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How do people with weak and strong pro-environmental worldviews process visual climate change information? An EEG study.

Running Head: EEG study on world view and climate change imagery processing

[4531 words]

Abstract [141 words]

In a pioneering work, this study explores the potential that might be found in combining the environmental psychological concept environmental worldview with the neurocognitive study technique electroencephalography (EEG). With this research, we aim to bridge between the research traditions of environmental communication and neuro-cognition by investigating in an qEEG experiment (N=19) if different levels of environmental worldview, measured by the NEP, influence the processing of visual climate change imagery, reflected by the theta and gamma oscillations in the frontal and parietal areas. Our results confirm the assumptions that there is a relationship between the degree of environmental worldview and visual environmental communication processing. The pattern is interpreted as an indication of that people with weak pro-environmental worldviews show cognitive signs of mismatch between what is in line with their environmental worldview and what they are confronted with in the visual stimulus.

Keywords: Environmental communication; EEG; Information processing; climate change imagery

Introduction

Visual representations of climate change are often used in media coverage (Sheppard, 2012) and in campaigns that aim to motivate citizens to mitigate and adapt to the predicted consequences of climate change (Klöckner, 2015). For this reason, the effect of climate change imagery on inducing behavioural change has been subject to a variety of studies (see Klöckner (2015) for a summary). However, this research is almost exclusively built on self-report measures, while neurocognitive research on the other hand could provide a way to investigate these questions from a neuronal level. This might help environmental psychologists to understand how psychological constructs impact people's reaction to visual information campaigns. This line of research is not well defined yet, therefore we decided to focus on a very selected section of analysis: How does the degree to which an environmental worldview is embraced, affect the patterns of brain oscillations in the theta and gamma bands after exposure to visual representations of climate change? First we will present what is known about the relationship between visual communication, environmental worldviews and pro-climate action, to follow with a description of what neurocognitive research could add to this line of research and finally the setup for the current study and the results will be presented and discussed.

Visual climate change communication, environmental worldviews and action

Visual environmental communication has the potential to enhance the understanding of climate change among the general public, by bridging between the abstract concepts surrounding climate change and every day experiences (Nicholson-Cole, 2005). Therefore, it is a promising tool to induce behavioural change among the general public (Klöckner, 2015). However, its effectiveness depends on the match between the targeted construct and where in the multi-staged process towards behavioural change the recipient is (for more information see Klöckner, 2014; Bamberg, 2013). For instance, environmental communication that aims to induce behavioural change by improving recipients knowledge regarding a specific environmental behaviour, has shown to only influence individuals with strong environmental orientated values (Bolderdijk et al., 2013). This is in accordance to current neurocognitive theories, which state that the human brain uses knowledge stored in the architecture of the brain derived from prior experiences, to steer attention or induce action based on the presented information (Engel, Fries, & Singer, 2001). In other words, the brain uses top-down processes to select input that is meaningful for the individual in that specific moment. Hence, how climate change images are perceived by the recipients is likely to vary due to differences in stored information. Although environmental and cognitive psychology theories seem to align perfectly, this has not yet been explored.

Environmental worldview has shown to be of influence when inducing behavioural change (Dunlap, 2008). One of the most widely used instruments to measure people's general environmental worldview is the New Environmental Paradigm (NEP) (Dunlap and Van Liere, 1978; Dunlap et al., 2000; Dunlap, 2008). This scale measures people's acceptance that resources are limited, that humans are part of nature and that the equilibrium of natural systems can be disrupted by human activity. It can therefore be seen as a general measure of worldview on humans' place in the world in relation to nature (Stern, 2000). In order to embrace the environmental worldview, specific knowledge regarding the statements should be acquired by the individual and stored in his or her memory. This paper will investigate if individuals with varying levels of environmental worldview will have different brain activation patterns while viewing climate change imagery.

Previous findings on the implications of differences in theta and gamma oscillations

With brain patterns we mean electrical signals measured on the scalp that oscillate within different frequencies bands across different brain areas. These oscillations arise from hundreds of thousands of neuronal cells that produce electrical activity and is a process the brain uses to communicate across different neuronal areas (Teplan, 2002; Başar et al., 2001; Pfurtscheller & Lopes, 1999). They enable an individual to reconstruct a visual stimulus into unique spatiotemporal patterns, e.g. shape, colour, spatial orientation, location or movement (Ungerleider and Haxby, 1994). Simultaneously, they activate memory templates to enable the accessibility of stored knowledge while processing the incoming visual stimulus (Engel, Fries and Singer, 2001; Basar et al., 1999, 2001; Buschman and Miller, 2007). How these bottom-up and top-down processes interact is not yet fully understood (Milner, 1995; Engel, Fries and Singer, 2001). However, it is thought that the information from both processes are being matched and that the information is utilized as a result from this match (Herrman et al., 2004). The frequency bands that have been associated with this top-down processing and with the matching between top-down and bottom-up processes in particular, are the theta (4 – 7 Hz) and gamma (~30 to 70 Hz) band (Herrmann and Demiralp, 2005; Klimesch et al., 1996; Osipova et al., 2006). Additionally, these top-down processes are thought to originate in the frontal and parietal cortex which are areas known for their involvement in semantic memory storage, of which environmental worldview is an example (Binder et al., 2009).

Therefore, in this paper we will look into the effect of environmental worldview on the processing of climate change imagery reflected by the gamma and theta band oscillations in the frontal and parietal brain areas. Individuals with weak or strong environmental worldview might show different oscillatory patterns, due to their difference in prior stored general environmental knowledge. More embracement of the environmental worldview might be reflected by an increase in gamma and theta oscillations in the frontal and parietal areas, as more environmental knowledge is stored in those individuals (Binder et al., 2009).

Method

Participants

Twenty healthy volunteers took part in the study, of which one was excluded due to a software error. Almost equal amount of male (N=11) and female took part. Nearly half was between the 21-25 years (N=12), the rest was between 26-30 years (N=4), 36-40 years (N=1) or 40-45 years (N=2). The participants had finished high school (N=7), bachelor (N=8), master (N=2) or PhD level (N=2) as highest education. As a response to the question "how often are you on average exposed to environmental communication", the participants reported zero to once (N=8), two to five times (N=9) or more than five times (N=2) per week. As a response to the question "when was the last time that you were exposed to environmental communication", the participants reported the day of the test day (N=11), within the last week (N=5) or before the last week (N=3).

All participants were informed about the scope and design of the study and gave their written consent for participation.

Instruments

Environmental worldview: was measured by the NEP [Cronbach's Alpha = .64; M = 57.21; SD = 6.71], which contained of 15 items that were rated on a 5-point Likert scale (Dunlap, 2010). The overall score per subject was calculated by summing up all item scores, after inverting some of the questions to control for reverse wordings. High scores mean stronger embracement of limitation of resources, delicate equilibria in nature and humans as part of a natural system.

Climate change imagery: were obtained, with permission, from a database with visual climate change imagery as often used by mass media. Containing images from UK, USA and Australian newspapers (O'Neill et al., 2013; O'Neill & Smith, 2014; O'Neill, 2013). *Brain oscillations:* were measured by quantitative electroencephalography (qEEG), a device that captures electrical neuronal activity with a high temporal resolution (Teplan 2002; Pfurtscheller & Lopes, 1999). Specifically, we used a 19 scalp site Tin-electrode cap (ElectroCap, United States), Mitsar amplifier (Mitsar EEG-201, St.Petersburg, Russia) and the WinEEG 2.84.44 software package (Mitsar, St.Petersburg, Russia). The arrangement of the electrodes was according the International 10-20 system against linked earlobes reference electrodes. The ground electrode was placed 1.5 cm anterior to the frontal midline electrode (Fz). Electro Gel and NuPrep gel (50:50) (ElectroCap, United States) were used to achieve contact between the electrodes and the scalp, and Ten 20 EEG paste (D-O. Weaver and CO, USA) to attain contact between the earlobes and the reference electrodes. Impedance was kept below 10 kΩ. Sampling rate was 250 Hz, and band-pass filter ranged from 0 – 70 Hz**.** A notchfilter was set to 45-55 in order to reduce electrical inference. The electrodes used for analyses were those recording neuronal signals from the frontal (Fp1, Fp2, F3, Fz, F4) and parietal (P3, Pz, P4) areas.

Climate change recognition (error percentage): in the task described below, participants were instructed to press a response button when they viewed two climate change images in sequence. We were interested in how environmental worldview affects the processing of these images. However, a potential confound is the lack of recognizing the climate change image as such. Therefore, we additionally measured the percentage of erroneous responses [M = 30,79; SD = 20,62].

Design

After the participants filled in the NEP they were seated in a comfortable chair, 1.5 m in front of a computer screen, to view stimuli shown on a 38 cm monitor using the Psytask (Mitsar Ltd.) software, while the EEG was recorded.

The task, a variant of the Visual Continuous Performance Task (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956), took approximately 45 minutes to complete. Three categories of images were used for the experiment, (1) climate change imagery ('EC'), (2) images from category 1, but altered using Photoshop to remove the environmental message ('non-EC'), e.g. in an image with a polar bear in a landscape, the polar bear was erased, (3) images of furniture ('furniture'). Each trial consisted of a pair of stimuli: EC – EC, EC – non-EC, non-EC – non-EC or furniture – furniture. However, since the latter two consists of images that are not climate change related, they are beyond the scope of this paper. The brain signals while viewing the first stimuli of the EC – non-EC trails are of interest, but unfortunately were lost due to a software error and therefore not included in the analyses of this study. The trials were equally distributed and shown in random order with a total of 100 trails per participant. Participants were instructed to *only* press a response button when the two climate change images were shown subsequently. The Visual Continuous Performance Task was chosen because of its strong validity in the original version and known effects on brain signals (Rosvold et al., 1956). However, after a pilot test using the original presentation times (100 ms) we noticed that the stimulus presentation of the images was too short for participants to understand the images and needed to be prolonged. Therefore, each image was shown for 1500ms, with a 1500ms break (see figure 1). As a consequence one male participant stopped after 70 trails and three (two male) after 50 trials due to fatigue, the provided data was included in the analyses.

EEG data modelling

Eye-blink artefacts were corrected by zeroing the activation curves of individual independent component analysis (ICA) corresponding to eye blinks (Vigário, 1997). In addition, the EEG was manually inspected to verify artefact removal. A filter was set at 4-8 Hz for the theta and 30-50 Hz for the gamma band. The data of stimulus presentation in EC-EC trails were computed into event-related oscillations, baseline corrected for activity prior to presenting stimulus one. Subsequently, the average power was calculated per electrode and frequency band while viewing stimulus one, two and during the break in-between those images.

Statistics

Statistical analyses were performed by Statistical Package for Social Sciences (SPSS inc. Chicago, IL, USA) for Windows version 23. Spearman's rank order correlation were used to analyse if the participants' gender, age group, education, frequency- and most recent exposure to environmental communication was related to the NEP score or percentage of trails that were answered erroneous. The correlation between the average theta or gamma power and NEP as well as the error percentage was calculated with Pearson coefficients.

Results

Gender, age, education, frequency- and most recent exposure to environmental communication had no relation to the NEP score, or percentage of errors. Also, NEP [M = 57.21; SD = 6.71] and the percentage of errors [M = 30,79; SD = 20,62] were not significantly correlated (r = -.25, *p =.31*). However, age correlated positively with education (r = .52, *p = .02*) and education correlated positively with gender (r = ,70 *p = .00*). Additionally, the last exposure to environmental communication correlated negatively with age (r = -.48, $p = .04$), with education (r = -.60, $p = .01$) and gender (r = -.48, $p = .04$).

Table 1 shows the correlations coefficients between the NEP with the theta and gamma oscillation power in different brain regions. We analysed the correlation between the NEP and brain oscillations while viewing stimulus 1, stimulus 2 and in between both viewings. It shows that NEP was significantly negatively correlated with the power of gamma oscillations in the right prefrontal area while viewing stimulus 1 [r = -.51, $p = .03$] and in between viewing stimulus 1 and 2 [r = -.58, $p = .01$]. This means that for participants with higher NEP scores gamma power decreased during and after processing a climate change related visual stimulus as compared to participants with lower NEP scores. It is important to note that no correction was performed to avoid alpha error inflation. This would exclude the two significant results. However, based on the rather substantial size of the correlation we chose to report them as preliminary results in an exploratory study. Additionally, the brain oscillations were correlated with percentage of error. There were no significant correlation between the percentage of error and the theta or gamma oscillations.

Discussion

This study analysed the processing patterns of climate change imagery in the brain by using qEEG. The purpose was to see if different degrees to which an environmental worldview is embraced influences how the brain processes visual climate change imagery as reflected by top-down processing. The results show that a stronger environmental worldview is negatively correlated with gamma oscillations in the right prefrontal cortex. In prior studies, the amount of gamma oscillations has been found to increase when new incoming information was matched with prior stored information (Herrmann and Demiralp, 2005). This is opposite to the pattern found in this study, were a stronger embracement of the environmental worldview let to a decrease in gamma oscillations. One could speculate that the oscillations do not reflect the amount of information that is already stored, but how the climate change issues are perceived. Since, the oscillations were not correlated to the recognition of the climate change images and additionally, a linguistic study that investigated the influence of worldview on information processing found an increase in gamma power when worldview was violated (Hagoort et al., 2004). Thus, individuals with more environmental worldview might have perceived the images (e.g. sea with windmills or polar bear on melting ice) as more compatible with their environmental worldview. This is in line with research showing that gamma oscillations are not only involved in matching new information with prior stored ones, but as well with the utilization of that information (Herrmann et al., 2004). Thus, our data might confirm that humans evaluate presented information according to their own views (Nerlich 2010) and that their brain notices if information is violating the current worldview.

Participants with a higher environmental worldview were *not* more accurate in recognising climate change images than those with lower environmental worldview. While this is an notable finding on first side, one should bear in mind that we used images as often used in mass media (O’Neill et al., 2013; O’Neill & Smith, 2014; O’Neill, 2013). Therefore, it is likely that participants have seen these or very similar images before.

Many oscillations bands did not show a correlation with environmental worldview. A part of this data does indicate a similar pattern in the gamma oscillations, but did not reach significance. One could speculate about what this result might reflect, for instance it could indicate that the top-down processes related to climate change information processing only take place in the gamma oscillations in the frontal areas. However, this line of research is too preliminary to speculate, since the non-significant findings could as well be due to some limitation(s). For instance, although the number of participants is not uncommon in EEG research (Fernandez et al., 2007; Tan et al., 2009; Siniatchkin et al., 2000; Kelly et al., 2009), the number is relatively low which makes it difficult to reach statistical significance even for relatively large correlation coefficients. Second, the scores on the NEP were normally distributed, but were all in the higher segment. This seems to be a characteristic of a university sample (Schultz, 1999). However, to get a clearer understanding of the influence of environmental worldview on information processing, it could be insightful for future studies to select participants with a wider range of NEP scores. Third, we prolonged the presentation time based on our pilot study to make sure participants had enough time to consciously process and understand the images. However, the increased duration may have lowered the concentration towards to end. Additionally, it makes it less clear which brain processes are captured in this prolonged presentation. Since, power in oscillations can be altered by external events as viewing climate change images but as well by internal events as pondering. Therefore, the prolonged presentation time might have increased the chance of capturing cognitive functioning unrelated to visual environmental communication processing.

In this study we have chosen to investigate the effect of environmental world view, since according to the Value-Belief-Norm theory (Stern 2000), the step where the activation of norms most likely stops is between environmental worldview and the triggers of personal norm. However, this might also happen earlier in the chain for instance at values, since this construct has shown to be most predictive for environmental behaviour (Steg et al., 2011). Therefore we would like to encourage other researchers to continue this line of research. Also, because in other domains of communication, the collaboration between neurocognitive psychology and marketing has shown effective. Neurocognitive methods have shown to be able to correctly predict effectiveness of commercials (Ariely & Berns, 2010) or product designs (Khushaba et al., 2013), without the social desirability bias self-report measurements can entail (Ariely &

Berns, 2010). A similar collaboration has the potential to improve the effectiveness of environmental communication.

Environmental psychologists are vital in investigating which constructs are important in inducing behavioural change (e.g. beliefs, values, emotion, perceived control) (Kollmuss & Agyeman, 2002). Neurocognitive psychology can subsequently investigate what type of communication will target those constructs best. Therefore, we hope to inspire other neuroscientists and environmental psychologists to seek collaboration.

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Figure 1

Schematic overview of EEG task

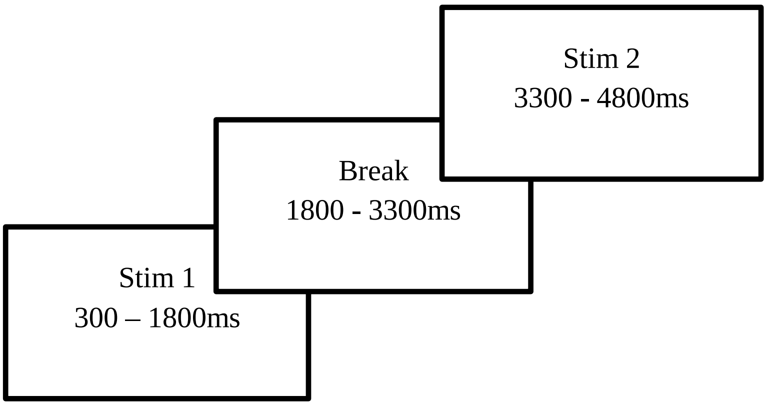

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Table 1

The table presents the correlation coefficients between the NEP and the oscillations from different brain areas (Fp1, Fp2, F3, Fz, F4, P3, Pz, P4), in the theta and gamma frequency band. Stim 1 refers to the viewing of the first image, stim2 to the viewing of the second image and break refers to the time in-between the two viewings.

NEP/oscillations	Fp1	Fp2	F3	Fz	F4	P3	Pz	P4
Theta stim 1	-.08	-.07	.17	.14	.20	.03	-.20	-.22
Theta break	-.16	-.12	.40	-.18	-.16	-.20	-.41	-.32
Theta stim 2	-.14	-.07	-.07	.15	-.18	-.11	-.17	-.23
Gamma stim 1	-.06	-.51* *p=.01*	-.02	.04	.02	-.22	-.36	.10
Gamma break	.24	-.58* *p=.03*	-.09	-.07	-.05	-.19	-.36	-.08
Gamma stim 2	-.28	-.44	-.05	-.22	-.18	-.21	-.21	-.15

*=p<.05

Please insert at the bottom of page 11 (end of the result section).