780674045231

Zhao, N. A. N., Azaria, A., & Paradiso, J. A. (2017). Mediated Atmospheres: A Multimodal Mediated Work Environment. In *ACM interact* (Vol. 1). https://doi.org/http://doi.org/10.1145/3090096

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