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Kim, Chan Mi; Van Rompay, Thomas; Louwers, G.L.M.; Yoon, Jungkyoon; Ludden, Geke

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# From a Morning Forest to a Sunset Beach: Understanding Visual Experiences and the Roles of Personal Characteristics for Designing Relaxing Digital Nature

Chan Mi Kim<sup>a</sup> , Thomas J. L. van Rompay<sup>b</sup> , Gijs L. M. Louwers<sup>c</sup> , Jungkyoon Yoon<sup>d</sup> , and Geke D. S. Ludden<sup>a</sup> 

<sup>a</sup>Department of Design, Production, and Management, University of Twente, Enschede, The Netherlands; <sup>b</sup>Department of Communication Science, University of Twente, Enschede, The Netherlands; <sup>c</sup>Department of Human Centered Design, Delft University of Technology, Delft, The Netherlands; <sup>d</sup>Department of Human Centered Design, Cornell University, Ithaca, New York, USA

## ABSTRACT

Nature experiences, especially the visual aspects of nature, have been widely used to facilitate relaxation. Fueled by digital technology, simulated visual nature experiences have gained popularity in creating healing environments that induce relaxation. However, while easily applicable, not all nature-imitating visuals lead to relaxation. How to effectively design relaxing visual nature experiences remains largely unexplored. This paper investigates how different nature qualities facilitate relaxing visual experiences and the roles of two personal characteristics (mood and nature-relatedness) play. Through an online survey and interviews, we assessed 16 nature video clips, representing eight distinctive nature qualities, and compared perceived experiences while considering the influence of personal characteristics. The results indicate four types of visual qualities (engaging, instinctive, ambient, and derivative) underlying nature-induced relaxation, and show that nature relatedness influences the degree to which nature video clips elicit relaxation. We discuss design implications for creating personalized digital nature.

## KEYWORDS

Simulated nature; digital nature; visual stimulation; relaxation; mood; nature relatedness; personalization; design framework; mixed-method study

## 1. Introduction

From a morning forest that makes us feel refreshed to a sunset beach that puts us in a mellow mood, nature experiences strongly influence how we feel, think, and behave (Bratman et al., 2012). Nature experiences play a crucial role in people's physical, psychological, and social well-being (Bratman et al., 2012; Grigsby-Toussaint et al., 2015; Li et al., 2008). In this paper, the term “nature experience” refers to dynamic interactions (e.g., visual, auditory, or haptic) with elements of living systems (e.g., plants, sunlight, or water bodies) (Bratman et al., 2012). Nature experiences can bring positive effects on health outcomes, such as enhancing sleep quality (Grigsby-Toussaint et al., 2015), pain control (Lechtzin et al., 2010), and immune system functioning (Li et al., 2008), while alleviating stress (Ulrich et al., 1991), anxiety (Bratman et al., 2015), aggression (Bogar & Beyer, 2016), depression (Gascon et al., 2015), and loneliness (Maas et al., 2009), with many of these benefits stemming from the relaxation facilitated by nature experiences (Bratman et al., 2015; Lechtzin et al., 2010; Li et al., 2008; Ulrich et al., 1991). By relaxation, we refer to a multidimensional construct including restoration (recharged energy) and tension reduction (Thayer, 2001). To explain how nature experiences bring diverse benefits, various theoretical

frameworks have been proposed including biophilia theory (BT) (Wilson, 1984), prospect-refuge theory (PRT) (Appleton, 1975), Savannah hypothesis (SH) (Orians & Heerwagen, 1992), stress reduction theory (SRT) (Ulrich, 1983; Ulrich et al., 1991), perceptual fluency account (PFA) (Joye & van den Berg, 2011), and attention restoration theory (ART) (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995). Most of these theories are based on evolutionary benefits in nature. They elucidate that when the qualities – the elements that define the characteristics of perceived visual experiences – in nature scenes are associated with advantages for survival and well-being, such as lack of threat (SRT), and ease of processing visual information (PFA), they lead to positive affective responses (e.g., relaxation, restoration, and stress reduction) and aesthetic responses (e.g., preference and pleasure) (Figure 1).

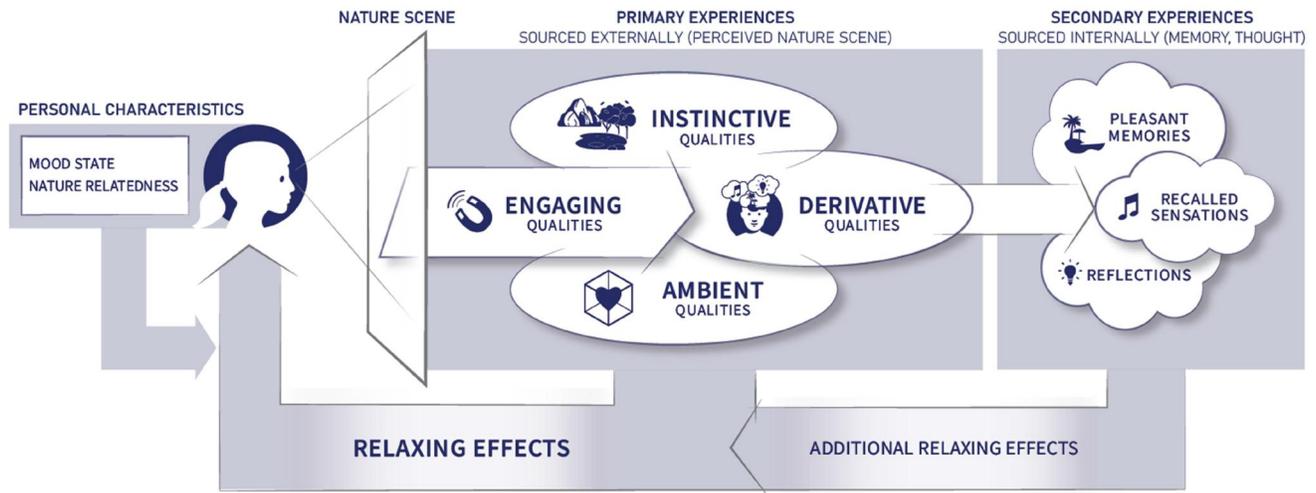
Given diverse health benefits, it is not surprising that interest in stimulating relaxation through nature experiences has rapidly emerged in the field of human-computer interaction (HCI). HCI researchers and designers have explored how to replicate the positive effects of nature by creating immersive and dynamic visual nature experiences using digital technologies across various domains such as workplace, home, and hospital (Ahmaniemi et al., 2017; M. H. E.

**CONTACT** Chan Mi Kim  [c.m.kim@utwente.nl](mailto:c.m.kim@utwente.nl)  Department of Design, Production, and Management, University of Twente, Enschede, The Netherlands

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**Figure 1.** Conceptual framework of nature-visual experiences inducing relaxing effects. All icons used in the framework from the nounproject. Used with permission. ([www.thenounproject.com](http://www.thenounproject.com)).

M. Browning et al., 2019; Veling et al., 2021). Further, these initiatives revealed new opportunities to bring the benefits of nature through simulated nature experiences to people who have limited access to real nature, such as intensive care patients in a windowless space. With advances in digital technology, simulated visual nature experiences have evolved from static images of nature to dynamic and immersive visual experiences such as virtual reality (VR) and immersive projection, which projects visual content in multiple dimensions (Hung et al., 2022; Malbos et al., 2013; Maltha, 2022; Veling et al., 2021). These novel forms of simulated nature, which we call digital nature, have demonstrated their potential to deliver similar benefits (at least to some extent) as real nature experiences. Recent studies (Brancato et al., 2022; W. D. Browning & Ryan, 2020; Kjellgren & Buhrkall, 2010) have shown the effectiveness of digital nature in stress reduction and restoration. However, while these results are compelling, the study by Kjellgren and Buhrkall (2010), for instance, underpinned limitations in current digital nature experiences, which can be less engaging and even lead to boredom over time, ultimately resulting in reduced experiential benefits.

Next to technological challenges, the current limitations of digital nature experiences stem from missing in-depth knowledge of what qualities in visual nature experiences foster relaxation. Current design applications of digital nature tend to be either a direct imitation of real nature scenes or are heavily reliant on the intuition of designers. Although theories explaining landscape preferences and restoration through nature provide a wealth of knowledge regarding the preferred characteristics of nature and the positive effects they bring, these theories alone do not translate easily into design guidelines for conceptualizing and designing digital nature. In other words, there is a substantial gap between the theories and the concrete design of relaxing experiences using interactive systems. Hence, it is crucial to understand what qualities of visual nature experiences lead to relaxation and how those qualities can be translated into the design of dynamic and interactive visual experiences effectively.

It is also important to note that the same nature scenes can be perceived differently depending on personal characteristics (Nisbet et al., 2009; Regan & Horn, 2005) such as one's relationship with nature (e.g., a strong or weak subjective connection with nature) and one's current mood states (e.g., being in a tense or cheerful mood). Nature relatedness (NR) refers to the way one views one's relationship with nature, in other words, to what extent one includes nature as part of one's identity (Nisbet et al., 2009). As a consequence, individual differences in NR influence the extent to which people appreciate or enjoy nature (Nisbet & Zelenski, 2013).

One's mood state is another important personal characteristic to consider. Moods are the affective background that is pervasive and long-lasting (Davidson, 1994; Parkinson et al., 1996; Xue et al., 2020) and moods constantly influence how people perceive and experience the world (Davidson, 1994; Xue et al., 2020). Henceforth, moods influence our experience of nature. For example, some people may find a walk in nature to be extra relaxing when they are tired, as it offers a contrast to the fatigue they are experiencing, including a change of scenery and a sense of rejuvenation. We postulate that, influenced by nature-relatedness and mood state, the same nature environment can be experienced differently, thereby resulting in different level of affective responses.

Previous studies have explored the effects of nature on mood enhancement (A. P. Anderson et al., 2017; O'Meara et al., 2020), as well as NR (Leung et al., 2022). However, the results of these studies are known to be inconsistent and warrant further investigation (Spano et al., 2023). Furthermore, there has been limited focus on the differences in various mood states concerning their perceived relaxing effects induced by nature experiences, even though this knowledge can be valuable for assisting designers in creating more personalized design solutions.

To address these conceptual and methodological gaps, this paper aims to develop a more nuanced understanding of visual experiences of nature-induced relaxation and the roles that personal characteristics play in the experiences.

We expect that there are widely varying qualities of nature experiences that serve different functions in inducing relaxation. Furthermore, we anticipate that the effects of nature experiences are perceived differently by individuals and are influenced by NR and mood state. Specifically, we predict that high levels of NR and negative mood states result in a greater need for relaxation and hence are correlated with stronger relaxation induced by nature. Based on the foregoing, we propose that:

H1: There is great diversity in the qualities of relaxing visual nature experiences, beyond what is explained by evolutionary theories, and they serve distinct roles.

H2: People with a high NR level will experience more nature-induced relaxation compared to people with a low NR level.

H3: People with a negative mood will experience more nature-induced relaxation compared to people with a positive mood.

The resulting insights will enable a systematic application of nature qualities into the design of future interactive systems that can induce relaxation. In the following sections, we first review current applications of nature experiences in HCI and the theoretical foundation of nature-induced relaxation. Next, we report on the process and results of an empirical study that identifies diverse qualities of relaxing visual nature experiences and reveals how NR and mood state influence their perception. Based on the results, we propose a framework that supports the design of personalized relaxing visual experiences with digital nature and discuss their design implications.

## 2. Related work

In this section, we review and discuss prior work on relaxing nature experiences. We first show how digital nature experiences have been studied in HCI. Next, we highlight the concept of relaxation based on mood theory. Lastly, we discuss theories that explain the affective responses to nature experiences, along with studies that investigated the qualities in nature inducing relaxation, and outline the existing knowledge gap.

### 2.1. Simulated nature experiences in HCI

HCI researchers have explored how technology can facilitate nature experiences for relaxation and other benefits. For instance, a VR display was developed for patients with psychiatric disorders to provide immersive 360° nature videos for relaxation (Veling et al., 2021). In a randomized crossover trial with 50 patients, this VR-supported relaxation session was found to be significantly more effective in temporarily improving anxiety, sadness, and cheerfulness than a standard relaxation session. An interactive behavioral health room concept (see Figure 2) was created to provide a soothing experience catered to behavioral health patients using an immersive projection of diverse nature themes such as forests, oceans, and starry nights (Maltha, 2022). The pilot study in a clinical setting showed that patients staying in a room with this interactive virtual nature



Figure 2. Philips Ambient experience room for behavioral health patients. Used with permission. Photo from Philips. ([www.philips.com](http://www.philips.com)).

experience tended to exhibit reduced violent behavior, a decreased need for restraints and sedation, and shorter lengths of stay (Maltha, 2022).

Vella et al. (2022) developed a networked garden concept using an Internet of Things (IoT) system to capture and present diverse nature sounds and images (e.g., video of birds calling) and demonstrated in a user test with a small group of local participants that it can stimulate engagement with nature. Feng et al. (2019) focused on multi-sensory engagement for people with dementia and proposed a concept combining ambient displays with nature scenes and a zoomorphic social robot to amplify a soothing effect and reduce anxiety, depression, and social isolation. A user test evaluation with nine dementia patients showed that this concept with a multi-sensory nature experience can elicit positive emotions, communication, and social bonding (Feng et al., 2019). Radikovic et al. (2005) developed a simulated window—making use of real-time rendered scenes corresponding to the viewer’s perspective—and emphasized the importance of three-dimensional properties such as motion parallax. Their study demonstrated how these properties make nature experiences more realistic, which is important considering that the evaluation with a small group of participants showed that realistic nature experiences using a simulated window have a greater effect in eliciting positive moods than less realistic ones from static images (Radikovic et al., 2005).

These diverse technological applications of simulated nature produced health benefits (Feng et al., 2019; Radikovic et al., 2005; Veling et al., 2021), and showed they could provide a greater therapeutic effect than less immersive technologies.

Despite promising technological applications of simulated nature in HCI, insights into or guidelines on how to create the actual content of nature experiences are still limited. Studies often consider nature content either at a very generic level (e.g., various nature scenes without specifying their intended effects) (Veling et al., 2021), or with a limited range of qualities (e.g., greenness or calming motions in nature) (Maltha, 2022), or for a limited time-span of the experience. Although some visual elements (e.g., exposure to repetitive or similar scenes) can generate a relaxing effect in

the short term, they could induce negative experiences (e.g., boredom and feeling disconnected) after a while (M. H. E. M. Browning et al., 2019). Furthermore, if the content mismatches with one's psychological needs, it can lead to undesirable effects (e.g., causing disruption when focus is required) (Newbold et al., 2017). To design effective digital nature, we need an empirical foundation that can inform us about which nature qualities contribute to a relaxing experience. This includes not only how to create the scene itself, but also how to arrange different scenes over time. Furthermore, it is important to understand how to systematically integrate various qualities of nature experiences to achieve the intended effects that correspond to one's psychological needs.

## 2.2. Relaxation as a mood state

Since relaxation is commonly used as a design goal in simulated nature experiences, there is a need to establish a better understanding of its concept. Being relaxed is a specific mood type. Mood theory explains that moods contribute to our well-being by monitoring the state of our internal resources (i.e., physical, psychological, and social) compared to perceived environmental demands and regulates the resources by changing our thoughts and actions toward investing or restoring resources (Frijda, 1994; Xue et al., 2020). For instance, when in a state of low resources (e.g., feeling tired), people tend to restore resources by retreating from situational challenges, while in a state of recharged resources (e.g., feeling energetic), they are more likely to be enthusiastic and optimistic toward new opportunities and events happening around them.

Combining energy and tension dimensions, Thayer (2001) distinguished four types of mood states: *Calm energy* (high energy-low tension), *Calm tiredness* (low energy-low tension), *Tense energy* (high energy-high tension), and *Tense tiredness* (low energy-high tension); and argued that calm energy is optimal as in this mood, people experience a balance of energetic and calm (absence of tension) without experiencing tiredness and negative emotions such as anxiety or fear. The state of calm energy is widely promoted in the healthcare context and often referred to as *being restored*, which indicates a state of recovery from high or low physiological and psychological arousal through energy recharge and positive change (Ulrich, 1981, 1984). *Relief* is similar to restoration in the sense that it involves a positive change: it occurs when people encounter any kind of conflict (e.g., harm, threat, or loss) in pursuit of their goals and subsequently experience the desired change (e.g., the removal of conflicts or the realization of something hoped for) (Lazarus, 1991). *Relaxation* is also popularly used in the healthcare context. In studies of mood and emotion (Desmet, 2012; Xue et al., 2020), being relaxed is considered a mood state free of tension or concerns such as feeling at ease, mellow, comfortable, peaceful, light-hearted, tranquil, and calm. Hence, it focuses mainly on tension reduction.

Following Thayer's (2001) concept, which also includes energy recharge, in this study, we focus on the aspects of

relaxation as the state of being balanced in both physical and psychological dimensions. Hence, relaxation in this study refers to the state in which one feels sufficiently recharged while being free from tension whereas negative moods surface when one is low on energy or under high stress and tension (Thayer, 2001; Xue et al., 2020). There are various ways to regulate moods including engaging in relaxing (sensory) stimulation, activities, or thoughts (Kim et al., 2022). In healthcare, relaxing visual stimuli, including nature scenes or objects (e.g., plants), have been frequently used as they are relatively easy to apply while highly effective in providing relaxation (Ulrich, 1979).

## 2.3. Nature experiences inducing relaxation

Several theories in environmental psychology have suggested what kinds of qualities in nature experiences bring relaxing effects. Major theories in this domain share the common ground yet can be categorized into two groups based on their dominant focus: (1) our innate connection to nature as in evolutionary-based accounts of nature experience, and (2) the experiential benefits of nature coming from our cognitive and sensory processes involve in nature experience. Theories taking the first perspective include BH (Wilson, 1984), PRT (Appleton, 1975), SH (Orians & Heerwagen, 1992) and SRT (Ulrich, 1983; Ulrich et al., 1991). BH proposes that humans have an innate emotional affiliation to other living organisms, and this affiliation is "hardwired" to respond emotionally to survival-relevant natural entities (Wilson, 1984). Other theories including PRT, SH, and SRT follow the same principle and suggest that nature qualities that provide strategic opportunities for survival elicit aesthetic pleasantness (Appleton, 1975; Orians & Heerwagen, 1992) and moderate arousal and negativity (Ulrich, 1983; Ulrich et al., 1991). These theories also specified corresponding physical qualities in nature: *an opportunity to see* (e.g., openness, panorama), *a shelter to hide* (e.g., climbable trees with spread canopy), and *resource availability* (e.g., water, biodiversity). See Table 1 for an overview.

On the other hand, theories departing from the second perspective focus on the experiential effects of nature such as ART (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995) and PFA (Joye & van den Berg, 2011). ART is based on a cognitive framework that differentiates voluntary (directed) attention from involuntary attention and explains that voluntary attention is critical to cope with the various demands posed by modern society, while its prolonged use can lead to fatigue (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995). ART postulates that when the nature environment contains qualities such as a sense of *being away* (conceptual shift from habitual activities and concerns), *fascination* (qualities in nature that capture effortless attention), *extent* (a sufficiently rich and coherent environment that can constitute a whole other world), and *compatibility* (environmental support for personal inclinations and purposes), it restores our direct attentional capability and brings restoration (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995). PFA also concerns the restorative effects of nature scenes, with a focus on fluent

**Table 1.** Qualities of nature described in theories explaining landscape preferences and restoration through nature.

Biophilia hypothesis (Wilson, 1984)	Prospect-refuge theory (Appleton, 1975)	Savannah hypothesis (Orians & Heerwagen, 1992)	Stress reduction theory (Ulrich, 1983; Ulrich et al., 1991)	Attention restoration theory (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995)	Perceptual fluency account (Joye & van den Berg, 2011)
<ul style="list-style-type: none"> <li>Biological diversity</li> </ul>	<ul style="list-style-type: none"> <li>Prospect: panoramas, vistas, depth cues, convex surface</li> <li>Refuge: place with a sense of boundary, access to refuge, or an escape route</li> </ul>	<ul style="list-style-type: none"> <li>Prospect: open grassland for a clear view to the distance, a big sky for a wide view</li> <li>Refuge: clustered climbable trees with spreading canopies</li> <li>Resource availability: high diversity of plant and animal life, scattered bodies of water</li> </ul>	<ul style="list-style-type: none"> <li>Affective environmental impression (<i>Preferenda</i>): moderate to high level complexity, structural properties establishing a focal point and patterning coherence, high depth, even ground surface texture, deflected vistas, lack of treat/tension, water</li> </ul>	<ul style="list-style-type: none"> <li>Sense of being away</li> <li>Fascination</li> <li>Extent</li> <li>Compatibility</li> </ul>	<ul style="list-style-type: none"> <li>Fractality</li> </ul>

visual processing rather than evolutionary factors (Joye & van den Berg, 2011). PFA posits that attention restoration and stress reduction are by-products of effortless processing, facilitated by visual fluency in nature scenes (Joye & van den Berg, 2011). Joye and van der Berg (2011) explained this quality in nature scenes as *perceptual fractality*, meaning self-similarity across a wide range of scales of magnitude. Table 1 summarizes these theories.

While these theories explain the basic mechanisms of nature-induced relaxing effects and what nature properties and qualities can be used, they tend to be generic to represent the richness and diversity that nature experiences offer. Think, for example, of how recognizing seasonal change from leaves turning red and brown can create a feeling of anticipation about the coming season, or of being amazed and feeling in awe of the beauty and vastness of the Northern lights. To benefit from the opportunities that the diversity of nature experiences can bring to the design of interactive systems, this study attempts to explore visual nature experiences in all their richness.

## 2.4. Biophilic design

Biophilic design is aimed towards integrating diverse values of nature experiences into design practice by analyzing nature stimuli and creating actionable knowledge. Research into biophilic design was pioneered in the field of architecture. The studies by Kellert (2008, 2018) and Browning and Ryan (2020) proposed a systematic interpretation of biophilic design and provides an extensive list consisting of 15 to 72 qualities ranging from *natural shapes and form* (e.g., biomimicry, geomorphology) to *natural patterns and processes* (e.g., information richness, fractals) (see Zhong et al., 2022 for an overview). While findings from these studies provide designers with a good overview of nature entities that can be used in design practice, they bring several limitations for HCI designers. First, they are developed specifically for the design of the built environment and miss qualities that are important for the use in HCI (e.g., motion, direction, and perspective). Second, these lists are based on Biophilic theories which focus on the preconscious level of nature experiences. This is only a partial element of interaction design or experience design as they also involve different levels of cognitive processes (Desmet & Hekkert,

2007; Ludden & van Rompay, 2015; Norman, 2004). Third, these lists do not specify which entity leads to which experiential effect. Therefore, to apply Biophilic design to HCI, we need more comprehensive and structured information about relaxing nature experiences taking into account experiential values and their underlying working mechanism.

Focusing on experiential effects, Kim et al. (Kim et al., 2022) identified a list of nature qualities that induce relaxation such as *mind-clearing* (a quality supporting one to focus on the self by emptying concerns and disturbing thoughts) and *mellowing* (a quality softening and brightening up one's mind by making one feel cozy and dreamy). While their study provided a more nuanced understanding of nature qualities, further investigation is required when applying the findings to visual experiences, as their focus was primarily on general nature experiences. Furthermore, the influence of personal characteristics has not yet been considered in aforementioned studies. To better cater to dynamic personal and contextual needs and to optimize relaxing effects, our study addresses this gap by examining how mood and NR influence nature experiences.

## 3. Method

To explore how different qualities foster relaxing visual experiences and to study the roles of personal characteristics, we designed a mixed-method study consisting of an online survey and a semi-structured follow-up interview. The online survey was set up to learn how different visual qualities of nature contribute to the experience of relaxation, and how personal characteristics (mood and NR) influence relaxing experiences. A follow-up interview explored further which specific visual qualities of digital nature stimuli contributed to perceived relaxation and which physical properties are involved. All methods described in this section were approved by the Ethics Committee of the University of Twente, the Netherlands (reference number: 2021.67).

### 3.1. Participants

For the online survey, we used convenience sampling. 35 participants (21 men, 14 women) were recruited from different age groups: 18 in their 20s, 11 in their 30s, 4 in their 40s, 1 in their 50s, and 1 in their 60s. The sample was

diverse in terms of country of origin; 13 nationalities were represented, with 23 European, six Asian countries, three South American, two North American, and one Oceanic. Fifteen of these participants took part in a follow-up interview. The interview sample was also diverse in terms of age and nationalities: their age ranged from 21 to 60 plus (8 in their 20s, 4 in their 30s, 1 in their 50s, and 1 in their 60s). The interview sample included participants from six nationalities: 10 from European countries, 2 from South America, 2 from North America, and 1 from an Asian country. All participants were recruited through university notice boards and social media and those who participated in the interview received a 10-euro gift card.

### 3.2. Nature video clips containing different relaxing qualities

A total of 16 video clips representing eight qualities (two per quality) were developed for the online survey by building on the typology of relaxing qualities in nature-based stimuli (Kim et al., 2022). We used this typology as it provides the categories of qualities based on their distinctive experiential effects. Most included qualities are related to existing theories explaining landscape preference and restoration induced by nature (Appleton, 1975; Orians & Heerwagen, 1992; Ulrich, 1983; Ulrich et al., 1991; Wilson, 1984) and one theory sometimes contributes to several categories if it involves multiple experiential effects. For instance, in the case of ART, the process of leading to restoration (recharging) involves various other phases, including nature experiences evoking gentle and unforced attention (immersing), minimizing stimuli causing direct attention (calming), and allowing one's mind to wander (mind-clearing). As a result, ART is relevant to multiple categories. To explore video clips that represent each quality, we created an initial list of associated qualities by interpreting the example quotes and related literature provided in the typology (Kim et al., 2022). Table 2 shows the full list of relaxing nature qualities and associated qualities.

All video clips were collected from *Pexels.com*, an online platform providing copyright free multi-media content. As our scope was to understand one's visual experience of nature, we selected video clips containing nature content that is close to real-life experiences. Therefore, we selected video clips portraying an eye-level perspective (e.g., no drone view), from a one-person perspective (e.g., no two-shot angle), at a natural speed (e.g., no slow or fast motion), and of natural size (e.g., no extreme close-up). We made one exception for the video clip for the quality *awe-inducing* (video 7 – Starry night), which contains a long shot that amplifies the effect of awe. We avoided video clips that contain strongly recognizable landmarks or too much built environment. In terms of content, we tried to diversify the landscape, nature phenomena, and time (of day) and season of nature scenes, as much as possible. As we intended to assess a variety of video clips with different qualities, we edited all selected video clips into the same duration of 11 seconds, which was the most commonly found duration

amongst selected videos from *Pexels.com*. The decision of duration was also made considering the practicality of the study and the burden of participants: each video clip should represent a distinct relaxing quality, but it should also be manageable for participants to quickly go through them. Short video clips (e.g., 10-second-long videos) have been found to be effective in engaging viewer's sense of immersion (Wang, 2020). Audio was not included in these video clips as our scope was to study visual stimuli.

The first author collected four video clips for each of the eight qualities (a total of 32 video clips) and narrowed them down to two per quality (a total of 16 video clips) based on whether the video clips distinctively represent their assigned quality. A pilot test took place with two design researchers with at least 10 years of experience to assess the initial selection of the video clips. The researchers scored each video clip on a 5-point Likert scale based on the extent to which they perceived eight qualities (including assigned quality) from the video clips. Three out of sixteen video clips were rejected as they scored lower than 3, indicating that their representation of the intended quality was not strong enough. For the final version of the selection, these video clips were replaced with new video clips which better represented the intended qualities (as indicated by the high scores of both researchers). The pilot test also verified that the duration of the video clip (11 seconds) served the purpose of the study as it allowed participants to perceive and assess various relaxing qualities in the video clips. The final version of the video selection is presented in section 4.2, Figure 3.

### 3.3. Procedure

#### 3.3.1. Online survey

Participants were instructed to take the online survey using their laptop in a quiet area for minimal distraction. All participants began by reading an introduction to the study, which described the aim of the study, the associated risks, compensation, and deidentification of collected data. Participants who gave their consent then filled in demographic information and self-assessed their mood by rating the extent to which their current mood state aligned with the eight common mood types classified by Desmet et al. (2012) – excited, cheerful, relaxed, calm, bored, sad, tense, and irritated – using a 5-point Likert scale. Next, participants filled out a short-form version of the nature-relatedness scale (NR-6) (Nisbet & Zelenski, 2013). This scale consists of six items such as “*My ideal vacation stop would be a remote, wilderness area,*” and “*My connection to nature and the environment is a part of my spirituality.*” Finally, participants watched 16 video clips, each lasting 11 seconds, in a randomized order. After each video, they rated the extent to which the video clip was perceived as relaxing on a 5-point Likert scale. Furthermore, each video clip was also rated on the eight relaxing qualities using a 5-point Likert scale, following the instruction: “*Please indicate the extent to which you agree with each statement.*” Eight relaxing qualities were framed in plain language, for instance, instead of “*immersing,*” the following sentence was used; “*it captures*

**Table 2.** Relaxing qualities included in this study with their definition and associated qualities.

Relaxing qualities	Original definition	Definition in plain language	Related theories	Associated qualities
Awe-inspiring	Making one become suddenly aware of something remarkable that leads to positive feelings and thoughts	It opens my eyes and gives a new perspective.	-	Gorgeousness, extraordinary, vastness
Calming	Reducing tense energy and leading one to a peaceful calm state of mind	It calms me down.	Stress reduction theory (Ulrich, 1983; Ulrich et al., 1991), Attention restoration theory (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995)	Calmness, stillness
Immersing	Strongly holding one's attention and eventually leading one to focus on the moment	It captures my attention.	Attention restoration theory (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995)	Extraordinary, attractive, repetitive movements
Mellowing	Softening and brightening up one's mind to think in a positive way by making one feel cozy and dreamy	It makes me feel dreamy.	-	Element reminding holiday feeling, pleasantly warm
Mind-clearing	Supporting one to have a clear state of mind and to focus on the self by emptying concerns and disturbing thoughts	It clears my mind.	Stress reduction theory (Ulrich, 1983; Ulrich et al., 1991), Attention restoration theory (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995)	Emptiness, openness, quietness
Reassuring	Resolving one's tension by making one feel safe and better	It makes me feel safe.	Prospect-refuge theory (Appleton, 1975), Savannah hypothesis (Orians & Heerwagen, 1992)	Being surrounded, seeing without being seen, the presence of other living being
Recharging	Resolving tiredness and fatigue and giving a feeling of being recharged	It makes me feel recharged.	Stress reduction theory (Ulrich, 1983; Ulrich et al., 1991), Attention restoration theory (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995)	Greenness, pleasantly cold
Uplifting	Creating positive tension by supporting one to feel inspired, happy, and energetic	It brightens up my mood.	-	Vibrance, beauty

*my attention.*” The full list of questions is available in Appendix A (Figure A1, Table A1). The procedure was conducted individually and took an average of 30 minutes.

### 3.3.2. Follow-up interview

After completing the online survey, participants filled in their available timeslots for a follow-up interview. Interviews were taken with individual participants between three and seven days after the online survey. At the beginning of the interview, participants were informed about the aim of the interview, associated risk, and deidentification of collected data, and gave their consent for the interview to be recorded. During the interview, participants watched the video clips they scored as most and least relaxing again to refresh their memory. Next, they were asked to explain why they (dis)liked the video clips and what aspects of the video clip made them feel (un)relaxed. The number of video clips varied from three to five as sometimes multiple video clips were scored equally high or low. The interviews lasted for 30 minutes each and were both audio- and video-recorded. The collected data were transcribed for analysis.

### 3.4. Analysis

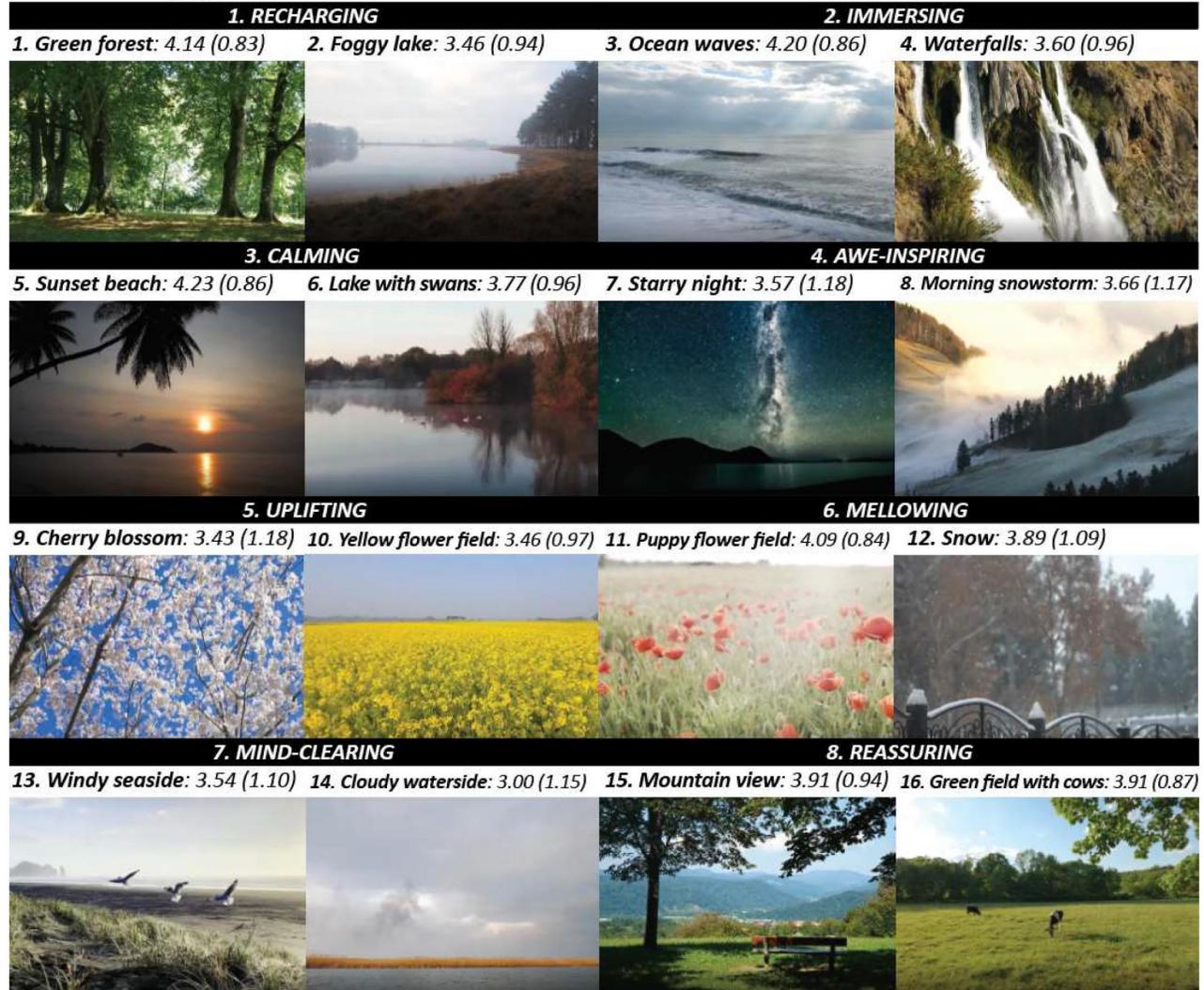
Quantitative data from the online survey were analyzed by using IBM SPSS Statistics Version 28. Qualitative data in the form of verbatim transcripts from follow-up interviews were analyzed through reflexive thematic analysis (RTA) (Braun &

Clark, 2006): the first and third authors first independently read the transcripts to familiarize themselves with the dataset; they then labelled sections of participants' responses (i.e., codes) through open coding. These codes captured information relevant to the research question i.e., which qualities of the video clips contributed to the relaxing visual experience according to the participant. Similar or repeated codes were removed. Through axial coding, the results of open coding were re-analyzed to identify important and general concepts (Creswell, 2013). The experienced qualities were derived from clustering recurring patterns between codes. The qualities were then interpreted by the first and third authors and grouped into quality themes. Next, the first author created a converged framework of quality themes and corresponding qualities. Finally, this framework was refined into a final version through independent discussions between the first author and the co-authors.

## 4. Results

The findings we report in this section converge around two primary research foci. The first is identifying qualities of nature video clips contributing to relaxation. From the analysis of interview data, we identified a list of relaxing qualities, and found distinctive roles of these qualities in inducing relaxation. Next, we collected the perceived relaxation scores of the nature video clips. By comparing these scores to the identified qualities, we draw the relationship between qualities and relaxing experiences and propose a

Video name: Mean (SD)



**Figure 3.** 16 videos representing 8 relaxing qualities of nature experiences. Image captures of the videos from Pexels.com. (Pexels.com). all videos can be found from supplementary materials.

framework that summarizes the insights. Secondly, we focus on the impact of personal characteristics, mood states and NR, on perceived relaxing experiences. Through univariate analysis, we outline how the differences in personal characteristics influence the perceived relaxing experiences of individuals. The following sections explicate these findings providing illustrative quotations from participants.

#### 4.1. Four themes of relaxing qualities in nature video clips

From the analysis of interview data, we identified that when participants view nature scenes in the video clips, they perceive certain qualities that characterize their visual experiences. For instance, from the video 9 - cherry blossom (nature scene), a participant perceived colors that are vibrant and catchy (qualities), that make the person feel brighten up (visual experience): “Very vibrant colors, they are very catchy and brighten up my mood” (P4, video 9).

To get detailed information on what qualities characterizes visual experiences in these video clips and how they

contribute to relaxing experiences, we conducted thematic analysis focusing on underlying qualities of the video clips. A total of 20 qualities were identified and categorized into four higher-level themes based on the role that qualities play in the process of inducing relaxation. Four themes are described below:

1. **Engaging qualities:** We identified qualities that direct and sustain one’s interest in the scene. In other words, they trigger and help one to picture themselves in a scene and by doing that, increase the chance of bringing and enlarging the effects of the scene. For instance, *Affordance* helps one to easily engage with a scene by triggering their (imagined) action possibilities in the scene, such as sitting on a bench or running into the sea: “I was envisioning myself sitting there (on a bench)” (P6, video 15), “The distance to the sea is very interesting. It creates some willingness to run (to reach the shore)” (P13, video 3). Motion qualities, such as *Soft dynamics* and *Hard dynamics*, were also found to be effective to keep one’s focus on the scene: “The waves

are like fire, you can endlessly look at it. It's the same but different all the time" (P10, video 3), "The birds are capturing my attention. Their movements are energetic" (P3, video 13).

2. **Instinctive qualities:** We identified a group of qualities related to our survival instincts as human beings – qualities that provide strategic opportunities to see, hide, and explore – and evoke immediate positive affective reactions to the scene. For instance, qualities like *Familiarity*, *Observatory*, *Refuge*, and *Quietude* were observed to automatically generate a feeling of safety, contributing to increased comfort and peacefulness: "I kind of grew up in the seaside (...). It makes me feel safe. Because I spent a lot of time at the sea, I feel comfortable" (P3, video 3), "The openness really helped me to relax" (P1, video 3), "The fact that trees are surrounding you gives you a feeling of protection" (P15, video 1), "The fact that nothing much is happening other than the movement of the water feels very peaceful" (P4, video 4).
3. **Ambient qualities:** We identified certain qualities that define the characteristics of an atmosphere, which can influence an individual's mood state in such a way that their mood becomes synchronized with that of the atmosphere. For instance, *Lively* qualities can affect one to feel pleasantly active and uplifted: "I also always like the contrast of the colors. very vibrant colors" (P6, video 9). On the other hand, *Diffused* qualities can make one feel calm: "You don't have an obvious stimulus to look at. It's a calming color" (P7, video 2). Some qualities

associated with the time of day, such as *Morning-like* or *Evening-like* atmosphere, are found to support one in aligning with the corresponding mood: "It also has that morning feeling with small water drops on the leaves. (...) It feels like a new day and that I am ready for the new day" (P12, video 11), "The sunset is beautiful. it creates the mood of the evening. makes me sleepy" (P11, video 5).

4. **Derivative qualities:** We identified that secondary experiences can enhance relaxing experiences. These experiences consist of qualities that are not present in an actual nature scene but are derived by viewing the scene. They induce affective reactions that contribute to relaxation. Taking an example of *Sensation-inspiring*, a type of Derivative quality, ocean waves can lead to recollection of a sound that is not actually present in the video clip, but makes the experience more relaxing: "I can hear the sound of the sea. Yes, the sound was not on, but I can hear the sound in my head" (P1, video 1). Other secondary experiences that amplify relaxation include recalling pleasant memories (*Memory-inspiring*) and reflecting on a scene from a different perspective (*Reflection-inspiring*): "It brings back fond memories of my childhood because I used to play in an area very similar to this" (P13, video 1), "The sky is open, it's endless. It makes me think that I am just a little person" (P5, video 7).

An overview of these four themes, identified qualities and example quotes is provided in Table 3.

**Table 3.** Experienced qualities and higher-level themes contributed to relaxing nature video.

Quality Themes	Qualities	Example quotes
Engaging	Affordance*	"I was envisioning myself sitting there (on a bench)." (P6, video 15)
	Beauty	"The first thing that captures my attention was palm trees. These were super pretty... also the sunset." (P6, video 5)
	Gentle flow*	"In this video, the camera was moving. I really liked it when it's moving. Because it kind of feels like I am there." (P4, video 2)
	Hard dynamics	"The power of the water falling down (in waterfalls), it is nice for me to relax." (P4, video 4)
	Soft dynamics	"The waves are like fire, you can endlessly look at it. It's the same but different all the time." (P10, video 3); "The soft vibration of the water, it is very subtle." (P15, video 5)
	Mystery (complexity)	"The shadows. It feels like you want to look there because it is a little bit dark and you want to see if there is something... like an animal." (P3, video 1)
	Longing place	"This is relaxing because it is something I long for. (...) being at the beach sounds very relaxing. I wish I was there." (P14, video 5)
Instinctive	Familiarity	"This one seems very familiar. I have been in many parks like this. It does seem like a safe place." (P4, video 1)
	Observatory	"The openness really helped me to relax." (P1, video 3)
	Positive prospects	"(...) cloud and there is this sun coming through. Hope for better weather. You can look forward to the sun." (P10, video 3)
	Quietude (uneventful)	"You can see the animals are fine. This can be reassuring. If animals are stressed then I become stressed. it means something is about to happen." (P2, video 16)
Ambient	Refuge	"The fact that trees are surrounding you gives you a feeling of protection." (P15, video 1)
	Solitary	"I found this place quite silent. And I felt like.. okay, I am alone and safe." (P3, video 2)
	Diffused atmosphere	"You don't have an obvious stimulus to look at. It's a calming color." (P7, video 2)
Derivative	Dreamy atmosphere	"It feels dreamy. The colors are very nice and bright. (...) also, it's a very light image, and slow movement. It almost feels like a Disney movie or something.. you know when it's (Disney movie) about to start." (P12, video 11)
	Lively atmosphere	"I also always like the contrast of the colors.. very vibrant colors." (P6, video 9)
	Time of day (Morning- or evening-like)	"It also has that morning feeling with small water drops on the leaves. You see the day is starting. It feels like a new day and that I am ready for the new day." (P12, video 11)
	Sensation-inspiring	"The sunset is beautiful.. it creates the mood of evening.. makes me sleepy." (P11, video 5)
Derivative	Memory-inspiring	"(It's relaxing) because I can hear the sound of the sea when I see the sea moving. Yes, the sound was not on, but I can hear the sound in my head." (P1, video 3)
	Reflection-inspiring	"It brings back fond memories of my childhood because I used to play in an area very similar to this when I was in grade school." (P13, video 1)
	Reflection-inspiring	"The sunset kind of makes me think of the solar system and the universe.. it makes you think more expansively.. and how small we are in the grand scheme of things and there is something calming for me about that." (P13, video 5)

\*: Qualities that are not necessarily nature-originated yet included as they are often an important part of perceived nature experiences. All quotes are written in *italic* and keywords related to the qualities are underlined.

#### 4.2. The relation between qualities in nature video clips and perceived relaxation scores

The mean values of the perceived relaxation scores from each video clip (to what extent a video clip was perceived as relaxing) ranged from 3.00 to 4.23. The video clips with the highest score were video 5 – Sunset beach ( $M=4.23$ ,  $SD=0.86$ ), video 3 – Ocean waves ( $M=4.20$ ,  $SD=0.86$ ), and video 1 – Green forest ( $M=4.14$ ,  $SD=0.83$ ). The least relaxing video clips were video 14 – Cloudy waterside ( $M=3.00$ ,  $SD=1.15$ ), video 9 – Cherry blossoms ( $M=3.43$ ,  $SD=1.18$ ), and video 10 – Yellow flower field ( $M=3.46$ ,  $SD=0.97$ ). An overview of the scores of all video clips is presented in Figure 3 (see Figure B1 for detailed scores).

Comparing the quantitative data with the qualitative data, we observed that nature video clips with high scores on perceived relaxation tended to contain multiple relaxing qualities across different themes. For instance, the video clips with the highest relaxing score (videos 5, 3, and 1) tended to contain qualities across all four themes while video clips with the lowest relaxing score (videos 14, 10, and 9) contain fewer qualities and miss derivative qualities (videos 10 and 14). Table 4 presents an overview of qualities from the video clips with the highest and lowest relaxing score.

Interestingly, we also observed that even among the videos with the highest scores, certain qualities could be perceived as unrelaxing by some participants. For instance, video 3 was perceived as relaxing due to qualities such as familiarity. However, its lack of refuge, stemming from its dominant openness, was perceived negatively by some participants: “The sea is interesting in the sense that I used to live near the sea. I enjoy it, but not as much as the forest. I do not like the openness of the sea. I don’t feel safe.” (P7, video 3)

#### 4.3. Physical properties and experiential effects related to relaxing qualities

Through the analysis of interview data, we observed that specific physical properties in nature video clips are

associated with perceived qualities. For instance, physical properties like the vibrant color of the sky and confetti-like movements of scattered cherry blossoms contribute to lively atmosphere. A structured overview of which physical properties are related to which qualities can inspire HCI designers on how to build content that conveys the intended qualities. To provide such information, we derived physical properties associated with each of the 20 qualities from interview data and created an overview (see Table 5).

Finally, we observed that qualities create various experiential effects that lead to relaxation. Taking examples: “You don’t have obvious stimuli to look at. It’s calming color. (...) it’s calming” (P7, video 2), “Snow (scene) is relaxing for me. Snow makes things quiet, tones everything down, and creates a relaxing atmosphere” (P23, video 12). The low contrast color scheme and minimal amount of sensory input in the scene (physical properties) contributed to a diffused atmosphere (qualities) which led to a calming feeling (experiential effect).

Figure 4 illustrates the structure of the complete experience of nature video clips used in this study which was derived from the observed relationship between physical properties in nature scenes and relaxing qualities in interview data: (1) physical properties (e.g., diffused color, low stimuli) being perceived as (2) qualities (e.g., diffused atmosphere), which create (3) experiential effects (e.g., calming) leading to relaxation.

#### 4.4. The influence of nature-relatedness in perceiving nature video clips

To test whether high NR enhances nature-based relaxation (regardless of type of nature video), a regression analysis with NR as the independent variable and overall relaxation as the dependent variable was conducted. The analysis yielded a significant relationship between NR and perceived relaxation ( $B=0.423$ ;  $p=.009$ ), indicating that people with higher levels of NR experience more relaxation after watching the video clips compared to people with lower levels of NR.

Table 4. Overview of qualities from the videos with the highest and lowest relaxing score.

	Videos with the highest relaxing score			Videos with the lowest relaxing score		
	Video 5 4.23 (0.86)	Video 3 4.20 (0.86)	Video 1 4.14 (0.85)	Video 10 3.46 (0.97)	Video 9 3.43 (1.18)	Video 14 3.00 (1.15)
Engaging	Beauty Soft dynamics Longing place	Soft dynamics Longing place	Beauty Soft dynamics Mystery	Soft dynamics	Beauty Gentle flow Chaotic movements	Soft dynamics Lack of engaging elements Lack of complexity
Instinctive	Familiarity Observatory Quietude Solitary	Familiarity Observatory Quietude Positive prospect Lack of refuge	Familiarity Quietude Refuge	<i>Negative prospect</i>	Positive prospect Unfamiliarity Too eventful	Observatory Negative prospect
Ambient	Time of day	Diffused atmosphere Time of day	Diffused atmosphere	Lively atmosphere	Lively atmosphere	Diffused atmosphere
Derivative	Memory-inspiring (childhood/holiday) Reflection-inspiring (awe)	Sensation-inspiring Memory-inspiring (childhood/holiday)	Sensation-inspiring Memory-inspiring (childhood/holiday)	–	Memory-inspiring (festival)	–

Unrelaxing qualities are written in *italics*.

**Table 5.** Overview of physical properties related to experienced qualities.

Quality Themes	Qualities	Physical properties
Engaging	Affordance	Something to sit on (e.g., bench), an enjoyable area/object (e.g., seawater on the beach) within a reachable distance
	Beauty	Preferred nature subjects (followers, sky, tree branches casting shadow etc.), vibrant colors, extraordinary, symmetry, richness, gorgeousness
	Gentle flow	The gentle motion created by moving camera angle, slowly rotating panorama view
	Hard dynamics	Powerful, energetic, and dynamic movements
	Soft dynamics	Diffused, slow, subtle, and rhythmic movements, motions with unity in variety, soft movements in overall stillness
	Mystery (Complexity)	Complex pattern and shape, ambiguity, moderate level of complexity, depth, and darkness in a scene triggering interest
	Longing place	Varied from typical holiday destinations (e.g., beach) to places with extraordinary experiences (e.g., seeing the Northern light)
Instinctive	Familiarity	Recognizable, nearby nature, holiday destination-like, hometown-like
	Observatory	Openness, horizon, spaciousness
	Positive prospects	Upward perspective, blue sky, the rays of the sun (through clouds)
	Quietude (Uneventful)	Quietness, stillness, stableness, low stimuli, calm animals, safe nature conditions (e.g., calm sea)
	Refuge	Enclosed, nebulous refuge (e.g., mist)
Ambient	Solitary	Quietness, solitary
	Diffused atmosphere	Diffused colors, low contrast color, a balance between light and darkness, low stimuli
	Dreamy atmosphere	Bright and light colors, slow and diffused movements, gorgeousness, unusual perspective (e.g., long shot video)
	Lively atmosphere	Vibrant color, high color contrast, upward camera angle, confetti-like movements
	Time of day (Morning- or evening-like)	Time-associated nature subjects (e.g., sunset, sunrise, dew drops on flowers)
Derivative	Sensation-inspiring	The rhythmic movements of ocean waves triggering virtual ocean sound, calm breathing, and ocean smell, soft movements of followers triggering virtual tactile sensations of wind
	Memory-inspiring	Places related to childhood memories, holiday memories, or places where relaxing activities take place (e.g., cycling, running)
	Reflection-inspiring	Extraordinary, gorgeousness, vastness, unusual perspective (e.g., long shot video), nature subject reminding the grand scale of the universe (e.g., sunset, milky way)

**Figure 4.** The structure of relaxation evoked by visual nature experiences involving three elements: physical properties, qualities, and experiential effects.

#### 4.5. The influence of mood in perceiving nature video clips

To further explore the interplay between the video clips and the different mood states, we used a median split for each mood state (e.g., low *irritation* versus high *irritation*) and conducted analyses of variance with video clip and (dummy-coded) mood state as independent variables, and relaxation scores as the dependent variable. The results show no significant main effects of video clip and the interaction between video and mood ( $p's > .05$ ). However, results show significant main effects ( $p's < .005$ ) of most mood states (i.e., *irritated*, *sad*, *relaxed*, *cheerful*, and *excited*) on overall relaxation. No significant effects ( $p's > .05$ ) were observed for the mood states *tense*, *bored*, and *calm* (see Table 6).

Given no interaction effects and the limitation of conducting a median split, finally regression analyses with, respectively, each of the eight mood states as the independent variable and overall relaxation as the dependent variable were conducted. For all eight mood states, no significant effects surfaced ( $p's > .05$ ), indicating that the direct relationship between mood and perceived relaxation is not significant.

**Table 6.** ANOVA Of the perceived relaxation in video clips and mood states.

Mood Group	M	SD	SE	df	SS	F	P
Bored							
High	3.39	0.95	0.04	1	0.41	.49	.484
Low	3.34	0.81	0.06				
Calm							
High	3.38	0.88	0.04	1	.00	.00	.994
Low	3.38	0.98	0.07				
Cheerful							
High	3.59	1.08	.074	1	15.54	19.19	.00*
Low	3.25	0.77	.041				
Excited							
High	3.45	0.98	0.05	1	3.93	4.74	.030*
Low	3.28	0.80	0.05				
Irritated							
High	3.48	0.92	0.05	1	8.71	10.60	.001*
Low	3.23	0.88	0.05				
Relaxed							
High	3.30	0.89	0.04	1	5.33	6.44	.011*
Low	3.50	0.93	0.06				
Sad							
High	3.48	0.88	0.05	1	6.38	7.73	.006*
Low	3.27	0.93	0.05				
Tense							
High	3.39	0.87	0.05	1	.03	.04	.830
Low	3.37	0.95	0.05				

\* $p < .05$ .

#### 4.6. Brief discussion of the findings

This paper discusses qualities that facilitate relaxing visual experiences through various nature video clips, as well as the influence of one's mood state and NR in perceiving relaxation. The result identified 20 relaxing qualities which were grouped into four themes (*Engaging*, *Instinctive*, *Ambient*, and *Derivative*) based on how they lead to relaxation. The effects of positive distraction and reassurance of *Engaging* and *Instinctive* qualities align with the previous theoretical frameworks (Appleton, 1975; R. Kaplan & Kaplan, 1989; S. Kaplan, 1995; Orians & Heerwagen, 1992; Ulrich, 1983; Ulrich et al., 1991; Wilson, 1984) on how visual nature experiences facilitate relaxation. Our findings specify the roles of these qualities and enhance their potential applications by providing a fine-grained set of qualities. For instance, the concept of (soft) fascination from ART (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995) can now be specified with qualities such as gentle flow and soft dynamics. On the other hand, the *Ambient* and *Derivative* qualities and how they contribute to inducing relaxation have not been explicitly explained in these theories. However, various types of experiences identified as *Ambient* qualities, such as a dreamy atmosphere, can contribute to the feeling of being away from ART (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995). In the field of ambient technology, color-relevant *Ambient* qualities, have been actively applied to light technology and their influence on arousal levels has been demonstrated (Kuijsters et al., 2015). Our finding on how secondary experiences (created by *Derivative* qualities) can enrich visual experiences supports the Psycho-evolutionary framework by Ulrich (1983) which proposed the influence of previous experiences in nature experiences. Our work expands this notion by providing clues as to how previous experiences influence perception; *sensation-inspiring* and *memory-inspiring qualities* are grounded in one's previous experiences as they recall bodily sensations and pleasant memories associated with or triggered by the scenes. Conversely, *reflection-inspiring qualities* are different in the sense that they are not based on previous experiences but comprise shifts in perspective, e.g., by inducing the feeling of being in the presence of something vast that challenges our understanding of the world. We observed (in line with Anderson et al., 2018) that these *reflection-inspiring qualities* can bring a profound sense of calm and relaxation.

These four themes are also associated with the qualities from the typology by Kim et al. (2022), which was used for selecting sample videos in the present study. For instance, *Engaging* qualities are related to "Immersing," and *Instinctive* qualities are related to "Reassuring." When *Ambient* qualities increase one's arousal level, it is experienced as "Uplifting" and when they decrease, it is experienced as "Calming" from the typology (Kim et al., 2022). While these connections, along with the fact that all these themes are often found in a single video, support that the diversity of qualities in the construct of relaxing visual stimuli is important, it remains challenging to verify the distinctive contribution of each quality. Furthermore, in comparison to our findings of three distinct components in visual experiences (physical properties, qualities, and experiential effects), our

current perspective suggests that the "qualities" from the typology (Kim et al., 2022) are closer to experiential effects.

Additionally, we observed that striking the right balance between conflicting qualities could produce positive effects by supplementing one another. For example, *soft dynamics* in overall *stillness* (e.g., moving clouds combined with a static camera angle) or combining *mystery* with *familiarity* (e.g., trembling bushes—as if something small is hidden—in a familiar park-like scene) would contribute to relaxing experiences by strengthening engagement with the scene. This observation is similar to what we found in studies in aesthetics and design research that explain the effects of balancing conflicting qualities on arousal (Berlyne, 1971; Hekkert, 2006). For instance, Appleton (1975) showed that balancing conflicting qualities can increase a sense of safety and pleasure (e.g., being able to safely hide when there is danger nearby).

Evidence has shown that visual exposure to nature can increase NR (Leung et al., 2022; Soliman et al., 2017) and the effect is greater when the experience is immersive (Leung et al., 2022; Spangenberg et al., 2022). Our findings on the significant influence of NR in perceiving relaxation (people with higher NR experience more relaxation from nature video clips than people with lower NR) further reinforce the benefits of digital nature. Increased exposure to digital nature enhances NR, which, in turn, also leads to greater relaxing effects of digital nature.

Previous studies also attempted to understand the influence of mood on nature experience. The study by Regan and Horn (2005), for instance, showed that individuals' mood states influence their landscape preferences, with both *relaxed* and *stressed* moods exhibiting a strong preference for nature features over urban features. Our findings on mood are mixed and do not warrant strong conclusions on the relationship between mood and (nature-based) relaxation. Although findings suggest that individuals in several mood states (e.g., *irritated* and *sad*) experience stronger relaxing effects from visual nature experiences compared to those in other mood states (e.g., *relaxed*), clearly follow-up research is required. Related to our study, findings by Anderson et al. (2017) and O'Meara et al. (2020) show a significant effect of virtual nature experiences in enhancing negative affect. Considering this, it appears that individuals in a more relaxed mood may have also benefited from the relaxing effects of nature video clips. However, since they were already in a *relaxed* mood, the additional relaxing effects of the video clips may not have been significant.

## 5. Discussion

### 5.1. Summary and contribution

This study aimed to investigate the qualities in nature that contribute to relaxing visual experiences, and the influence of personal characteristics (i.e., mood and NR) in experiencing visual-induced relaxation. This study advances the literature by:

- Identifying 20 experienced qualities grouped into four themes based on their roles in inducing relaxing experiences (*Engaging*, *Instinctive*, *Ambient*, and *Derivative* qualities)

- Formulating a conceptual framework and three-level components (physical properties – qualities – experiential effects) that support an understanding of how these different qualities in nature lead to relaxing visual experiences
- Demonstrating how both mood and NR as personal characteristics are associated with the extent to which one experiences relaxation

The identified 20 qualities, categorized into four themes, enhance our understanding of the elements that constitute relaxing nature experiences and serve as a valuable resource for designers creating relaxing digital nature or other kinds of relaxing visual experiences. In the design process, our discovery of three-level components can assist designers in translating relaxing qualities into design language. Additionally, the list of physical properties can serve as a source of inspiration. Importantly, our results indicate that NR strongly influences the extent to which people derive benefits from visual nature experiences and suggest that people are additionally more likely to do so when in a negative mood state (e.g., high levels of *irritation* or *sadness*). When considering that in many healthcare settings such as hospitals, people experience relatively high levels of stress or anxiety, our findings are of relevance to the design of interactive systems for healing environments. In the remainder of this section, we discuss further how our findings extend current knowledge on the use of nature experience for relaxation alongside their implications for the design and development of well-being enhancing digital nature.

### 5.2. A systematic approach to creating more relaxing visual experiences

One of our key findings is that nature video clips that are perceived as highly relaxing contain qualities across all four themes (*Engaging*, *Instinctive*, *Ambient*, and *Derivative* qualities). This suggests that to design relaxing visual experiences, a scene should include multiple qualities complementing different functions: directing and sustaining engagement to the scene (*Engaging* qualities), appealing to instinctive evolutionary-based needs such as safety (*Instinctive* qualities), eliciting an affective positive ambiance (*Ambient* qualities), and encouraging secondary experiences (*Derivative* qualities). Next to their role in inducing relaxation, we observed that these qualities can lead to different experiential effects. For instance, *Engaging* qualities were deemed to provide a distraction that can alleviate tension, whereas addressing *Instinctive* qualities provides reassurance. *Ambient* qualities are more likely to produce arousal effects e.g., calming or activating effects. *Derivative* qualities can stimulate diverse affective effects, e.g., joy, awe, and nostalgia, that eventually lead to relaxation.

By proposing the three-level component model (see [section 4.3](#)), this study provides HCI designers with an understanding of how these effects are derived from physical properties in nature and can help them design relaxing visual experiences. This notion of how different qualities contribute to visual nature experiences and how they manifest in nature-induced relaxation can support various stages of

design processes. For instance, when working with existing nature-inspired stimuli such as virtual nature scenes in VR or simulated window concepts, our framework and model can support the analysis of specific relaxing effects and their associated properties. This contributes to the improvements of these stimuli in serving their intended purposes. When generating new concepts for creating relaxing experiences, the four themes and the extensive list of relaxing qualities can serve as a source of inspiration. Furthermore, the list of physical properties can provide hints on how to incorporate specific qualities into design concepts.

In summary, our study offers a conceptual framework and a three-level component model that provide structured knowledge of what constructs relaxing visual experiences along with the list of qualities that serve as actionable insights for design applications. These findings can enable HCI designers to approach the development of digital nature in a more systematic manner and create greater relaxing effects.

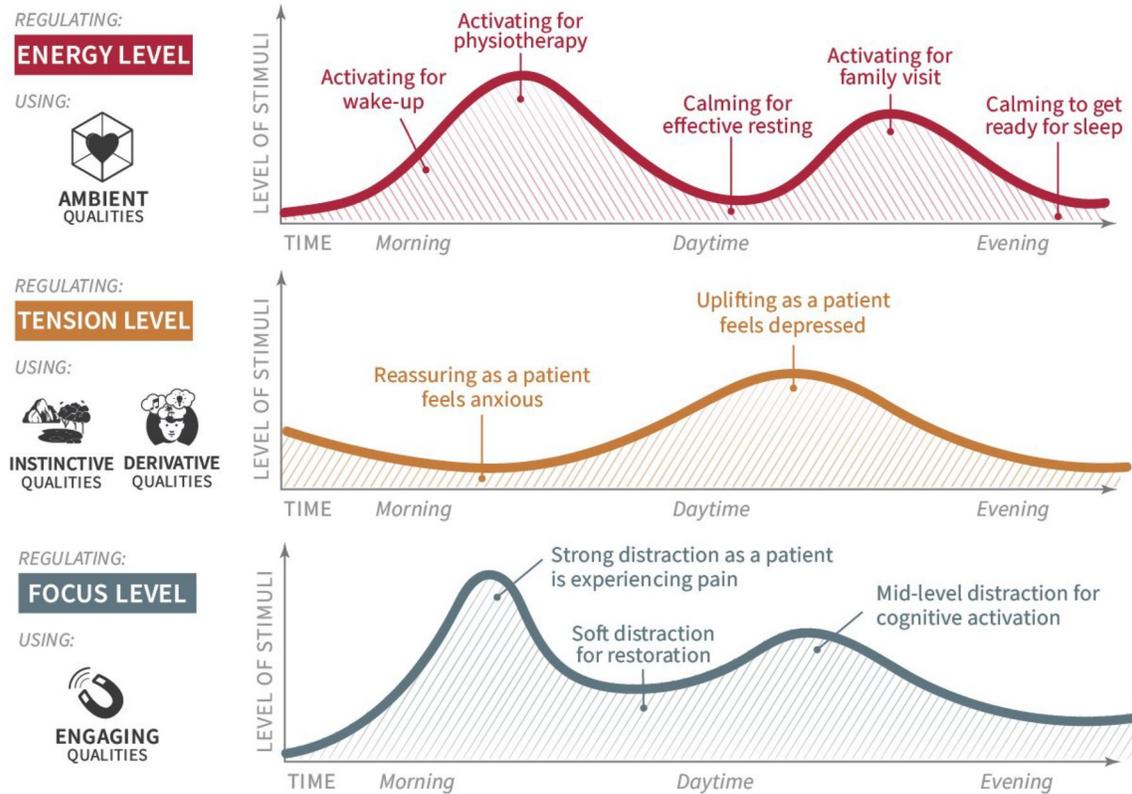
### 5.3. Toward personalized digital nature: application possibilities

Our findings also draw attention to the importance of understanding personal characteristics in creating digital nature which has been raised previously in the HCI field; existing evidence showcased that a mismatch of stimulus and personal needs can bring an undesirable effect (Newbold et al., 2017). We also observed specific and sometimes unique relations between qualities and mood states. Finding an optimal fit between these is therefore key to the design of digital nature with an optimal relaxing effect. To clarify, we provide an example of how the insights of our study can support catering to different needs (of mood states). Looking at the case of hospital environments where a variety of situational needs occur that have large influences on patients' recovery and well-being, an ambient display with digital nature could be designed that takes into account the various negative experiences that patients go through.

To support the circadian rhythm of patients who spend most of their time indoors, *Ambient* qualities could create accurate time-of-day atmospheres that support the appropriate energy level of patients throughout the day. *Engaging* qualities could direct the focus of patients away from pain and concerns. To regulate the tension level of patients, *Instinctive* qualities could be applied for a reassuring effect or *Derivate* qualities could be used to inspire pleasant memories. [Figure 5](#) illustrates an overview of how different qualities can be applied considering the fit between their experiential effects and the variety of needs of patients.

## 6. Limitations and future work

While the present paper offers new insights into the experience of relaxation in the digital-nature context, we acknowledge some limitations to be addressed in future research. The present study provides an overview of relaxing nature qualities and their key physical properties based on 16 nature video clips. These video clips may be limited in terms



**Figure 5.** The hypothetical scenario of applying different qualities considering the fit between experiential effects and the needs of patients.

of their comprehensiveness representing diverse and dynamic nature scenes. Further study could explore a wider variety of physical properties using different kinds of nature video clips. In this study, we used relatively short video clips (11 seconds). Although we found that they were sufficient for our explorative purposes, for further investigation and follow-up studies on users' perception and behavior in response to digital nature over time, we recommend using longer video clips. This would also allow fine-grained assessments of how exposure to nature videos can induce variations in mood, and to what extent long-term exposure can promote enduring shifts in nature connectedness. Additionally, although the 20 relaxing qualities in nature experiences presented in the results section are derived from interview data, their individual contributions to one's relaxing experience require further verification. Further studies could investigate this in controlled settings. While the participants had diverse nationalities, the majority were European. Further studies could be carried out with a more varied, diverse population. Furthermore, while we have gained valuable insights with the current sample size ( $n = 35$ ), validation with a larger sample size is warranted. The scope of our study was restricted to visual experiences, even though relaxation through multisensory experiences is likely to enhance relaxation. Further studies focus on relaxing qualities in other sensory modalities, such as sound, are needed to identify how they can be combined to create harmonized relaxing experiences. Although our findings highlight the importance of considering a "person-nature" fit by factoring into personal characteristics, firm

conclusions warrant additional studies in real-life settings. We invite follow-up studies to establish a solid foundation for mood-sensitive design of digital nature.

## 7. Conclusion

Emerging digital technology has enabled us to bring the health benefits of nature experiences to people encountering contextual and situational barriers. Consequently, it has become increasingly important to gain actionable knowledge on how to create visual experiences that effectively deliver the benefits of nature. This paper advances understandings of the working mechanism of visual experiences inducing relaxation and provides actionable insights into how to deliberately create relaxing nature experiences. As such, we expect that the insights from the paper can contribute to the development of digital nature promoting the well-being of people without access to real nature in a variety of contexts ranging from hospitals to long-haul flights.

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## ORCID

Chan Mi Kim  <http://orcid.org/0000-0003-0495-9158>  
 Thomas J. L. van Rompay  <http://orcid.org/0000-0002-6126-5462>  
 Gijs L. M. Louwers  <http://orcid.org/0000-0003-1173-3042>  
 Jungkyoon Yoon  <http://orcid.org/0000-0003-3955-5217>  
 Geke D. S. Ludden  <http://orcid.org/0000-0003-4508-9865>

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## About the authors

**Chan Mi Kim** is Ph.D. candidate in the Interaction Design group at the University of Twente working on the Digital Nature project with Philips Healthcare. Her interest is in human-environment interactions, specifically positive sensory stimuli inspired by nature and their implementation into the design for patient well-being.

**Thomas J. L. van Rompay** is Associate Professor in the department of Communication Science at the University of Twente. His work addresses symbolic meaning portrayals via visual communication and (product and environmental) design and their impact on behavior and well-being.

**Gijs L. M. Louwers** is Ph.D. candidate on the VitalSounds: Sounds for Clinical Well-being project with Philips Healthcare and the department of ICU at Erasmus Medical Center in Rotterdam. With Critical Alarms Lab at Delft University of Technology, he is currently investigating the effect of positive soundscapes for critically ill patients' well-being.

**Jungkyoon Yoon** is Assistant Professor of the Department of Human Centered Design at Cornell University. His research focuses on experi-

ence design with an emphasis on affective experiences, subjective well-being, and design-mediated behavior change.

**Geke D. S. Ludden** is Full Professor and chair of the Interaction Design group at the University of Twente. Her work focuses on the (theoretically informed) development and evaluation of products and services that support healthy behavior or that otherwise contribute to people's well-being.

## Appendices

### Appendix A. Questionnaires used in online survey

**Table A1.** Questionnaire for assessing overall relaxation and individual relaxing qualities.

Quality	Questionnaire
Overall relaxation	It makes me feel relaxed.
Recharging	It makes me feel recharged.
Immersing	It captures my attention.
Mind-clearing	It clears my mind.
Calming	It calms me down.
Uplifting	It brightens up my mood.
Awe-inspiring	It opens my eyes and gives a new perspective.
Mellowing	It makes me feel dreamy.
Reassuring	It makes me feel safe.



	Definitely Not	Probably Not	Might or Might Not	Probably Yes	Definitely Yes
It makes me feel <b>relaxed</b> .	<input type="radio"/>				
It makes me feel <b>recharged</b> .	<input type="radio"/>				
It captures my <b>attention</b> .	<input type="radio"/>				
It <b>clears my mind</b> .	<input type="radio"/>				
It <b>calms</b> me down.	<input type="radio"/>				
It <b>brightens up</b> my mood.	<input type="radio"/>				
It <b>opens my eyes</b> and gives a <b>new perspective</b> .	<input type="radio"/>				
It makes me feel <b>dreamy</b> .	<input type="radio"/>				
It makes me feel <b>safe</b> .	<input type="radio"/>				

**Figure A1.** Example of video assessment page in online survey.

**Appendix B. Overall relaxation and other qualities scores of 16 nature videos**

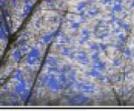
INTENDED QUALITIES	RECHARGING				IMMERSING				CALMING				AWE-INSPIRING			
VIDEO	1		2		3		4		5		6		7		8	
																
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
RELAXING	<u>4.14</u>	0.83	<u>3.46</u>	0.94	<u>4.20</u>	0.86	<u>3.60</u>	0.96	<u>4.23</u>	0.86	<u>3.77</u>	0.96	<u>3.57</u>	1.18	<u>3.66</u>	1.17
RECHARGING	3.80	1.21	2.89	1.01	3.57	1.32	3.51	1.08	3.66	1.29	3.17	1.25	3.11	1.17	3.17	1.28
IMMERSING	3.74	1.08	3.31	1.04	3.77	1.04	4.14	0.96	4.03	0.94	3.63	0.96	4.23	1.10	3.74	1.15
MIND-CLEARING	3.83	1.06	3.34	0.95	3.83	1.21	3.54	1.10	3.86	1.12	3.43	1.05	3.37	1.29	3.40	1.18
CALMING	3.89	1.06	3.34	1.04	3.94	1.19	3.40	1.15	3.97	0.97	3.54	1.02	3.26	1.29	3.40	1.10
UPLIFTING	3.69	1.09	2.57	0.90	3.20	1.33	3.49	1.11	3.80	1.12	3.03	1.06	3.34	1.24	3.23	1.17
AWE-INSPIRING	3.00	1.22	2.80	1.04	3.14	1.25	3.00	1.04	3.17	1.36	3.00	1.15	3.69	1.28	3.14	1.17
MELLOWING	3.37	1.22	3.11	1.04	3.46	1.20	3.17	1.16	4.03	0.91	3.37	1.15	3.80	1.24	3.26	1.25
REASSURING	3.63	1.07	2.83	0.94	3.11	1.17	2.91	1.00	3.60	1.07	3.23	0.99	2.94	1.19	2.97	1.11
INTENDED QUALITIES	UPLIFTING				MELLOWING				MIND-CLEARING				REASSURING			
VIDEO	9		10		11		12		13		14		15		16	
																
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
RELAXING	<u>3.43</u>	1.18	<u>3.46</u>	0.97	<u>4.09</u>	0.84	<u>3.89</u>	1.09	<u>3.54</u>	1.10	<u>3.00</u>	1.15	<u>3.91</u>	0.94	<u>3.91</u>	0.87
RECHARGING	3.17	1.30	3.09	1.18	3.49	1.11	2.94	1.19	3.40	1.38	2.69	1.12	3.54	1.20	3.40	1.22
IMMERSING	4.11	0.92	3.69	1.01	3.89	0.95	3.57	1.13	4.29	0.88	2.97	1.08	3.43	0.90	3.77	1.02
MIND-CLEARING	3.37	1.27	3.06	0.92	3.60	0.99	3.40	1.13	3.51	1.13	2.77	1.15	3.51	1.05	3.26	1.05
CALMING	3.11	1.06	3.11	1.04	3.71	0.94	3.60	1.13	3.34	1.19	3.03	1.11	3.71	0.97	3.57	0.99
UPLIFTING	3.54	1.25	3.46	1.10	3.83	1.00	3.14	1.10	3.49	1.16	2.29	1.00	3.49	1.05	3.46	1.20
AWE-INSPIRING	3.00	1.07	2.89	1.04	3.00	1.15	2.77	0.96	2.94	1.22	2.40	1.05	3.14	1.17	2.83	1.21
MELLOWING	3.26	1.25	2.94	1.07	3.66	1.31	3.54	1.15	2.83	1.18	2.60	1.05	3.17	1.11	2.77	1.12
REASSURING	3.03	1.11	2.97	1.11	3.49	1.00	2.86	1.07	3.00	1.24	2.69	1.14	3.34	1.09	3.26	1.13

Figure B1. Overview of overall relaxing and individual quality scores of 16 nature videos (three highest mean scores were underlined).