Exploring associations of older adults with virtual nature: a randomised factorial online survey

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Abstract

Loneliness and social isolation are important social determinants of wellbeing of older adults. Conversational exchanges can promote connectedness between older adults, however, conversations may not always come easy. Research shows that exposure to nature-based stimuli such as pictures and videos can stimulate social aspirations and trigger associations that could facilitate conversations, in particular when nature scenery is perceived as fascinating, mysterious, spacious and suited for social interaction. Therefore, this study investigated whether exposure to these nature characteristics (high *versus* low) lead to associations that could act as conversational material. A randomised factorial design, using a virtual reality-based approach for experimental control, led to 17 different virtual representations of nature (VN). In total, 150 participants (60 years and older) were recruited for an online survey. Spontaneous associations were coded on personal engagement and valence. The number of associations was measured with one multiple-choice question. VN exposure successfully triggered personally engaging and positively valenced associations and were related to multiple associations, in particular when the VN were high on mystery. Furthermore, positive effects of VN exposure was more pronounced for participants with high (rather than low) levels of nature relatedness and many (rather than few) available nature opportunities. These findings indicate that VN exposure provides fertile ground for conversations as a means to promote connectedness and social wellbeing of older adults.

Introduction

The social wellbeing of older adults needs to be addressed, because 50 per cent of older adults living in Europe experience loneliness (Vozikaki *et al.*, 2018). Moreover, loneliness is related to serious health issues such as depressive

symptoms, chronic and cardiovascular disease (Valtorta *et al.*, 2016; Vozikaki *et al.*, 2018) and increased mortality risk (Holt-Lunstad *et al.*, 2015). This stresses the importance of interventions that aim to reduce or prevent feelings of loneliness in older adults, of which the first step is to strengthen social interactions. Interestingly, images of nature, videos and computer-animated nature scenes can promote social aspirations (Van Houwelingen-Snippe *et al.*, 2020*b*), elicit diverse associations (Schertz *et al.*, 2018) and stimulate social interactions (Piff *et al.*, 2015). Moreover, with virtual reality development software such as Unity (https://unity.com), researchers have the potential to create and systematically manipulate nature characteristics and thereby produce virtual representations of nature (VN). Therefore, this study investigated whether VN, implemented in the current study as computer-animated nature images, can trigger associations that could serve as conversational material.

Current solutions to diminish or prevent feelings of loneliness frequently aim at increasing social interaction, including video conferencing, reminiscence interventions, discussion groups, indoor gardening and physical exercise (Jarvis *et al.*, 2020; Quan *et al.*, 2020), and most interventions have shown positive results (Gardiner *et al.*, 2018; Jarvis *et al.*, 2020). These findings indicate that various methods can be used to increase social interaction, varying in terms of setting, use of technology and availability of support. This diversity suggests that social connectedness is a multi-level concept that comprises both interpersonal interactions and feelings of connectedness to neighbourhoods and society at large (Morgan *et al.*, 2021). However, research has focused less attention on initiating social interactions, *e.g.* conversations. By having a conversation, empathy and development of new social bonds are encouraged, and intimacy and bonding in existing relationships are strengthened (Fivush *et al.*, 1996; Cohen, 1998). Therefore, an intervention aimed at stimulating conversations could possibly be a suitable method to encourage social interaction and, in turn, social wellbeing.

In research on social wellbeing, the role of the environment is generally under-acknowledged. Considering social wellbeing, however, exposure to natural environments, such as forests, parks and gardens, has been related to benefits including social cohesion and perceived social support (Keniger *et al.*, 2013). This also is apparent in the lives of older adults; a systematic review showed that horticulture therapy, such as gardening, has wellbeing and social benefits (Nicholas *et al.*, 2019), and other research showed that more urban park visits are related to having a closer social network (Enssle and Kabisch, 2020). Moreover, persons with dementia and their care-givers reported nature experiences to be important for social aspects and reminiscing (Hendriks *et al.*, 2016; Evans *et al.*, 2019), while a meta-analysis showed that horticulture promotes, amongst other aspects, social behaviour in persons with dementia (Zhao *et al.*, 2022). Hence, these combined findings suggest that nature experiences can promote social interaction among older adults.

An important question is how nature experiences can promote conversations and whether exposure to different natural environments varies in the extent to which it triggers conversational material. Previous research has shown that nature experiences can trigger a wide range of associations. For instance, research by Hendriks *et al.* (2016) showed that for people with dementia, nature experiences

can be traced to eight different benefits: social contact, reminiscing, listening to/ looking at nature, having fun, feeling useful, rest/relaxation, feeling fit and feeling free. Furthermore, Schertz *et al.* (2018) revealed that visiting parks that were closer in appearance to wild (rather than cultivated) nature were more frequently associated with topics such as spirituality and life. Accordingly, it seems that nature experiences can provide a wide range of associations that might be used as conversational material, warranting research further identifying which specific type(s) of natural environments are particularly promising in this regard.

The findings from Hendriks *et al.* (2016) and Schertz *et al.* (2018), however, do not identify specific nature characteristics (*e.g.* high or low tree density, presence or absence of water) that should be considered when selecting natural environments or designing representations of them. Regarding the types of associations triggered, arguably, associations are more suited for conversational purposes if they are personally engaging and of positive valence. Negative associations (*e.g.* bitterness revival: 'The recall of memories about unjust treatments, providing the justification to maintain negative thoughts and emotions to others'; Westerhof *et al.*, 2010: 700) are related to lower levels of mental health. Additionally, when experiencing nature leads to more associations, it also more likely provides (diverse) conversational material. The current study therefore extends previous research by investigating whether nature experiences using VN can provide conversational material by measuring personal engagement, valence and the number of associations, and seeks to pinpoint key nature characteristics.

To test the effects of nature characteristics, a virtual reality-based approach is used to allow for experimental control over the key variables. In addition, VN might prove a welcome complementary means to interact with nature for older adults who have difficulties accessing nature due to mobility constraints (Schwanen and Páez, 2010; Mitra *et al.*, 2015). Although VN cannot and should not replace real nature (Kahn *et al.*, 2009), the literature does show that representations of nature can convey similar benefits to real natural environments. For instance, VN exposure positively influences prosocial aspirations and behaviour (Zhang *et al.*, 2014; Van Houwelingen-Snippe *et al.*, 2020*b*) and feelings of connectedness to the community (Van Houwelingen-Snippe *et al.*, 2020*a*). Moreover, improved social engagement after experiencing VN was reported in a case study (Ludden *et al.*, 2019). Hence, VN might be very well suited to investigate nature characteristics and to explore the positive effects that nature experiences may have on social interactions.

Nature characteristics and the study's hypotheses

Natural environments are diverse; they vary from deserts to tropical rainforests. However, the question of which specific nature characteristics are most influential with respect to social wellbeing has been largely ignored in previous research (Marselle *et al.*, 2021). Importantly, when selecting and designing VN, strategic and practical choices must be made as to which nature characteristics are implemented, further stressing the importance of insights into relationships between specific nature characteristics and the associations they trigger. Attention restoration theory (ART; Kaplan and Kaplan, 1989), the dominant framework in studies on

nature experiences, provides four initial directions: soft fascination, mystery, spaciousness and compatibility, described in detail below along with their corresponding hypotheses.

Soft fascination is an essential characteristic of nature experiences in ART. Stressing restorative aspects of nature experiences, ART proposes that experiencing nature is restorative, as it is generally softly fascinating, *i.e.* highly engaging and at the same time non-demanding in terms of cognitive effort (Kaplan and Kaplan, 1989; Kaplan, 1995). Examples include the presence of water, leaves rustling in the wind, clouds rolling by or a field of colourful flowers. By being fascinating and aesthetically pleasing, VN experiences could trigger associations that are engaging and of positive valence. Accordingly, the following hypothesis is proposed:

- Hypothesis 1 (H1): Exposure to VN high (rather than low) in soft fascination leads to more associations with VN, more personally engaging associations and more positive associations.

Mystery (*i.e.* unpredictability; Van Rompay and Jol, 2016) also is considered a key characteristic in ART, as it stimulates curiosity and exploration by suggesting that there is more to experience if one travels deeper into a nature scene (Kaplan and Kaplan, 1989). Examples include a winding path with no obvious destination, twilight or midnight reducing overall visibility, or hills obscuring (parts of) the distant horizon (Kaplan and Kaplan, 1989). Viewing nature images that are more mysterious resulted in better cognitive (Szolosi *et al.*, 2014) and creative performance (Van Rompay and Jol, 2016). Consistent with these findings, the following hypothesis is proposed:

- Hypothesis (H2): Exposure to VN high (rather than low) in mystery leads to more associations with VN, more personally engaging associations and more positive associations.

Spaciousness (*i.e.* extent; Kaplan and Kaplan, 1989) is considered important both in ART and awe research, as it is associated with overview, opportunities for exploration and positive emotions, including awe, an emotion that is traced to interactions with vast settings that inspire a sense of feeling 'small' and feeling connected to the world at large (Keltner and Haidt, 2003; Piff *et al.*, 2015). In natural environments, such as parks and forests, spaciousness can be related to tree density, with more spacious environments having a lower tree density (Van Houwelingen-Snippe *et al.*, 2020*b*). Of relevance to the current study, exposure to more spacious natural environments has been found to enhance social aspirations, *e.g.* 'I would like to meet here with a friend' (Van Houwelingen-Snippe *et al.*, 2020*b*). Moreover, visiting parks with a spacious layout promoted personal reflection by visitors when they were invited to write down their thoughts (Schertz *et al.*, 2018). Based on these findings, the following hypothesis is proposed:

- Hypothesis (H3): Exposure to VN high (rather than low) in spaciousness leads to more associations with VN, more personally engaging associations and more positive associations.

Compatibility is described as the link between the environment and human aspirations (Kaplan, 1995). When older adults think about nature experiences, it triggers tendencies to engage in social interaction (Hendriks *et al.*, 2016). Hence, natural environments compatible with social interaction should provide affordances for doing so, *e.g.* benches for comfort while having a conversation or appropriate lighting to feel safe and secure during social interaction. In line with this notion, findings from a recent study showed that exposure to cultivated (rather than wild) nature positively affected social aspirations (Van Houwelingen-Snippe *et al.*, 2020*a*). Consequently, the following hypothesis is proposed:

- Hypothesis (H4): Exposure to VN incorporating characteristics compatible with having conversations, *i.e.* high compatibility (rather than low), leads to more associations with VN, more personally engaging associations and more positive associations.

In addition to nature characteristics, the effects of nature experiences vary depending on an individual's physical contact and mental connection with nature (Marselle *et al.*, 2021), referred to as nature relatedness by Nisbet *et al.* (2009). Generally, people with high nature relatedness spend more time in nature and are more concerned about how their behaviours affect nature (Nisbet *et al.*, 2009). Additionally, the amount of nature nearby affects time spent in nature and has been shown to, amongst other impacts, influence perceptions of social support (Maas *et al.*, 2009). Consequently, the following hypothesis is proposed:

- Hypothesis (H5): When exposed to VN, people who are more related to nature or have more nature opportunities available have more associations with VN, more personally engaging associations and more positive associations.

Taken together, soft fascination, mystery, spaciousness and compatibility are characteristics of nature environments that are hypothesised to affect positively the personal engagement, valence and number of associations people have with VN. These associations could, in turn, serve as conversational material, possibly making VN a useful instrument for promoting conversations and social interaction.

Methods and materials
Stimuli
The VN were created with purpose-built software developed using the 3D development platform Unity3D by the BMS Lab at the University of Twente. A demo version of the software is accessible online (BMS Lab, 2020). The software allows for VN environments to be authored and then exported as videos and images. The current study made use of VN environments in the form of images. *Soft*

fascination was manipulated with the presence or absence of water, which has proven to be an important antecedent of soft fascination perception (Kaplan, 1995); *mystery* with the presence or absence of hills, as Szolosi *et al.* (2014) demonstrated in their study where they obscured parts of the scene from view; *spaciousness* with low and high tree density, resulting in an open or denser scene (Van Houwelingen-Snippe *et al.*, 2020*a*); and *compatibility* with the presence or absence of a bench, which is compatible with the needs for social interaction in a comfortable setting (Kaplan and Kaplan, 1989). In the VN images, these four characteristics could be present or not, leading to 16 different VN designs. Examples of the VN images can be seen in Figure 1. For explorative purposes, one extra VN image was designed using a *night-time* version of one of the daytime versions. In total, 17 VN images were created.

Research design

A randomised factorial design was used to investigate the effect of exposure to different characteristics of VN on the associations of older adults. To balance the power of the study and feasibility of recruitment, each participant was shown four VN images. To prevent confusion caused by seeing VN images that might be too similar, four sets (Sets 1–4) of four VN images were created to ensure that the VN images within a set would deviate from each other as much as possible. One extra set (Set 5) was created that contained the night-time version of its daytime counterpart in Set 4. The other three VN images were identical in Sets 4 and 5. Each participant was randomly assigned to see one set of four VN images, which were shown in random order.

Outcome measures

Associations with the VN images were measured using three dependent variables: *personal engagement*, *valence* and the *number of associations*. Personal engagement and valence were obtained from qualitative data collected when participants were asked for their spontaneous associations with the VN images. They could type their response in a text box and were asked to be as detailed as possible when describing their self-expressed associations. In this way, the potential of VN exposure to stimulate conversations was explored. When a subsequent VN image produced associations already noted by the participant, *e.g.* when participants wrote 'Same as previous', their previous association(s) also were assigned to that particular VN image.

Personal engagement was constructed as an ordinal variable of five levels (0–4): none, observation (*e.g.* 'I see a forest'), affective judgement (*e.g.* 'nice scenery' or 'beautiful clouds'), utilisation (*e.g.* 'walking' or 'resting on that bench') and personal reflection (*e.g.* 'On this bench I see myself sitting and musing for a while' or 'This reminds me of our vacation in the Netherlands last year').

Valence was measured as an ordinal variable with three levels (0–2): negative (*e.g.* 'unattractive'), neutral/ambivalent (*e.g.* 'none', 'walking') and positive (*e.g.* 'This landscape is fantastic!'). Higher scores indicated more personal engagement or a more positive valence.
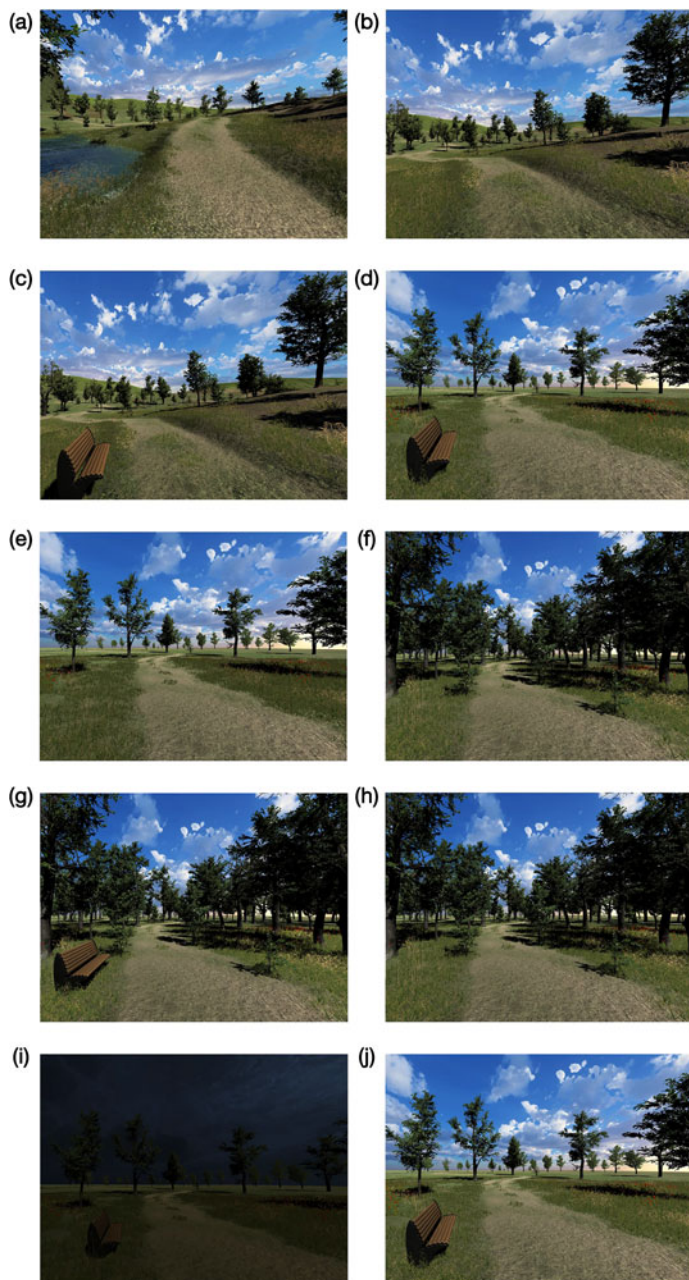
Figure 1. Examples of the virtual representations of nature (VN) images for each manipulated nature characteristic.

Notes: The VN images consisted of a high or low level of soft fascination (a = high, b = low), mystery (c = high, d = low), spaciousness (e = high, f = low) and compatibility (g = high, h = low), resulting in 16 variations. Additionally, one extra night-time VN image (i) was designed and compared to its daytime counterparts (j).

The *number of associations* was measured quantitatively using one multiple-choice question: 'Which of the following answers do you find most fitting with the image?' The participants could select more than one of the following associations, based on results from Hendriks *et al.* (2016): social contact, reminiscing, feeling free, listening/looking at nature, having fun, feeling useful, rest/relaxation and feeling fit. In addition, the participants could choose the option 'other'. Each association was measured as a dichotomous variable, and for each participant, a total score was calculated as the sum of the selected associations.

Covariates

Nature relatedness reflects an individual's connectedness with the natural world (Nisbet *et al.*, 2009) and was measured and scored using the short version of the Nature Relatedness Scale (Nisbet and Zelenski, 2013), consisting of six items (Cronbach's alpha current sample = 0.876), such as 'My relationship to nature is an important part of who I am' and 'My ideal vacation spot would be a remote, wilderness area'.

Available nature opportunities was measured using a multiple-choice question: 'Which nature opportunities are currently available to you?' There were six options: private balcony, private garden, communal garden, nearby park, nearby nature area and other. The participants could select more than one option.

Procedure

Older adults eligible to participate received either an email with a link to the online survey or, in the case of nursing home residents, staff provided a laptop with the link to the survey and helped with typing if necessary. When entering the survey, the participants were first briefed about the topic and aim of the survey. Subsequently, the survey software registered on which device the survey was performed. Only desktop computers (PCs) and laptops were allowed, and mobile devices (*e.g.* smartphones or tablets) were rejected because these devices could not show the stimuli as intended. If participants tried to enter the survey using a mobile device, they received a notification (explaining why the survey ended) and a link to start a new response on a PC or laptop. After the briefing and device checking, informed consent was obtained. When consent was not given, the participants received a notification of why the survey ended. When agreeing to consent, a non-nature example question was shown to familiarise the participants with the questions concerning their associations with VN. After the example, the participants were randomly assigned to one of the five sets. First, the self-expressed associations were measured for all four VN images in the set, followed by the number of associations of the same four VN images. Next, nature relatedness and nature opportunities were measured, and demographic characteristics were obtained. After completing the survey, the participants were debriefed about the purpose of the study and had the opportunity to leave questions or remarks. Finally, the participants were thanked for their contribution.

Participants

The recruitment of Dutch participants occurred in accord with two organisations. One in Utrecht, the Netherlands, aims to improve the digital skills of older adults.

Table 1. Overview of the demographic characteristics of the participants

Demographic characteristic	Specification	Participants (%)	Comparison between VN sets[1]	
			χ^2 (df)	p
Age	60–69	3	9.213 (12)	0.69
	70–79	61		
	80–89	28		
	90 and older	8		
Sex	Female	33	13.747 (8)	0.09
	Male	67		
	Other	1		
Educational level	Primary or secondary school	21	4.782 (8)	0.78
	Vocational degree	34		
	College or university degree	44		
Household	Single person	33	1.877 (4)	0.76
	Multiple persons	67		
Residential situation	Independent	83	6.178 (8)	0.63
	Partially dependent	3		
	Fully dependent	14		

Notes: N = 150 participants. VN: virtual representations of nature. df: degrees of freedom. 1. Comparison between all five VN sets on the demographic characteristics was performed with Pearson's chi-square (χ^2).

They recruited participants by sending email invitations to their research panel consisting of older adults. Additionally, participants were recruited in person by staff of a nursing home located in Kampen, the Netherlands. Using these two organisations allowed for the inclusion of older adults. The two organisations themselves contacted eligible participants: adults aged 60 years and over. No further inclusion or exclusion criteria were applied. In total, 263 older adults responded. Among the responses, 98 were incomplete, and two participants did not provide fully informed consent. Another 13 responses had to be removed because participants started on a mobile device. In the final analyses, 150 participants were included. The measured demographic characteristics were age, sex, highest educational level, household (single or multiple persons in their household) and residential situation (independent, partially dependent or fully dependent). Table 1 shows the percentages of the demographic characteristics of the participants and corresponding statistics. The average age of the participants was 78.3 years (standard deviation (SD) = 6.4, range = 62–98), and the majority were male (67%), had a college or university degree (44%), lived together with others (67%) and lived independently (83%). Randomisation did not lead to significant differences in demographic characteristics among the five sets of VN images ($p > 0.05$).

Table 2. Personal engagement, valence and number of associations for the total sample and for the virtual representations of nature (VN) characteristics

| | | VN characteristics | | | | | | | | | |
| | Total sample | Soft fascination | | Mystery | | Spaciousness | | Compatibility | | Night-time | |
		H	L	H	L	H	L	H	L	H	L
Personal engagement (%):											
None	3	2	4	2	4	3	2	3	3	5	3
Objective	2	2	4	2	4	3	2	3	3	5	3
Affective judgement	24	25	23	18	31	26	23	24	24	26	24
Utilisation	24	25	24	26	22	23	25	27	21	21	24
Personal reflection	47	46	47	52	41	45	48	44	49	42	47
Valence (%):											
Negative	15	13	16	9	20	18	12	16	13	68	13
Neutral	38	37	41	38	40	37	40	37	40	21	39
Positive	47	51	43	53	40	45	48	47	47	11	48
Mean number of associations (SD)	2.4 (1.5)	2.5 (1.6)	2.4 (1.5)	2.6 (1.5)	2.3 (1.5)	2.3 (1.4)	2.6 (1.6)	2.5 (1.5)	2.4 (1.5)	1.7 (1.7)	2.5 (1.5)

Notes: N = 150 participants. For the total sample, the number of responses is 600. For each level (H: high level, L: low level) of the virtual representations of nature (VN) characteristics, the number of responses is 300, except for night-time; high level is 19 and low level is 581. SD: standard deviation.

Analyses

The qualitative data (self-expressed associations) were analysed using both deductive and inductive methodology in a blended approach, also referred to as abduction (Skjott Linneberg and Korsgaard, 2019). In the first cycle, inductive analysis on a subsample revealed that associations differed on valence (positive, neutral, negative) and that associations varied on personal engagement: from none to impersonal/no personal meaning (*e.g.* 'I see a meadow') and personal meaning (*e.g.* 'This reminds me of our vacation in the Netherlands last year … [description of vacation]'). In the second cycle, all authors decided on using the above-mentioned valence codes, and consensus led to the use of four personal engagement codes (none, objective, affective judgement, personal meaning). In the third cycle, inductive coding revealed that personal meaning should be divided into utilisation and personal reflection, after which all responses were assigned a valence code and a personal engagement code. In the last cycle, the assignments of valence codes and personal engagement codes were reviewed, and the assignment of codes was finalised. ATLAS.ti version 9.1 was used for the qualitative analyses.

Results

Description of associations with VN

In Table 2, the results of the *personal engagement*, *valence* and *number of associations* are shown for the total number of responses and per VN characteristic. The associations (N = 600) provided by the participants consisted, on average, of 12 words (SD = 10). In total, 5 per cent were not categorised as an association or regarded as objective observations due to their lack of any type of engagement (*e.g.* 'does not remind me of anything' or 'I see a forest'). All other associations were personally engaging as follows: affective judgement at 24 per cent, utilisation at 24 per cent or personal reflection at 47 per cent. Associations lacking any personal engagement were the least reported (2%) after exposure to VN with a high level of soft fascination (water present), a high level of mystery (hills present) and a low level of spaciousness (high tree density). Personal reflective associations of participants were most frequently seen (52%) after exposure to VN high in mystery.

In total, the valence of the associations was mostly positive (47%), followed by neutral (38%) and negative (15%). Negative valence was most frequently seen after exposure to VN with a high level of night-time (68%), neutral valence most frequently after exposure to VN with a low level of soft fascination (absence of water; 41%) and positive valence most frequently after exposure to VN with a high level of mystery (presence of hills; 53%).

With respect to the number of associations, in the total sample, on average, 2.4 (SD = 1.5) associations were chosen. The most chosen associations after VN exposure were listening/looking at nature (50%) and rest/relaxation (50%), followed by feeling free (42%), feeling fit (28%), reminiscing (19%), having fun (16%), social contact (12%), and feeling useful (8%). The option 'other' was chosen in 19 per cent of the responses.

Exposure to VN with a high level of mystery (presence of hills) and low level of spaciousness (high tree density) led to the highest number of associations: 2.6 (SD

= 1.5) and 2.6 (SD = 1.6), respectively. Exposure to VN with the presence of night-time led to the lowest number of associations: 1.7 (SD = 1.7). The descriptive results show that VN exposure, in general, can trigger several associations among older adults, which can be (very) personal and of positive valence.

Effects of VN characteristics (H1–H4)

Soft fascination did not have a significant effect on personal engagement ($F(1, 17)$ = 0.405, $p = 0.525$) or number of associations ($F(1, 17) = 0.846$, $p = 0.358$). Soft fascination did have a marginally significant effect on valence ($U = 41,258$, $p = 0.054$), as the results showed that exposure to VN images high in soft fascination (rather than low) led to more positive associations. Second, mystery had a significant effect on personal engagement ($F(1, 17) = 13.579$, $p < 0.001$, $\eta_p^2 = 0.023$) and valence ($U = 37,456$, $p < 0.001$) but not on the number of associations ($F(1, 17) = 2.535$, $p = 0.112$). Exposure to VN images high in mystery (rather than low) led to more personal engagement and more positive associations. Third, spaciousness had no significant effect on personal engagement ($F(1, 17) = 1.350$, $p = 0.246$) or valence ($U = 42,413$, $p = 0.183$). Spaciousness did have a marginally significant effect on number of associations: $F(1, 18) = 3.394$, $p = 0.066$, $\eta_p^2 = 0.006$. Exposure to VN images high in spaciousness (rather than low) led to fewer associations. Fourth, compatibility did not have a significant effect on personal engagement ($F(1, 17) = 0.332$, $p = 0.565$), valence ($U = 44,075$, $p = 0.634$) or number of associations ($F(1, 17) = 1.304$, $p = 0.254$). Finally, night-time had a significant effect on valence ($U = 2,125$, $p < 0.001$) but not on personal engagement ($F(1, 17) = 0.288$, $p = 0.592$) or number of associations ($F(1, 17) = 1.119$, $p = 0.291$). The valence of the expressed associations was more negative after exposure to night-time VN images than after exposure to daytime VN images.

Correlations between personal engagement, valence and number of associations

Personal engagement correlated significantly with valence (Spearman rho = 0.191, N = 600, $p < 0.01$) and number of associations (Spearman rho = 0.171, N = 600, $p < 0.01$). Participants who expressed higher levels of personal engagement also expressed themselves more positively and had more associations with the VN images. Moreover, valence correlated significantly with number of associations (Spearman rho = 0.323, N = 600, $p < 0.01$). Participants who expressed themselves more positively had more associations with VN images.

Influence of nature relatedness and nature opportunities (H5)

The current results partly confirmed H5. Nature relatedness had a positive significant correlation with personal engagement (Spearman rho = 0.084, N = 600, $p = 0.039$) and number of associations (Spearman rho = 0.112, N = 600, $p = 0.006$). The participants expressed higher levels of engagement and had more associations with VN images when they felt more related to nature. Moreover, available nature opportunities had a positive significant correlation with number of associations (Spearman rho = 0.236, N = 600, $p < 0.001$). Participants with more available nature

opportunities had more associations with VN images than participants with fewer available nature opportunities. Valence was not related to nature relatedness (Spearman rho = 0.050, not significant (ns)) or available nature opportunities (Spearman rho = 0.066, ns). Because of these results, nature relatedness and available nature opportunities were used as covariates in the analyses on personal engagement and number of associations.

Discussion

The aim of the current study was to explore whether exposure to virtual representations of nature (VN) can trigger associations that can act as conversational material for older adults and to test which nature characteristics best suit this purpose. VN exposure was related to several distinct associations, and nearly half of all self-expressed associations were personal reflections and of positive valence. The number and diversity of associations show that VN exposure triggers a range of topics that can be used for conversational material. Moreover, these personal reflections can improve social wellbeing, as personal information enables people to better understand, empathise and bond with each other, thereby creating and sustaining social relationships (Fivush *et al.*, 1996; Cohen, 1998). In addition, the predominantly positive valence of the associations can be beneficial for social wellbeing since negative associations can have adverse effects on mental health (Westerhof *et al.*, 2010). Finally, the weak (though significant) association between personal engagement and valence of associations further suggests that higher levels of personal interaction with nature are more likely to trigger positive rather than negative associations, confirming the potential of nature interaction to benefit social wellbeing. This shows that, in general, VN exposure can trigger associations among older adults and that these associations are largely positive and personal and hence suitable for promoting pleasant and engaging conversations.

Regarding soft fascination (presence of water), this study could not confirm the proposed hypothesis (H1). In contrast, the literature shows that soft fascination can have restorative benefits, as suggested in the Attention Restoration Theory (ART; Basu *et al.*, 2018). However, the literature demonstrating any relationship of soft fascination to conversations or social wellbeing is scarce (Marselle *et al.*, 2021). In addition, soft fascination can be related to a wide variety of aspects in nature. For instance, apart from the current manipulation of water, consider leaves rustling in the wind, clouds rolling by or a field of colourful flowers. Follow-up studies should further explore how soft fascination relates to other nature elements and whether perceptions of soft fascination indeed benefit conversations.

The hypothesis for mystery (H2) was partly confirmed. Exposure to VN with high levels of mystery (presence of hills) led to the expression of more personal engagement and more positive associations, suggesting that hills are more suited for promoting conversation. This is in accordance with previous research in which a high level of mystery had positive effects on cognitive and creative performance (Szolosi *et al.*, 2014; Van Rompay and Jol, 2016). In ART (Kaplan and Kaplan, 1989), mystery is described as the promise that, if one were to enter more deeply into an environment, more might be experienced. Current findings suggest that exposure to mysterious nature triggers associations by presenting

something that is not fully revealed and leaves room for one's imagination (*e.g.* 'What is behind those hills?'). Next to the hills used in this study, curving pathways, partial concealment and shadows are among the kinds of characteristics that can enhance perceptions of mystery in natural environments. Future research should investigate whether other implementations of mystery can be as effective.

For spaciousness, the hypothesis (H3) was not confirmed, in contrast to the positive effects of exposure to spacious natural environments described by Piff *et al.* (2015) and Van Houwelingen-Snippe *et al.* (2020*b*). A possible explanation could lie in the fascinating qualities of dense nature (Van Houwelingen-Snippe *et al.*, 2020*b*). Moreover, it could be that dense VN images in the current study were more appealing or more realistic, as one participant wrote: 'This looks more like it, because at least a little bit of mystery and a little bit of "real" nature is suggested.' Another wrote: 'Nice woods! I continue walking and wonder what lies ahead.' Clearly, this characteristic needs further investigation.

Concerning compatibility, the hypothesis (H4) could not be confirmed. Our findings suggest that social aspirations do not differ across exposure to VN that are high or low in social compatibility. This is in accordance with the finding that social aspirations did not differ after exposure to cultivated *versus* wild nature scenes (Van Houwelingen-Snippe *et al.*, 2020*b*). An important question is, therefore, how to implement social presence in VN. Arguably, other or additional cues (*e.g.* seeing or hearing other people in a scene, or cues suggestive of the presence of others such as footsteps or the sounds of children playing in the background) might lead to more promising results.

With respect to the VN night-time characteristic, no hypotheses were formulated. The findings revealed that exposure to the night-time VN images led to significantly more negative associations. For instance, participants related the night-time VN image to sombreness and retreat because of inclement weather approaching. Night-time VN images should therefore be avoided because of the potential harmful consequences of negative associations on mental health (Westerhof *et al.*, 2010).

The results partly confirmed the hypothesis on nature relatedness and available nature opportunities (H5). In older adults, nature relatedness was positively related to the number and personal engagement of associations but not to valence. Additionally, in older adults, availability of nature opportunities was positively related to number of associations, but available nature opportunities did not relate to personal engagement or valence. These findings corroborate previous findings by Nisbet *et al.* (2009) and Maas *et al.* (2009) and highlight the importance of both nature relatedness and available nature opportunities when investigating effects of VN exposure in older adults.

Arguably, more opportunities for nature interaction might result in higher levels of nature relatedness, which also could influence the impact of exposure to VN in our study. Hence, nature opportunities, both in real nature and through VN, can be beneficial for older adults in several ways. First, having more nature opportunities in general leads to positive effects on (precursors of) social wellbeing, which is supported by previous research (Maas *et al.*, 2009; Van den Berg *et al.*, 2019). However, apart from the importance of stimulating contact with nature in general, our findings further suggest that having more opportunities for real nature interaction also

increases the impact of VN exposure on social wellbeing. Finally, older adults can experience mobility constraints for various reasons (Schwanen and Páez, 2010; Mitra *et al.*, 2015). Consequently, VN exposure can be considered a complementary means of nature experience for older adults with limited or no access to real nature. All these arguments call attention to the relevance of using VN, because it can provide nature opportunities that could, in turn, promote social wellbeing in older adults.

Limitations

In the current sample, being 60 years of age or older was used as an inclusion criterion, and no other inclusion or exclusion criteria were used. This means that other extraneous factors could have had an influence on the results. For instance, although nursing staff responsible for participant recruitment considered (cognitive) skills required for participation, (subtle) differences across participants in terms of cognitive impairments could have affected our results.

Due to COVID-19-related restrictions, the current study made use of an online survey and relied on available hardware and software configurations for stimulus presentations at participants' homes. This resulted in a relatively small scale (13–30 inches; *i.e.* exposure via laptop or PC), rather than large-scale (*e.g.* 200 inches; *i.e.* wall projections), presentation format, which may have weakened the effects of the VN exposure in general (Yeo *et al.*, 2020) and exposure to the specific VN characteristics in particular (*e.g.* spaciousness; Van Houwelingen-Snippe *et al.*, 2020*b*). Moreover, sample screen size could not be controlled for within the current study, although only desktop computers and laptops were allowed. Previous studies, however, showed that only small screen sizes (4.6 inches; *e.g.* smartphone) show reduced immersion compared to medium (13 inches; *e.g.* laptop) and large (30 inches; *e.g.* desktop monitors) screen sizes (Rigby *et al.*, 2016), while there were no differences found between medium (13 inches) and large (30 inches) (Rigby *et al.*, 2016) or between large (31 inches) and extra-large (72 inches) screen sizes (De Kort *et al.*, 2006). Hence, the current variance in screen size (desktops *versus* laptops) is unlikely to have affected the results of this study.

Additionally, the current study made use of static and single-sensory exposure to VN (low immersion) rather than dynamic and multisensory exposure (high immersion). This could have influenced the results, as research indicates that higher levels of immersion lead to more positive effects on mood and nature relatedness (Yeo *et al.*, 2020) and stress recovery (Annerstedt *et al.*, 2013). It is important to note, however, that too much detail or a mismatch between different modalities (*e.g.* bird sounds without birds that can be seen) can negatively affect nature experiences (Annerstedt *et al.*, 2013; Neo *et al.*, 2021).

Finally, although the current study investigated four VN characteristics, exposure to other VN characteristics also might influence associations with nature. These can be related to the natural environment itself (*e.g.* animals and/or flowers) but also to the individual who is exposed to the natural environment (*e.g.* recognisability, personal preference). Specifically, exposure to more diverse natural environments is correlated with more psychological wellbeing (Fuller *et al.*, 2007), and nature experienced as beautiful promotes prosocial behaviour (Zhang *et al.*, 2014).

Manipulation checks with intended target groups are therefore highly recommended to control for such confounders.

Recommendations for future research

In this paper, VN exposure has been shown to stimulate personal associations in older adults, which can be useful conversational material. However, the current study instructed participants to write down any associations that arose while they viewed the VN image. This instruction might have made the participants feel obliged to write down anything, even though they had no limits in time, word length or topic to express their associations. Future research should therefore focus on stimulating actual conversations, for instance, by investigating the number and duration of conversations and aspects such as turn-taking when older adults are exposed to environments with VN. By implementing the results of such studies, VN exposure has the potential to become an effective instrument to improve social interaction and wellbeing among older adults.

Moreover, technologies that promote conversations, such as smartphones, digital picture frames and touchscreen computers, have been proven successful for people with dementia (Goodall *et al.*, 2021). However, these technologies seem to rely on active use of the technology by caretakers and/or people with dementia, which might be difficult to sustain because people might lose interest or find it challenging to understand and use the technology. A solution could be a well-designed VN setting that gently persuades people to interact socially, similar to how a cosy library accompanied by a reading lamp and comfortable chair may encourage people to start reading. Further research is therefore required to investigate whether VN settings, by simply being present, can effectively promote social interaction in an unobtrusive manner.

Practical implications

In nursing homes, people might have fewer nature opportunities due to mobility constraints (Schwanen and Páez, 2010; Mitra *et al.*, 2015) and less-frequent social interactions, causing feelings of loneliness (Slettebø, 2008). VN exposure could be considered a complementary means for interacting with nature, and due to its personally engaging and positive associations, it also might be a means for promoting valuable social interaction. Implementing VN technology for enhancing the wellbeing of residents in nursing homes (using various means, such as projections on walls, digital picture frames or screensavers on computers) would therefore be an important topic for further investigations.

Conclusion

The results of the present study show that exposure to VN elicited personally engaging and positive associations, suggesting that VN could be used to provide conversational material for older adults. However, these findings warrant follow-up studies testing whether VN exposure can actually initiate and sustain conversations that are essential for the social wellbeing of older adults.

References

Annerstedt M, Jonsson P, Wallergard M, Johansson G, Karlson B, Grahn P, Hansen AM and Wahrborg P (2013) Inducing physiological stress recovery with sounds of nature in a virtual reality forest – results from a pilot study. *Physiology & Behavior* **118**, 240–250.

Basu A, Duvall J and Kaplan R (2018) Attention restoration theory: exploring the role of soft fascination and mental bandwidth. *Environment and Behavior* **51**, 1055–1081.

BMS Lab (2020) *Virtual Nature Healing Environment.* Available at https://bmslab.utwente.nl/virtual-nature-healing-environment/.

Cohen G (1998) The effects of aging on autobiographical memory. In Thompson CP, Herrmann DJ, Bruce D, Read JD and Payne DG (eds), *Autobiographical Memory: Theoretical and Applied Perspectives.* Mahwah, NJ: Lawrence Erlbaum Associates, pp. 105–123.

De Kort YAW, Meijnders AL, Sponselee AAG and Ijsselsteijn WA (2006) What's wrong with virtual trees? Restoring from stress in a mediated environment. *Journal of Environmental Psychology* **26**, 309–320.

Enssle F and Kabisch N (2020) Urban green spaces for the social interaction, health and well-being of older people – an integrated view of urban ecosystem services and socio-environmental justice. *Environmental Science & Policy* **109**, 36–44.

Evans SC, Barrett J, Mapes N, Hennell J, Atkinson T, Bray J, Garabedian C and Russell C (2019) Connections with nature for people living with dementia. *Working with Older People* **23**, 142–151.

Fivush R, Haden C and Reese E (1996) Remembering, recounting, and reminiscing: the development of autobiographical memory in social context. In Rubin DC (ed.), *Remembering Our Past.* Cambridge: Cambridge University Press, pp. 341–359.

Fuller RA, Irvine KN, Devine-Wright P, Warren PH and Gaston KJ (2007) Psychological benefits of greenspace increase with biodiversity. *Biology Letters* **3**, 390–394.

Gardiner C, Geldenhuys G and Gott M (2018) Interventions to reduce social isolation and loneliness among older people: an integrative review. *Health and Social Care in the Community* **26**, 147–157.

Goodall G, Taraldsen K and Serrano JA (2021) The use of technology in creating individualized, meaningful activities for people living with dementia: a systematic review. *Dementia* **20**, 1442–1469.

Hendriks IH, Van Vliet D, Gerritsen DL and Droes RM (2016) Nature and dementia: development of a person-centered approach. *International Psychogeriatrics* **28**, 1455–1470.

Holt-Lunstad J, Smith TB, Baker M, Harris T and Stephenson D (2015) Loneliness and social isolation as risk factors for mortality: a meta-analytic review. *Perspectives on Psychological Science* **10**, 227–237.

Jarvis M-A, Padmanabhanunni A, Balakrishna Y and Chipps J (2020) The effectiveness of interventions addressing loneliness in older persons: an umbrella review. *International Journal of Africa Nursing Sciences* **12**, 100177.

Kahn PH, Severson RL and Ruckert JH (2009) The human relation with nature and technological nature. *Current Directions in Psychological Science* **18**, 37–42.

Kaplan S (1995) The restorative benefits of nature – toward an integrative framework. *Journal of Environmental Psychology* **15**, 169–182.

Kaplan R and Kaplan S (1989) *The Experience of Nature: A Psychological Perspective*. Cambridge: Cambridge University Press.

Keltner D and Haidt J (2003) Approaching awe, a moral, spiritual, and aesthetic emotion. *Cognition and Emotion* **17**, 297–314.

Keniger LE, Gaston KJ, Irvine KN and Fuller RA (2013) What are the benefits of interacting with nature? *International Journal of Environmental Research and Public Health* **10**, 913–935.

Ludden GDS, Van Rompay TJL, Niedderer K and Tournier I (2019) Environmental design for dementia care – towards more meaningful experiences through design. *Maturitas* **128**, 10–16.

Maas J, Van Dillen SME, Verheij RA and Groenewegen PP (2009) Social contacts as a possible mechanism behind the relation between green space and health. *Health & Place* **15**, 586–595.

Marselle MR, Hartig T, Cox DTC, de Bell S, Knapp S, Lindley S, Triguero-Mas M, Bohning-Gaese K, Braubach M, Cook PA, De Vries S, Heintz-Buschart A, Hofmann M, Irvine KN, Kabisch N, Kolek F, Kraemer R, Markevych I, Martens D, Muller R, Nieuwenhuijsen M, Potts JM, Stadler J, Walton S, Warber SL and Bonn A (2021) Pathways linking biodiversity to human health: a conceptual framework. *Environment International* **150**, 106420.

Mitra R, Siva H and Kehler M (2015) Walk-friendly suburbs for older adults? Exploring the enablers and barriers to walking in a large suburban municipality in Canada. *Journal of Aging Studies* **35**, 10–19.

Morgan T, Wiles J, Park H-J, Moeke-Maxwell T, Dewes O, Black S, Williams L and Gott M (2021) Social connectedness: what matters to older people? *Ageing & Society* **41**, 1126–1144.

Neo JRJ, Won AS and Shepley MM (2021) Designing immersive virtual environments for human behavior research. *Frontiers in Virtual Reality* **2**, 603750.

Nicholas SO, Giang AT and Yap PLK (2019) The effectiveness of horticultural therapy on older adults: a systematic review. *Journal of the American Medical Directors Association* **20**, 1351.

Nisbet EK and Zelenski JM (2013) The NR-6: a new brief measure of nature relatedness. *Frontiers in Psychology* **4**, 813.

Nisbet EK, Zelenski JM and Murphy SA (2009) The Nature Relatedness Scale linking individuals' connection with nature to environmental concern and behavior. *Environment and Behavior* **41**, 715–740.

Piff PK, Dietze P, Feinberg M, Stancato DM and Keltner D (2015) Awe, the small self, and prosocial behavior. *Journal of Personality and Social Psychology* **108**, 883–899.

Quan NG, Lohman MC, Resciniti NV and Friedman DB (2020) A systematic review of interventions for loneliness among older adults living in long-term care facilities. *Aging & Mental Health* **24**, 1945–1955.

Rigby JM, Brumby DP, Cox AL and Gould SJJ (2016) Watching movies on Netflix: investigating the effect of screen size on viewer immersion. In *Proceedings of the 18th International Conference on Human–Computer Interaction with Mobile Devices and Services Adjunct*. New York: Association for Computing Machinery, pp. 714–721.

Schertz KE, Sachdeva S, Kardan O, Kotabe HP, Wolf KL and Berman MG (2018) A thought in the park: the influence of naturalness and low-level visual features on expressed thoughts. *Cognition* **174**, 82–93.

Schwanen T and Páez A (2010) The mobility of older people – an introduction. *Journal of Transport Geography* **18**, 591–595.

Skjott Linneberg M and Korsgaard S (2019) Coding qualitative data: a synthesis guiding the novice. *Qualitative Research Journal* **19**, 259–270.

Slettebø Å (2008) Safe, but lonely: living in a nursing home. *Nordic Journal of Nursing Research* **28**, 22–25.

Szolosi AM, Watson JM and Ruddell EJ (2014) The benefits of mystery in nature on attention: assessing the impacts of presentation duration. *Frontiers in Psychology* **5**, 1360.

Valtorta NK, Kanaan M, Gilbody S, Ronzi S and Hanratty B (2016) Loneliness and social isolation as risk factors for coronary heart disease and stroke: systematic review and meta-analysis of longitudinal observational studies. *Heart* **102**, 1009–1016.

Van den Berg MM, Van Poppel M, Van Kamp I, Ruijsbroek A, Triguero-Mas M, Gidlow C, Nieuwenhuijsen MJ, Grazuleviciene R, Van Mechelen W, Kruize H and Maas J (2019) Do physical activity, social cohesion, and loneliness mediate the association between time spent visiting green space and mental health? *Environment and Behavior* **51**, 144–166.

Van Houwelingen-Snippe J, Van Rompay TJL and Ben Allouch S (2020a) Feeling connected after experiencing digital nature: a survey study. *International Journal of Environmental Research and Public Health* **17**, 6879.

Van Houwelingen-Snippe J, Van Rompay TJL, De Jong MDT and Ben Allouch S (2020*b*) Does digital nature enhance social aspirations? An experimental study. *International Journal of Environmental Research and Public Health* **17**, 1454.

Van Rompay TJL and Jol T (2016) Wild and free: unpredictability and spaciousness as predictors of creative performance. *Journal of Environmental Psychology* **48**, 140–148.

Vozikaki M, Papadaki A, Linardakis M and Philalithis A (2018) Loneliness among older European adults: results from the Survey of Health, Aging and Retirement in Europe. *Journal of Public Health* **26**, 613–624.

Westerhof GJ, Bohlmeijer E and Webster JD (2010) Reminiscence and mental health: a review of recent progress in theory, research and interventions. *Ageing & Society* **30**, 697–721.

Yeo NL, White MP, Alcock I, Garside R, Dean SG, Smalley AJ and Gatersleben B (2020) What is the best way of delivering virtual nature for improving mood? An experimental comparison of high definition TV, 360 degrees video, and computer generated virtual reality. *Journal of Environmental Psychology* **72**, 101500.

Zhang JW, Piff PK, Iyer R, Koleva S and Keltner D (2014) An occasion for unselfing: beautiful nature leads to prosociality. *Journal of Environmental Psychology* **37**, 61–72.

Zhao Y, Liu Y and Wang Z (2022) Effectiveness of horticultural therapy in people with dementia: a quantitative systematic review. *Journal of Clinical Nursing* **31**, 1983–1997.