Exposure to virtual environments: Potential antecedents to the Green Space Effect

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Abstract

This study sought to determine if watching a 15-minute video of an urban or natural environment would increase cognitive capacity by attentional restoration. Additionally, the concept of Nature Relatedness as a trait was measured to explore if this construct could explain variation on score differences between trials. Members of the general public (N = 28) completed a survey containing the NR-6 scale, then participated in an experimental online meeting. The online meeting required participants to engage in reading for 10 minutes to establish attentional fatigue. The full battery of Digit Span tests, Digit Span Forwards, Digit Span Backwards, and Digit Span Sequence were taken in a pre-test and post-test format around a 15 minute video of either a green forested (n = 13) or urban city (n = 15) first person point of view video condition. A series of Wilcoxon Ranked Sum tests were conducted to determine if there was a difference between the green and urban conditions. No significant difference was found for Digit Span Forward scores. However, for Digit Span Backwards a large significant relation was found between conditions, with the green condition generating a median 2 digit increase in score. A small significant difference was found for Digit Span Sequence scores, alternatively the urban condition gained a median increase of 2 digits. The Digit Span Backwards test is supported for use in the field, however distinctly from Digit Span Forwards. Digit Span Sequence provides a novel area of interest as to why urban areas might provide a better environment to induce spatial cognition. A series of Kendall's Tau correlations were conducted, and p values corrected to explore if Nature Relatedness did mediate difference in performance on Digit Span tests. No significant relationship was found. Age had no effect on Digit Span test scores or NR-6 means. No significant result that discredits Nature Relatedness as providing a moderating mechanism by which the green space effect takes place, was found. However, this is most likely due to small sample sizes,

further implications for research are explored including using an expanded nature relatedness scale for greater sensitivity.

Introduction

In the context of written history, cities with large populations (1,500,000<; OECD, 2020) have been scattered and rare (Morris, 2010). It is the last century that has witnessed a rapid uptake for urban living. Urban space comes at a premium and an increase in urban populations provides temptation for city planners to provide as much residential space as is physically feasible. The peril of unregulated urban development has already been seen in the case of Kowloon, a former Chinese enclave within Hong Kong. Kowloon was an urban area 6.5 acres in size with in excess of 50,000 inhabitants at its peak until it was torn down in the early 1990s. Kowloon became rife with gang activity and its inhabitants were in poor health. Though the existence of such an area was not due to lack of planning, rather historic bureaucracy, it still serves as an extreme example of the detrimental health impact of unsustainable living conditions that can develop if due regard to human psychological needs are not met. It is known that urban populations are more likely to develop psychiatric disorders (Peen et al., 2010), and as the trend for global populations to continue migrating into cities is to increase, it is of vast importance to be able to implement green policies into cities as they develop.

Environmental or green policy in urban planning has seen a rise in interest due to an increasing body of evidence that suggests that people are healthier and happier when they are in closer proximity to green urban areas (Mark J. Nieuwenhuijsen et al., 2017; van den Bosch & Ode Sang, 2017; Wolch et al., 2014). General long-term effects include greater mental wellbeing and life expectancy. Notably, this includes the slowing of cognitive decline. When retroactively analysed those in the Lothian Birth Cohort who were closer in proximity to available green spaces in childhood through to adulthood demonstrated a slower cognitive aging (Cherrie et al, 2018). This represents just one, yet undoubtedly important, finding in a vastly growing body of research on the Green Space Effect (GSE) that is determining how

diverse the benefits are of the incorporation of nature in human lives. While there is a plethora of salutogenic effects of nature, it is the cognitive aspect which is of particular interest for this study. Many cross-sectional studies have shown that students of all ages are able to cope with more demand in school after visiting green spaces (Browning & Rigolon, 2019; Dadvand et al., 2015; Wallner et al., 2018). An improvement in academic work has been found across various scales of measurement, most consistently longitudinal improvement in end of semester exam marks but findings for studies on achievements are only significantly positive for schools which featured higher populations of trees (Browning & Rigolon, 2019). This exhibits an issue in understanding what elements of nature and the type of interaction that is required to elicit GSEs. There is less understanding on the particular cognitive mechanisms and variations on medium of exposure than what has been measured in tangible academic outcomes of students. Understanding why the green space effect takes place first in an instance by instance manner by cross-sectional examination, may lead to identifying the particular mechanisms by which the long term salutogenic and beneficial effects take place. Subsequently a possible difference may be found to occur in complimentary short-term and long-term systems, similarly to those that can be seen in other physiological and psychological processes such as the circadian rhythm, that give rise to the extended health benefits that occur over a lifetime. Many studies have shown the effect of nature is cross cultural and is applicable to wide communities regardless of demographics. The Green Space Effect has been exhibited in the UK (Barbosa et al., 2007; White et al., 2013), Sweden (Kjellgren & Buhrkall, 2010), USA (Kondo et al., 2018; N. M. Wells, 2000), Spain (Dadvand et al., 2015), Austria (Wallner et al., 2018), South Africa (Liprini & Coetzee, 2017), Australia (Astell-Burt et al., 2014) and many other nations. It is regardless of age, gender, marital status, and income (Alcock et al., 2014; E. Wood et al., 2018; Zhang et al.,

2014). As such a broader population sample of the general public is needed to examine if similar cross-sectional results are replicable in a broader age range.

There are a couple of theories which suggest that there are potential traits and characteristics of nature which are responsible for inducing beneficial effects. Both Attention Restoration Theory (Kaplan, 1995) and Stress Reduction Theory (Ulrich et al., 1991) claim that there are certain points in which people engage with nature to an extent for a purpose. After engaging with nature through the relevant means, a detrimental psychological state is ameliorated. In interest for this particular study is the potential for recovery of short-term cognitive ability, specifically directed attention which is a part of working memory. In general usage attention must be utilised in order to keep making well evaluated decisions on how to interpret stimuli in the surroundings. Cognitive processes such as attention require psychological resources which are depleted through tasks such as reading and engaging with digital devices (Attia et al., 2017; Jiang et al., 2019). Attention Restoration Theory (Kaplan, 1995) posits that green spaces rejuvenate cognitive ability through soft fascination with natural objects and their motion as they do not require concentration in order to predict and make judgements on. Stress Reduction Theory (Ulrich et al., 1991) suggests that due to evolutionary design humans react to environments rich in resources which induce parasympathetic response which in turn restore the psychological state. Research has found that the Green Space effect is replicated by inherently unnatural, by virtue of their medium, pictures and film. However, there is a need for clarity in the precise function by which the green space effect is produced. There are findings which appear to be contradictory (Browning & Rigolon, 2019). The use of technological devices in relation to green spaces appears to change the effect (Jiang et al., 2019) which presents uncertainty as to the practical applications of the green space effect given the increasingly technological orientation of cultural and societal behaviours. The cause for and mechanism by which GSE occurs is

largely unknown however (Browning & Rigolon, 2019; Maas et al., 2006). This may be due to the plethora of possible stimulus; olfactory and auditory (Hedblom et al., 2019), visual (R. S. Ulrich, 1984), individual psychological perceptions (Snell et al., 2019), even more unusual possibilities such as air-borne microbes and ions (Craig et al., 2016) are all suspect to influence the extent of the green space effect. Given the wide variety of possible factors, a wide variety of studies are required to identify potential covariables or mediators to the green space effect. Nature Relatedness (Nisbet et al., 2011) is such a trait that has been found to both predict perception and be moderated by perception of nature.

Attention Restoration Theory

Mental resources required to stay focused are depleted after demanding cognitive tasks. Attention Restoration Theory posits that these resources can then be replenished, to an extent, after exposure to a green space in order to exert more effort into completing another task. The theoretical framework suggests that an environment requires (1) a shift in stimulus, going as far to suggest even a conceptual shift will work, (2) be inherently fascinating without the need to devolve constructed thought processes in order to understand what is happening, (3) have the potential for an abundance of diversity, and (4) that there must be a connection between the individual's goal state and the purpose of the environment. Kaplan suggests that together the presence of these key environmental characteristics and how the person relates to the environment come together to create a psychological state that does not challenge preconceived expectations and induces a state of reduced awareness of other such cognitively fatiguing tasks for example bodily or behavioural awareness. As such the environment constitutes as restorative because the immediate perception required in soft fascination is fast whereas the top down processing required for judging urban objects is slow and demanding. A demanding task, such as judging multiple changes in the immediate environment for example traffic, depletes cognitive resources leading to 'impaired performance'. Attentional fatigue is the cognitive state that arises from this process (Kaplan, 1995). If this fatigue can be avoided by replenishing resources via exposure to natural environments, there would be a general benefit from the associated positive effects of having a greater attentional capacity.

Stress Reduction Theory

Ulrich et al. (1991) posits that natural areas pose a diverse and abundant possibility for vital resources such as streams of running water providing potable water sources, food

and various other important necessities for a species that evolved as hunter gatherers. Due to the evolutionary necessity to evaluate and memorise what potential physical resources are available in an area the brain may make extra psychological resources available in order to better increase survival. It is hypothesised that this advantage remains and is reflected in contemporary and current findings that show that the parasympathetic system is activated by natural scenes. Ulrich notes that urban environments do not induce the same parasympathetic reaction as their natural counterparts. Interestingly Ulrich justifies that Attention Restoration Theory is limited as physiological markers for engagement and attention were described as indicating increased activity during a stressful task (video depicting bodily harm).

In tandem to the notion that diversity in ecological resources presents a greater effect, an environment with running water may also present greater depth of resource and range of ecology and such a greater psychological effect (E. Wood et al., 2018). A study among adolescents reported that larger green spaces induced a longer and more sustained effect (Wallner et al., 2018). Forest settings have been shown to produce larger effects over smaller urban parks, further reinforcing the potential that it is biodiversity that induces the green space effect.

Green Space Effect

The range of natural environments that have been evaluated for their restorative capabilities include a football pitch in a city (L. Wood et al., 2017) to ancient forest land (Kjellgren & Buhrkall, 2010), including various urban green spaces such as dog parks and roadside vegetation (van Dillen et al., 2012). There appears to be a relationship between both quantity and quality in biodiversity which produce a greater restoration or beneficial effect (E. Wood et al., 2018). Environments rich in biodiversity and potential resources have been shown to induce greater recovery than urban areas with little natural diversity (for example a

football playing ground; White et al., 2013). Evidence of the green space effect extends into manipulating the way that elements of nature are experienced, by making plants visible indoors (Dreyer et al., 2018) or through windows. Various studies have compared green and urban views from windows and found significant benefit from overlooking green vistas (Benfield et al., 2015). Previous studies have explored upon the physiological effect of windows that overlook green spaces (Honold et al., 2016; R. S. Ulrich, 1984). Postoperative patients in the same hospital who were pair matched for characteristics and care and recovered on average just short of a day faster, and more notably, required much fewer strong analgesics during their recovery when patients overlooked a small cluster of trees rather than their concrete overlooking counterparts (R. S. Ulrich, 1984). Cortisol, the hormone for stress, was found to be lower in people whose windows at home had greater biodiversity and quantity (Honold et al., 2016). Classrooms overlooking green views had students attain higher academic scores (Benfield et al., 2015). Although in another study proximity and density of green spaces to living areas wasn't actually found to effect scholastic achievements (Markevych et al., 2019). However a classroom that has direct views on green spaces will improve students perceptions to a more positive review of the course (Benfield et al., 2015). Windows will only be able to present a fairly static environment however which may present a plateau of interest. To many people nature will have a dynamic connotation, developed from walking or moving in vehicles through outdoor spaces. As such moving stimuli present a richer potential for effect. Participants physiological stress levels were ameliorated after being exposed to an audio-visual film of natural scenes (Ulrich et al., 1991). There is some evidence to show that sounds contribute to a part of the restorative system (Alvarsson et al., 2010). The pronounced physiological response that calms the body works has been seen to work in tandem to a similar effect psychologically, after young mens' mood and heartrate variability were assessed concurrently in either an urban or park walk (Song et al., 2014).

Studies have shown that the parasympathetic system reacts to reduce stress regardless of the medium by which the green space exposure happens (Hystad & Cusack, 2019; Snell et al., 2019; Twohig-Bennett & Jones, 2018). The representation of nature through a portal, such that there is a divide between the real environment and the person experiencing said environment are of interest as digital screens, which act similarly as portals to another 'world', are becoming increasingly ubiquitous in daily life. The difference between what is attainable from a window view and the potential capability of a digital screen needs to be clarified. One such experiment applied a procedure which utilised a single environment as their real-world condition, and a slide show of 97 photographs of views looking out over the same space for a simulated exposure as the alternative condition (Kjellgren & Buhrkall, 2010). This simulated experience did not include audio recordings of the space, nor were elements of the environment able to be seen to move as movement in the scenic elements would induce soft fascination. Kjellgren & Buhkrall (2010) reported that while stress was reduced, concentration was not piqued and participants became bored. They speculated that a simulated environment may actually require directed attention. Indeed, they reported that while participants felt positively about the experience, they felt that it was not a replacement for a real environment. There have been many studies finding that walks in green areas versus urban have a benefit on cognition and affect that display distinct effect sizes; children with ADHD that walked in a green area improved their Digit Span Backwards scores significantly, reporting Cohen's d at .77 (Taylor & Kuo, 2009). Contrary to the Kjellgren & Buhrkall (2010) finding that virtual exposures are less effective as opposed to real environments may be because the virtual version is not an accurate depiction of what is possible with simulations now a decade later on. If simulations on digital screens have the potential to produce a GSE, we may expect to see similar results reflected by simulated walks in a green area than versus a simulated urban area as have been seen in real green versus

urban walks. However, there is the issue of a shifting baseline in the general attitude towards technology (Kahn et al., 2008). As people become more reliant on screens there may be less of an effect of fascination with these items as digital life becomes increasingly normalised. If there is little differentiation between simulated green and urban environments, then a pronounced effect will be absent.

Exercise as a Covariable

Additional reasons to conduct an experiment that utilises digital screens to simulate moving environments with audio is to assess if the major effect is produced by sensory inputs as has been suggested before (Alvarsson et al., 2010; Ulrich et al., 1991) or due to other covariables such as microbes or exercise. It is well known that physical exercise promotes greater cognitive ability as well as a plethora of positive affects (McAuley et al., 2000). Physical exercise in conjunction with other factors such as social company has been found to change the matrix of response as opposed to walking alone. When walking with a companion a participant felt a greater state of calmness, but also experienced more tiredness (Johansson et al., 2011). Exercise included both green and urban settings, suggesting that being alone elicits a different affect, specifically more restoration for cognitive abilities (Johansson et al., 2011; Plante et al., 2001). However, the effect from exercise itself may confound accurately measuring the GSE in studies that have participants physically move themselves through a green space. Therefore, isolating the sensory experience from the inherent benefits of exercise is necessary to understand if GSE can be attributed to a perceptual or physiological system. Individuals who were moved through an outdoor environment on a wheelchair were more cognitively creative than those sat indoors (Oppezzo & Schwartz, 2014) though the kind of environment that was classified as outdoors was not specified and the influence of natural features unknown. As far as novel concepts are considered the current study is the

first known to utilise point-of-view videos to simulate natural environments as compared to slideshows of pictures, a real life window, or a live view of a fixed window. Should an effect be found, this will present a diverse opportunity for potentially unlimited restorative environments.

Manipulating and Quantifying Attention

There are several practices that appear in experimental design in studies that assess the effect of exposure to visuals on green space with working memory tasks. It is a norm in GSE studies to implement an attention depletion/deliberate fatiguing task in order to repeat measures and establish an individual baseline. Psychologically demanding tasks and stressors have ranged from videos depicting bodily injury (Ulrich et al., 1991), proof-reading (Cohen et al., 1986), public speaking (Pasanen et al., 2018), and arithmetic tasks (van den Berg et al., 2015). Visually stimulating tasks have been used in studies with children with ADHD. Puzzle tasks have been implemented to deliberately fatigue children with ADHD (Schutte et al., 2017; Taylor & Kuo, 2009). Some studies have used digital ways to measure attention. Pasanen et al. (2018) utilised the SART via a laptop in the forest; however, using a device outdoors can change the restorative effect of nature (Jiang et al., 2019). Kaplan & Berman (2010) suggest that self-regulation, the capacity one has to continue in a task, and executive functioning draw from the same pool of resources. By reading a challenging text with complex use of language and literary concepts this activates both the need to rationalise what is being conveyed and to maintain attention in order to complete the task for the given time (Frey & Bosse, 2018). Aside from techniques for manipulating attention, the Digit Span test (Weschler, 1955) appears in a number of studies. The Digit Span test is comprised of three sub scales. Each subscale requires that a string of numbers is recalled in a certain order, and every other trial the length of digits expands. These subscales include the Digit Span

Forwards (DSF), where a participant needs to recall a string of digits in the same order in which they are encountered, which requires short term audial memory. However, Digit Span Backwards (DSB) and Digit Span Sequence (DSS) require a that the person retain the series of digits and manipulate them in their head. It is suspected that for some people the Digit Span Forwards works as a warm up task (Raiford et al., 2010). Whereas DSB measures fluid intelligence (Banken, 1985), DSS is posited to add a different dimension of complexity to the overall Digit Span test (Meyer & Reynolds, 2018). As such each component scale of the Digit Span test is suggest to measure different cognitive abilities. This creates a degree of uncertainty as to the validity of the number for studies which only employ one subscale of the Digit Span test. There is variation as to the results seen on Digit Span tasks in various studies. Slightly older children performed better after a walk in nature on other working memory tasks, Continuous Performance Task and Distance error, but not DSB (Schutte et al., 2017). This was unexpected and not in line with the literature. The researchers suggest this is due to diminished restoration after the green exposure as DSB was administrated after other tests. Oppezzo & Schwartz (2014) found that another cognitive ability, creativity, was increased but only for a short span of a couple of minutes. For this reason, a battery of tests must be efficient at measuring their intended psychological construct. The presence of multiple tests with distinctly different approaches may present an additional cognitive load as the participant must understand what is required of them for the activity. As such the three digit span tests exhibit a succinct and diverse range of testing abilities which, if found to be significant, would make the three valid for further use in this field.

However many studies actively limit the number of trials to 14 (Van Hedger et al., 2019), which creates a cap at the possible digit span score (Gignac et al., 2019). There is also variation between starting lengths, some studies opt for two digits as is recommended for conducting the WAIS-IV (Raiford et al., 2010) however others start at three digits. DSB is

varyingly administered by visual prompts (Van Hedger et al., 2019) or presented audially (Berman et al., 2012). Presenting the digits engages the phonographic loop and requires information to be processed visually, thereby engaging making meaningful interpretations of data bits which deplete the same resources demanded by the reading task (Sliwinska et al., 2015).

Few studies include both the Digit Span Forwards and Digit Span Backwards. A study that utilised DSF and DSB had participants only engage in these tasks once however, as the purpose was to understand if there was a difference among window view types all natural, mostly natural, mostly built, or all built (Tennessen & Cimprich, 1995). Example of built views consisted of an immediate view over a brick wall. Unlike taking a walk in an expansive urban environment this does not give a person a perception of extent. Their results did not yield a significant result for the DSB nor DSF tests. A recent study which reflects the current experiment's design and materials required that participants sit in either a real world setting and spend time on their laptop as they would for a break. Two other control groups sat without an electronic device in both a green and built environment. As expected the green group without a laptop performed significantly better than both the built conditions but notably the green with laptop showed the least improvement of any group (Jiang et al., 2019). Measures in this study utilised both DSF and DSB, however they averaged the two scales to create one score for each participant. Doing so has been advised as misinformed because scores do not represent the same cognitive systems (Gignac et al., 2019).

Many of these studies use exclusively the digit span backwards component of the Digit Span test. Rarely the Digit Span Forwards is utilised and the digit span sequence even less so. As to why this is, is not explained. The relatively newer Digit Span Sequence which presents a suspected unique dimension of cognitive ability should also be assessed for its value in measuring working memory. Because the Digit Span Sequence (DSS) is said to

utilise the phonological feedback loop (Werheid et al., 2002), it makes the DSS of particular interest as it will draw on the same resources as is used by the reading task.

Nature Relatedness

Nature Relatedness (NR) is the name for a construct in personality that involves affinity for nature. Aspects of it arise both as a trait and a state. It seems that trait wise it is stable (McMahan & Estes, 2015); however, it can be raised temporarily by exposure to a green space (Martyn & Brymer, 2016). Additionally, Nature Relatedness is compounded by repeated visits to green spaces such as parks, forests, and mountains (Kals et al., 1999). NR has been associated with psychological well-being (Howell et al., 2011)

Kals et al. (1999) found that emotional affinity (conceptions/perceptions of nature i.e. romanticism, escapism), past experiences, present experiences all factor into a cognitive connection with nature. Similarly, a higher cognitive appreciation of beauty indicated whether a person would derive greater psychological wellbeing from exposure to green spaces and was related to higher nature connectedness (Zhang et al., 2014). Among a UK populace Nature Relatedness was found to be the most influential indicator for frequency of green space use and sufficient exercise (Flowers et al., 2016). A longitudinal study among Dutch adolescents suggested that a higher rating of importance towards green space indicated how frequently they would visit a park (Bloemsma et al., 2018). Proximity to a park & concentration of park areas did not factor into the frequency of green space visitations, rather it was subjective measures such as personal perceptions of availability (Ries et al., 2009) and the importance of green spaces (Bloemsma et al., 2018; Ries et al., 2009) that predicted use. Similar findings in regard to proximity of green spaces and their effect, or lack thereof, on general outcomes mirror these findings. This similarity may potentially be indicative of

Nature Relatedness potentially sharing one or more underlying mechanisms with the Green Spaces effect.

However, the researchers acknowledged that their findings in regard to proximity did not confer with the findings of other similar studies (Bloemsma et al., 2018). Among a large middle aged Australian population green space density did predict increased physical exercise (Astell-Burt et al., 2014). This may be something to do with climate differences, or representative of a change in lifestyle as aging occurs. However there are several inconsistencies in the literature, which may be due to self-report (Bloemsma et al., 2018). Though the only identified demographic to indicate how much an adolescent will utilise green spaces was level of parental education (Bloemsma, 2018). It may be possible stemming from this that an education on the importance of nature affects the perception of value in green spaces and their use. Regardless, there is an effect of the Nature Relatedness trait which encompasses perceptions and personal relations to nature as a motivator for green space use. If NR predicts greenspace use and with greater greenspace use comes better psychological well-being and stress recovery, then perhaps Nature Relatedness may moderate attentional restoration after exposure to Green Spaces.

Hypothesis 1 (H1): Performance on all digit span tests will be improved in a green condition to a greater extent than an urban condition.

Hypothesis 2 (H2): Higher Nature Relatedness will correlate with greater improvement for participants in green conditions.

Hypothesis 3 (H3): Age will have no relation with digit span scores nor Nature Relatedness.

Really what were testing is whether an urban environment that contains extent will hold up to ART and replicate similar findings to previous studies.

Method

Inclusion.

Participants were included on the basis of being English speaking and having access to a device with internet access.

Participants.

Members of the general public (N = 37) were recruited via online advertising and on forums related to urban development, and green spaces. No payment was given, and participation was voluntary. All participants were recruited, and data collected between June and July. Total time required by participants for both the survey and zoom stages took approximately an hour. Experiments took place virtually, participants joined from residential locations. Individual participants were assigned on rotation to the two conditions as indicated by the literature to produce the greatest difference in effect, the Urban walking and Green & River walk (Neilson et al., 2017; Nguyen et al., 2018). Ethical approval was granted by the College of Science and Engineering at University of Glasgow. As indicated by an initial power calculation ($\beta = 0.80$, $\alpha = 0.05$) the intended sample size was 32, however 28 participants progressed through to complete all stages of the experiment. All participants who finished the online meeting were debriefed as to the hypothesises and aims of the study.

Materials and Conditions.

Digit span test. All participants were given the same set of numbers for consistency. Digit sequences can be found in Appendix B. Digit Span Forwards, Digit Span Backwards, Digit Span Sequence were all conducted. The Digit Span Forwards (DSF) requires the participant to recall a series of random numbers in the same order in which they are heard. Digit Span

Backwards (DSB) requires the series to be recalled in the reverse order. Digit Span Sequence (DSS) requires that the numbers in the series are recalled in ascending order.

Video conditions. There were two video conditions. The first video condition represented moving through a green space with a walk in a forest along a creek. Footsteps, birds, running water and other ambient forest noises are present. The alternative video condition represented an urban environment with a walk through Manhattan, New York. Traffic, conversation, construction noise and other city sounds can be heard. Both videos are captured in summertime. Permission was granted as videos used were found on youtube.com. Participants were directed to the online video hosting platform as it was the most feasible and familiar to participants and did not represent a novel challenge in itself that transferring a large video file would have required. Stills from each video condition can be seen in figure 1.

Literary text. Participants were given a pdf of "The Time Machine" (H. G. Wells, 2000) as it is a challenging text in the public domain.

Table 1.

Frequency and percentage of conditions and participant characteristics.

Participant Demographics	N = 28		Green (n =13)		Urban (n = 15)	
	N	%	N	%	N	%
Gender						
Female	19	68	9	70	10	67
Male	9	32	4	30	5	33
Age						
22-25	16	58	6	46	10	67
26-30	7	25	5	38	2	13
31-40	2	7	-	-	2	13
46	1	3	1	8	-	-
65	2	7	1	8	1	7
Ethnicity						
White	23	82	11	85	12	80
Asian	2	7	1	8	1	7
Arab	1	4	1	8	-	-
Hispanic	1	4	-	-	1	7
Mixed/Multiple Ethnic Groups	1	4	-	-	1	7
Main Occupation						
Student	8	29	6	46	2	13
Sales	3	11	-	-	3	20
Communications	3	11	1	8	2	13
3D Artist	2	7	1	8	1	7
Teacher	2	7	1	8	1	7
Retired	2	7	1	8	1	7
Hospitality	2	7	1	8	1	7
N/A	2	7	1	8	1	7
Whiskey Broker	1	3	-	-	1	7
Health & Safety Consultant	1	3	1	8	-	-
Scientist	1	3	-	-	1	7
Developer	1	3	-	-	1	7

Note: Percentages have been rounded to nearest integer.

NR-6. The NR-6 (Nisbet & Zelenski, 2013) focuses on perceived connectedness rather than including environmental attitudes which is included in the full 21 point measure (Nisbet et al., 2011) . There are 6 questions that relate to a person's connection to nature. Questions are answered on a 5-point Likert scale ranging from 1 "Disagree Strongly" to 5 "Agree

actions affect the environment". The full set of questions is available in the appendices (Appendices A).

Design.

An experimental between-subjects design compared the effect of virtual environments on working memory (measured by the Digit Span Test) as well as exploring the relationship with the covariable of the Nature Relatedness trait (NR-6). The experiment took place over two stages and was comprised of an initial online survey and an online meeting. The online survey acted both as a point of contact and to gather basic demographic details as well as the NR-6 measure.

A Zoom session was then held. First an attentional deficit was established by a 10-minute reading period. All three digit spans (DSF, DSB, & DSS) were measured. A 15-minute extract of a video of either environment was watched and immediately after the three digit span tests were measured again.

Procedure.

A GDPR compliant survey was hosted on Microsoft Forms. The online survey acted both as a point of contact and to gather basic demographic details as well as the NR-6 measure. Demographics collected included age, gender, main occupation, and ethnicity. Contact details, email and optionally telephone number were also requested to follow up for the organisation of a Zoom session.

Participants attended the experiment session in their own homes via an online meeting workspace (Zoom). Experiment sessions were recorded audio visually.

Participants were given an unfamiliar extract of a literary text to read for 10 minutes. Participants were informed that they would not be assessed on the content of the extract and to read as they would in a regular working day.

After 10 minutes reading, the Digit Span Test was introduced. Before the first trial of each measure brief instructions and an example were given. For example, for the DSS "if I say 5, 3, 1, 3, you would say 1, 3, 3, 5". After 2 consecutive errors on the same length number the trial was ended. Then the next Digit span test was introduced, and an example given until all three tests were completed.

Participants then watched 15 minutes of the online virtual environment. All participants were asked to maximise their viewing screen and to adjust the ambient sound in the video to a level that was comfortable.

After the 15 minutes passed participants were reintroduced to the Digit Span measures and told there would be the same tasks but with different numbers. After DSF, DSB, & DSS were completed participants were debriefed. A debrief email with further details, psychological resources and participant withdrawal information was sent after the online meeting ended.

Statistical Analysis.

Data from the survey containing the NR-6 questions and score sheets were compiled into R (R Core Team, 2019). Packages used include "dplyr" (Wickham et al., 2019) and "effsize" (Torchiano, Marco, 2013). A mean NR-6 score and a change in score from pre-test Digit Span Test to post-test Digit Span Test was created for each participant. Distribution for pre-test scores, post-test scores, and overall change in score for DSF, DSB and DSS were checked using Shapiro Wilk normality. Wilcoxon's Rank Sum test was conducted to assess if change in score between conditions on all three digit tests were significant (Wilcoxon, 1945).

Digit span tests were not average to compile a sub score as the validity of one overall sub score is criticised as there is low internal consistency (Gignac et al., 2019) suggesting different types of cognitive ability are utilised for each scale hence the need to analyse each measure separately. Kendall's Tau correlations were run between NR-6, DSF, DSB, and DSS for each condition as well as for the total sample (Kendall, 1938). Another set of Kendall's Tau was run for age against total population scores for DSF, DSB, DSS, and NR-6. A Bonferroni-holm correction was conducted to minimise familywise error (Holm, 1979).

Figure.1. Stills from both green (left) and urban (right) video conditions.

Results

Of the 37 participants that initially completed the survey, 28 continued to complete the entire experiment as five participants neglected to schedule a time for the online meeting which constituted as the second stage. Of these 28 participants there were no exclusions made for statistical analysis. The green condition received 13 participants while the urban condition received 15. Of the 28 participants that reached completion, no data was missing.

Change in score was analysed over each digit test sub scale. An average score was created from the NR-6 items (M = 3.86, sd=0.69, N=28). NR-6 means were roughly equivalent between green (M=3.9, sd = 0.7, n=13) and urban (M=3.82,sd=0.71,n=15) conditions. Normality of distribution was violated for all measures, as such non-parametric statistical analyses were used. A Wilcoxon rank sum test was used to determine if there were significant differences between change in score for each digit span across both conditions. Change in DSF for the green condition (Mdn = -1) was lower than that of the urban condition (Mdn = 0). This finding was not significant however (W = 63, p = .107). Change in DSB for the green condition (Mdn = 1) was higher than that of the urban condition (Mdn = -1), however the difference between medians of both groups surpassed the critical value and this was significant (W = 153, p = .01). Change in DSS for the green condition (Mdn = -1) was lower than that of the urban condition (Mdn = 1). Based on a critical value of 61 the distance between these groups was significant, however this may be due to chance (W = 58, p = .062). Results are displayed as a boxplot below (Figure 2).

Kendall's Tau correlations between Digit Span tests and NR-6 scores (Table 1) were not significant, as such no further analysis was conducted to confirm effect or interaction. The data showing changes in respective Digit Span tests in relation to NR-6 means are plotted with linear regression and confidence intervals displayed (Figure 2). Age showed no significant correlation with NR-6 (τ = -.083, p = 1), DSF (τ = -.092, p =1), DSB (τ = -.061,

p= 1), or DSS (τ = 0.16, p = 1). An effect size was calculated, both DSF and DSS resulted in a small effect size (A < .56; Vargha & Delaney, 2000), however the effect size between of DSB was large (A > .71; Vargha & Delaney, 2000).

Table 2

Kendall's Tau correlations between change in Digit Span Test scores.

Digit Span Test	NR-6					
	Green		Urban		Both Conditions	
	τ	p	τ	p	τ	p
DSF	.12	1	.23	1	.11	1
DSB	.25	1	-.32	1	-.06	1
DSS	-.56	.27	-.13	1	-.13	1

Note * = p<.05, ** = p<.01, *** = p<.001

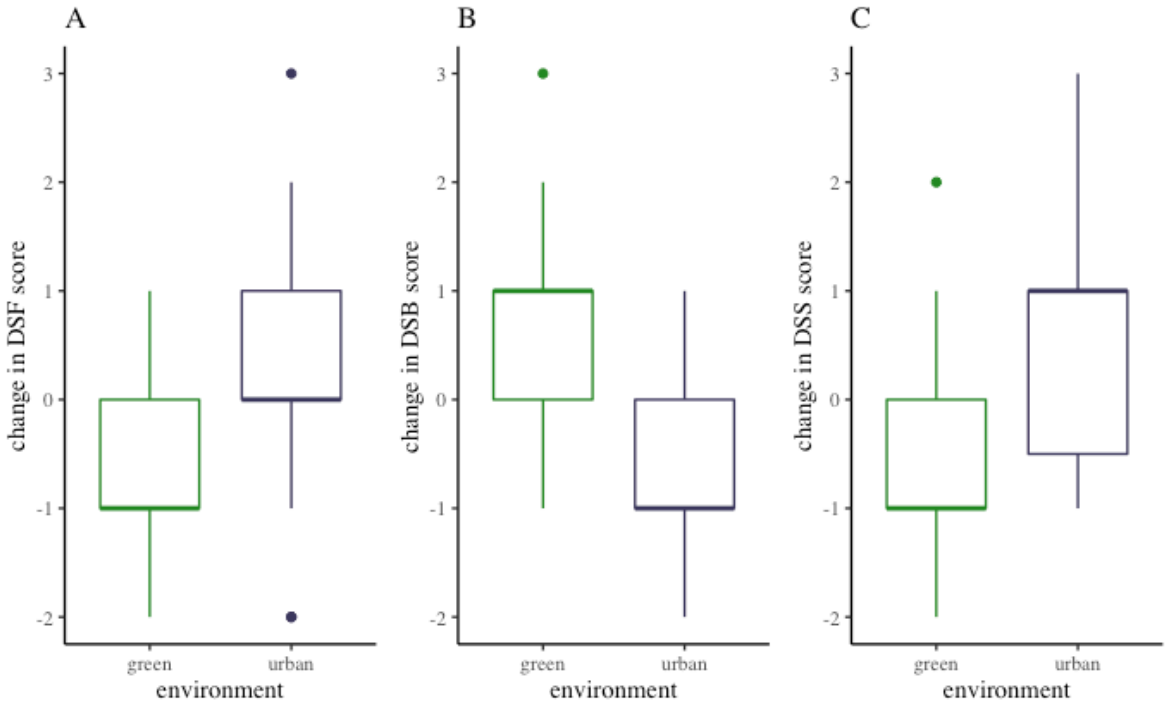

Figure 2. Boxplots of change in A) DSF score, B) DSB score, and C) DSS score between green and urban conditions.

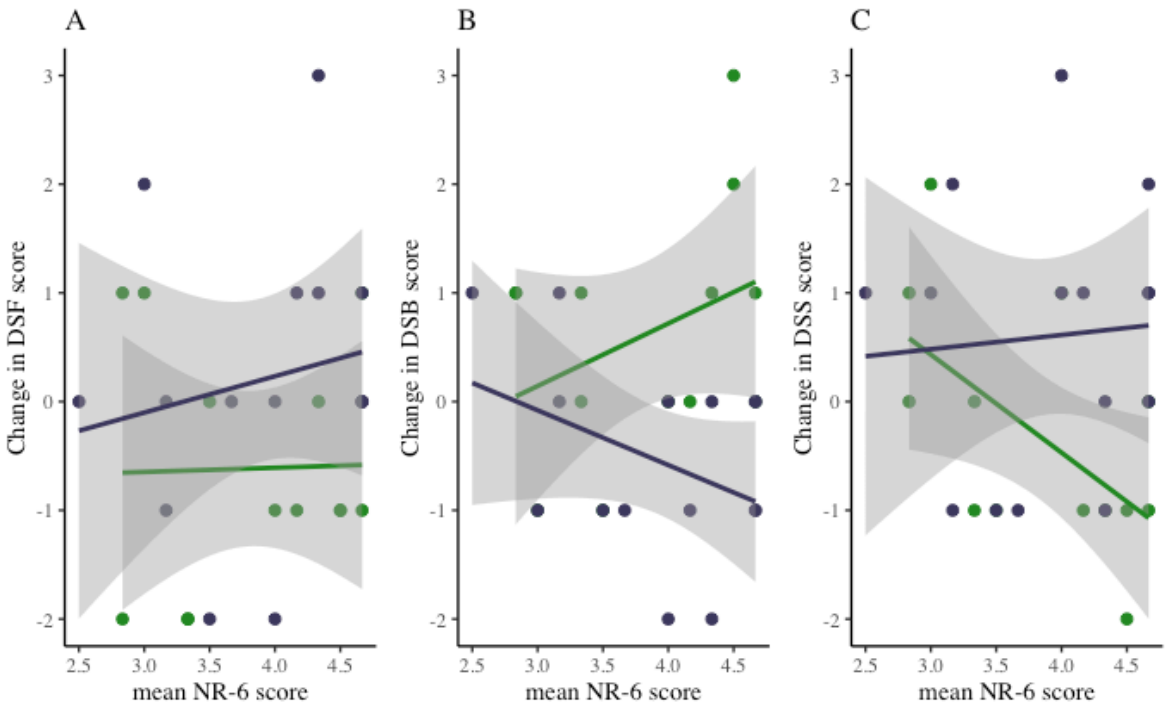

Figure 3. Scatter graphs with linear regression and 95% CI displaying correlation between NR-6 score and change in A) DSF score, B) DSB score and C) DSS score

Table 3

Descriptive statistics for pre-test and post-test digit span scores in all conditions.

Digit Span Test	Green (n = 13)				Urban (n=15)						
	Before		After		Before		After				
	Mdn (Range)	M (SD)	Mdn (Range)	M(SD)	Mdn (Range)	M(SD)	Mdn (Range)	M(SD)	W	p	Vargha and Delaney's *A*
DSF	7(6-9)	7.46(1.05)	7(5-8)	6.85(1.07)	7(4-9)	6.6(1.3)	6(4-10)	6.8(1.7)	63	0.107	.32
DSB	5(4-7)	5.31(0.95)	6(4-8)	5.92(1.18)	5(4-7)	5.33(0.98)	4(3-6)	4.8(1.08)	153	0.01*	.78
DSS	7(5-7)	6.62(0.65)	6(5-9)	6.31(1.11)	5(4-7)	5.47(1.06)	6(5-8)	6.07(0.96)	58†	0.062	.3

Note: * = p<.05, ** = p<.01, *** = p<.001 † Significant based on critical value of 61

Discussion

This study sought to explore whether it was possible to elicit a similar difference in cognitive ability between urban and green conditions by using a digital screen as to what has been reported in previous literature that utilises real world environments. The conditions did elicit different reactions though they were unusual in comparison to what theory suggests, but not completely out of line with results from previous studies that are similar which utilise multiple measures and find limited significant results. As the causality of the GSE is not known (M.J. Nieuwenhuijsen et al., 2016) this study also aimed to explore if there was potential for a trait which measures perceived connection to nature as moderating factor to the GSE. As perception had already been identified to have a moderating effect (Bloemsma et al., 2018; Kahn et al., 2008; Snell et al., 2019; Taylor & Kuo, 2009).

Relation to previous theory

Both Attention Restoration Theory and Stress Reduction Theory suggest that an effect should be possible as long as the videos represented nature in a way that appealed to the viewer. Findings have already been established that parasympathetic response occurs after watching a video of green spaces (Alvarsson et al., 2010). The results of this analysis only go so far as to partially support Attention Restoration Theory but only in the realm of DSB. The lack of significant finding certainly does not provide a rebuttal against Attention Restoration Theory however, more understanding is required, however it bares considering that this study constitutes towards an already mixed body of results with relatively few significant findings.

Digit Span test

An increase in Digit Span Forwards (DSF) may have been explained by practice, or as it was the first measure it may have benefitted from a mechanism similar to that which was

responsible for the short increase in cognitive ability that was found for creativity (Oppezzo & Schwartz, 2014). However, the green condition performed slightly worse on the second performance of the DSF. This drop in performance has not been seen in previous studies.

As expected, the green condition performed better than the urban condition for Digit Span Backwards (DSB). It is interesting that the urban condition actively performed worse for this particular measure as urban performance was better on both other measures. This finding shows that previous literature has been correct to include the DSB element of the Weschler intelligence battery as a measure of positive influence of green space. Though only DSB resolves to significantly favour Attention Restoration Theory or Stress Reduction Theory over both the rarely used DSF and the under-utilised DSS subscale. This does introduce a potential discrepancy in selective measures which are more inclined to favour a researcher's hypothesis. The large effect size found in DSB is in line with previous results however it is inequitable as the sample populations were not the same demographics (Taylor & Kuo, 2009).

The results on Digit Span Sequence heralded the most unexpected results, providing significant difference in urban environments over a green environment. Digit Span Sequence provides a novel area of interest as to why urban areas might provide a better environment to induce spatial or hierarchical cognition.

Nature Relatedness

Though the NR-6 analyses did not show any significant moderating effect of Nature Relatedness in the green space effect, figure 3 graph B shows that among people with the highest Nature Relatedness scores a clear separation is present between conditions. Though at this time the population sample was too small to have a clear understanding of if these NR-6 results are by chance, by looking at the plot there may be a potential for repeated experiments

to assess whether Nature Relatedness or similar constructs predict performance by condition. Any similar research looking into the moderating effect of Nature Relatedness should seek to use the full 21 item measure (Nisbet et al., 2011) as a more sensitive measure which allows for assessment between subscales may heed clarity on whether the construct can be attributed to the GSE mechanism. Age showed no relation which is what was expected be found from previous literature

Overall

Though Kaplan's key tenets of restorative effect of nature include 'being away, fascination, extent & compatibility' (Kaplan, 1995). These are still ideas that can be applied to an urban environment if one is so compelled towards them. Kaplan talks about soft fascination, in which attention is held in the inherent property of an object, however it is plausible for large urban areas to induce a state of wonder.

As shown in figure 1, there was a small park in the urban condition. However previous literature has established that there are limited benefits to urban green spaces, especially with limited biodiversity. Though the urban video featured a small green area, it had a limited number of trees and featured low cut maintained grass (E. Wood et al., 2018) suggest that this is unlikely to produce an effect as the biodiversity is low. However, whereas previous research had participants in static environments that were immediately restrictive, i.e. looking over a brick wall (Tennessen & Cimprich, 1995) or completely concrete areas (Jiang et al., 2019). The current study employed a video of a busy and energetic popular New York city area which may have induced a state of curiosity and interest in participants who are inclined to such places. Ideally future research will establish a counterpart scale to NR. It is plausible that some people may be genuinely connected to city living and should also be explored. The density and type of urban environment should be assessed for varying levels of cognitive

detriment or even benefit. It is possible to expect there to be a large difference in fascination invoked by places that represent a large conceptual shift, have a rich set of stimulus, and have a connection with the individual. Further still it may be possible that rich urban environments pose as a unique source of abundance. Exploration into olfactory effects are limited (Roger S. Ulrich, 1983) and may have a greater connection with psychological state than initially acknowledged.

Participants mentioned that they felt sleepy or unalert after the green condition with some noting that some use nature sounds to induce sleep. Alvarsson (2010) found that natural sounds induce the parasympathetic system which may be why some participants felt drowsy. This may also inconclusively suggest that further research in support of Stress Reduction Theory is warranted. Though there has been some evidence that screens do still produce an effect (Ulrich 1991) there has been some evidence that LCD screens negate the effect (Kahn et al., 2008). Though it appears that this particular study shows that the virtual pre-recordings of environments have an effect, though perception in this case did not appear to factor into the results. There may well be a difference between types of perceptions of nature, potentially explicit and implicit. Explicit perception for example as such in the case of teens who valued green spaces highly utilising them more frequently (Bloemsma et al., 2018) and better physiological restoration when plasma may be perception of the environment, whereas Nature Relatedness may present an implicit perception of oneself as a part of the environment which may be an ineffectual measure for the kind of perception that moderates the GSE.

Expanding on the design utilised by Jiang (2019) allowing a third condition to use their laptop however they so wished for 15 minutes to control for if there is a difference between videos and no video to understand if there is another confounding variable happening. The potential use of screens to induce the benefits of the green space effect is of particular value and exceedingly so in the unstable circumstances regarding COVID-19 in

which this study took place. Under lockdown regulations that covered much of the globe, a majority of people had limited interaction with natural environments. As the current understanding of COVID-19 is developing, the possibility of further prolonged periods of internal isolation may reoccur. Thus, an understanding for potential restorative methods such as virtual exposures to natural environments is of genuine and novel health interest.

Limitations and Further Research

There were potential covariables that were unable to be mitigated or controlled for due to the limitation of experimental design. As the experimenter was present even virtually there may be an effect of a known presence (Johansson et al., 2011; Plante et al., 2001) as most participants were friendly acquaintance. A considerable number of participants were interrupted either by online advertisements or by external parties entering the room the participant was in. Excluding these participants was not possible due to retaining a sufficient sample size to conduct an analysis. It was not possible to externally regulate the level of dB for each participant due to remote nature of experiment, which has been shown (Ulrich et al., 1991). Time of day due to light level has been shown to potentially effect results (Sievertsen et al., 2016) and sessions took place between 8 am and 7pm so. There was high variability in intensity and type of light, for example some participants had the curtains on their windows drawn and others had their room lights on. However, Snell et al (2019) did an analysis on this in their study and found that intensity of natural light did not create a variable in effect on restoration. Additionally the level of greenery in immediate field of view was unknown as being in a classroom with green views, or a workplace with plants, or having a plant within view have all been noted to create and effect (Benfield et al., 2015; Dreyer et al., 2018; Kim et al., 2020).

Due to time restrictions on data collection this study takes a cross sectional approach to a one-time exposure. This has been identified as a shortcoming in reviews in this area (Browning & Rigolon, 2019). A future study would give the same participants different videos of similar environments and repeat over time, as well as administering the NR-21 (Nisbet et al., 2011). Other issues included with sampling were that as conditions were determined by order of survey completion and some participants did not proceed past the survey, some changes had to be made to allocate participants to conditions which introduced some degree of researcher interference. As is often an issue in psychological studies, a WEIRD sample arises due to the nature of sampling approaches and those who are able to access items such as laptops. Even online and distributed among forums for environmental interests, 82% of respondents reported that their ethnicity was white. Bloemsma et al. (2018) found that the level of parents' education factored into teens' use of green spaces, and as can be seen in table 1 there are many participants whose main occupations require some form of further education further reinforcing the WEIRD sample.

The current study would have benefitted from utilising a multiple repeated measures procedure. Assessing Digit Span Test scores before the attentional depletion task might have benefitted so as to control for the degree of deliberate fatiguing that was actualised (Jiang et al., 2019; Kjellgren & Buhrkall, 2010). As previously mentioned using the full NR-21 scale in further research may prove more fruitful if applied in a real green space environment, specifically in different levels of biodiversity. A study which may seek to explore if static environments provide a plateau of interest, as the previously mentioned studies may be inadvertently measuring the cognitive detriment of boredom that is induced by a lack of unique or engaging stimulus (Danckert & Merrifield, 2018).

Conclusion

It can be widely acknowledged that most people in some part appreciate natural spaces. Whether this is by intrepid explorers seeking a seldom spotted mountain vista, or a sea scape framed in a commercial office, natural scenes hold a universal appeal. How far this universal appeal reaches into the conscious and subconscious levels of the psyche is being explored. The Green Space effect is the name given to a wide variety of physiological and psychological benefits from being around or in nature or places with natural elements such as plants. This particular study looked at whether the Green space effect extends past the immediately natural into the realm of digital screens and virtual experiences. Attention Restoration theory holds that natural scenes provide a stimulus that is easy to be perceived and requires little top-down processing to be understood there by letting psychological resources recover in order to expend further cognitive effort on tasks immediately following the natural scene. Building on this theory if the key beliefs of Attention Restoration are separable from the inherent physicality of a green space, and replicable outside nature and unique to nature only, then a marked difference between cognitive ability scores as measured by the complete digit span test should demonstrate a difference between scores of people who were exposed to virtual green environments as opposed to virtual urban environments. Though however the unique finding from this study that urban environments promote higher scores in an under-utilised measure of Digit Span Sequence, it may be that different types of environments elicit different forms of cognitive activity. Additionally, this study explored the already established connection between perception of natural environments and restoration could be further explained by measuring Nature Relatedness. Further still there may be potential for a persons' personal appeal to various types of environment, for example whether they feel more at home in the countryside or a city that may also factor into the perceived value and engagement with an environment. It is suggested that further research explores

developing a measurement of individual perception on both green and urban environments, not as a single sliding scale but as multiple dimensions. Perceived engagement should also be explored as ubiquity of natural videos are increasing and their content utilised for different purposes. Largely, the mechanisms of the Green Space Effect are still unknown, and though properties of what is actually being restored or replenished is being explored, what that resource is is yet to be established.

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List of Tables

List of Figures

Appendix A SHORT FORM VERSION OF THE NATURE RELATEDNESS SCALE (NR-6)

Instructions: For each of the following, please rate the extent to which you agree with each statement, using the scale from 1 to 5 as shown below. Please respond as you really feel, rather than how you think "most people" feel.

1) Disagree strongly 2) Disagree a little 3) Neither agree or disagree 4) Agree a little 5) Agree strongly

1. My ideal vacation spot would be a remote, wilderness area.
2. I always think about how my actions affect the environment.
3. My connection to nature and the environment is a part of my spirituality.
4. I take notice of wildlife wherever I am.
5. My relationship to nature is an important part of who I am.
6. I feel very connected to all living things and the earth.

Appendix B LIST OF DIGIT SPAN TEST DIGITS

PRE-TEST						
No. #	Trial	DSF	DSB	CORRECT DSB	DSS	CORRECT DSS
3	1	356	657	756	826	268
3	2	428	249	942	916	169
4	3	8346	8754	4578	2752	2257
4	4	3726	9278	8729	1897	1789
5	5	28754	21743	34712	24542	22445
5	6	92765	98656	65689	87654	45678
6	7	652397	983697	796389	576752	255677
6	8	273685	281374	473182	139218	112389
7	9	6723548	7156843	3486517	6682642	2246668
7	10	5162735	2876358	8536782	7451978	1457789
8	11	39768452	82136874	47863128	92756763	23566779
8	12	27386484	46759329	92395764	83873457	33457788
9	13	918277483	645753387	783357546	593578673	335567789
9	14	276547536	254317284	482713452	197354631	113345679
10	15	2736584611	4575349764	4679435754	9172428732	1222347789
10	16	3987672552	3456167382	2837616543	1875265367	1235566778
11	17	91862384568	83677167237	73276177638	91725376312	11223356779
11	18	24156256337	35719981345	54318991753	75826167235	12235566778
12	19	872638219822	265896915721	127519698562	782627853167	122356677788
12	20	376837687464	351912745943	349547219153	712563286847	122345667788

POST-TEST						
No. #	Trial	DSF	DSB	CORRECT DSB	DSS	CORRECT DSS
3	1	853	958	859	285	258
3	2	246	392	293	947	479
4	3	7645	6352	2536	1285	1258
4	4	6925	4914	4194	9742	2479
5	5	21629	48136	63184	63517	13567
5	6	85913	59366	66395	71842	12478
6	7	934712	676512	215676	396427	234679
6	8	825497	585539	935585	495167	145679
7	9	5217392	7682816	6182867	2687354	2345678
7	10	6729463	2846959	9596482	3619587	1356789
8	11	81936287	56461753	35716465	74583291	12345789
8	12	27398462	88732629	92623788	79475196	14567799
9	13	918737264	654112717	717211456	196475746	144566779
9	14	829463912	212653725	527356212	591128137	111235789
10	15	9282187538	1873795788	8875973781	9575258281	1225557889
10	16	5235297384	8412347276	6727432148	8714264538	1234456788
11	17	93672238472	681927633484	484336729186	87635628494	23445667889
11	18	82493754926	987246738962	269837642789	68152672658	12255666788
12	19	647265418482	2826372512734	4372153736282	792518725812	1122277889
12	20	865284961973	8753827345912	2195437283578	857298382167	1223778889

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