PSYCHOLOGICAL WELL-BEING MODULATES NEURAL SYNCHRONY DURING NATURALISTIC FMRI

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Bachelor of Science, University of Lethbridge, 2021

A thesis submitted in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE
in
NEUROSCIENCE

Department of Neuroscience
University of Lethbridge

LETHBRIDGE, ALBERTA, CANADA

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Date of Defence: December 1st, 2023

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DEDICATION

To my family, friends, and partner.

Thank you for your unconditional support throughout this process.

ABSTRACT

Psychological well-being (PWB) is a combination of self-acceptance, life purpose, personal growth, positive relationships, and autonomy, and has a significant relationship with physical and mental health (Huppert, 2009). Previous studies using resting-state functional magnetic resonance imaging (fMRI) and static picture stimuli have implicated the anterior cingulate cortex (ACC), posterior cingulate cortex (PCC), orbitofrontal cortex (OFC), insula, and thalamus in PWB, however, the replication of associations across studies is scarce, both in strength and direction, resulting in the absence of a model of how PWB impacts neurological processing (King, 2019). Naturalistic stimuli better encapsulate everyday experiences and can elicit more “true-to-life” neurological responses, and therefore may be a more appropriate tool to study PWB. The current research uses data from the Naturalistic Neuroimaging Database (Aliko et al., 2020; v2.0) to examine differences in comparative low and high levels of PWB using functional magnetic resonance imaging (fMRI). In four experiments, we assessed neural synchrony patterns associated with comparative low and high levels of PWB, and how this neural synchrony may be modulated by the emotional valence of the incoming stimulus. Results from this thesis emphasize that differing levels of PWB impact naturalistic processing, serving as an implicit prime for how we perceive the world, and that the valence of incoming stimuli modulates the neural response differently based on PWB level. These findings bridge the gap between PWB and "real-world" cognitive processing.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my supervisor, Dr. Chelsea Ekstrand, for allowing me an opportunity to pursue my Master's degree and gain experience in the field of neuroimaging at the University of Lethbridge. Your unwavering support has been instrumental in my success, and your supervision has allowed me to not only grow as a student, but also as a person. Your guidance has taught me that there is no challenge too big to overcome, and you have provided me with an environment that has allowed my passion for learning and science to grow throughout our time together.

I would also like to thank my co-supervisor, Dr. Robert Sutherland, and committee members Dr. Robbin Gibb and Dr. Bryan Kolb for your feedback, help, and support. I am extremely appreciative that you provided me with this opportunity and for your guidance throughout the past two years. I would like to give an additional thank you to Dr. Artur Luczak for your time as the chair of the defence.

Lastly, I would like to thank Master's students from the Ekstrand Neuroimaging Lab, Joshua Craig, Christina Haines, and KiAnna Sullivan. The team that we have built over the past two years, despite the blocks we encountered, is something I do not take for granted, and I am grateful for your support. To the independent study students in the Ekstrand Neuroimaging Lab, Anja Gassner, Lucas Ferrari do Amaral, Jane O'Connor, and Rylee Weavers, thank you for your support and encouragement over the past few months.

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Chapter 2: Examining Neural Correlates of PWB Using Naturalistic fMRI

LIST OF ABBREVIATIONS

ACC	Anterior Cingulate Cortex
CBF	Cerebral Blood Flow
EEG	Electroencephalography
EPI	Echo Planar Imaging
FDR	False Discovery Rate
FEF	Frontal Eye Field
fMRI	Functional Magnetic Resonance Imaging
GLM	General Linear Model
IFG	Inferior Frontal Gyrus
ISC	Intersubject Correlation
IPS	Intraparietal sulcus
LME	Linear Mixed Effects
LOC	Lateral Occipital Cortex
MFG	Middle Frontal Gyrus
MTG	Middle Temporal Gyrus
mPFC	Medial Prefrontal Cortex
MRI	Magnetic Resonance Imaging
NIH	National Institute of Health
NNDb	Naturalistic Neuroimaging Database
OFC	Orbitofrontal Cortex
SFG	Superior Frontal Gyrus
SMART	Servier Medical Art
SPL	Superior Parietal Lobule
STG	Superior Temporal Gyrus
SWB	Subjective Well-Being
TE	Echo Time
TPJ	Temporoparietal Junction
TR	Repetition Time
PCC	Posterior Cingulate Cortex
PET	Positron Emission Tomography

PFC	Prefrontal Cortex
PWB	Psychological Well-Being
vmPFC	Ventromedial Prefrontal Cortex

CHAPTER 1: General Introduction

1.1 Psychological Well-Being

Well-being refers to optimal functioning (Lyubomirsky et al., 2005; Ryan & Deci, 2001) and is a complex trait-like construct that has evolved over time. The investigation of well-being generally asks what it means to live a good life, and the framework for understanding well-being historically distinguishes between hedonic and eudaimonic well-being (King, 2019). Eudaimonic well-being relates to the consequences of self-growth and self-actualization, whereas hedonic well-being relates to immediate sensory pleasure, happiness, and enjoyment (Ryff, 1989). In the contemporary investigation of well-being, the most frequently used terms are subjective well-being (SWB) and psychological well-being (PWB), which are thought to respectively originate from hedonic and eudaimonic traditions (King, 2019). PWB and SWB are correlated constructs, where SWB involves life satisfaction, the absence of negative emotions, and the presence of positive emotions (Hausler et al., 2017), whereas PWB incorporates experiencing positive relationships, life purpose, and the development of potential (Huppert, 2009). Although some researchers consider them to be distinct, current models suggest strong correlation and a lack of discriminant validity between the two terms (King, 2019). PWB is therefore seen as an umbrella term encompassing hedonic and eudaimonic aspects of well-being, aligning with theoretical perspectives (Salsman et al., 2014). In other words, PWB considers life satisfaction, positive/negative mental and emotional states (e.g., feelings of happiness, sadness, etc), and sense of purpose/meaning in life (Steptoe et al., 2015).

1.2 Psychological Well-Being and Physical/Mental Health

While research generally focuses on neurological mechanisms underlying psychopathology, the past 60 years has demonstrated an increase in the literature devoted to the study of well-being (King, 2019), in part due to the discovery that higher PWB is linked to better physical and mental health outcomes (Huppert, 2009). Specifically, evidence has suggested that positive hedonic states, eudaimonic well-being, and life evaluation are relevant to health and quality of life as people age (Steptoe et al., 2015). It has been well established that impaired PWB is associated with increased risk of physical illness due to the long-standing acceptance that psychological distress is strongly correlated with reduced quality and duration of life, increased use of health services, and physical morbidity (Winefield et al., 2012). However, evidence has shown that positive PWB could be a protective factor for health (Lyubomirsky et al., 2005) as studies have suggested that positive hedonic states and life evaluations predict lower future mortality and morbidity (Chida & Steptoe, 2008). Positive PWB is associated with reduced cortisol output during the day (Steptoe et al., 2005; Chida & Steptoe, 2008), which may impact immune regulation and lipid metabolism (Winefield et al., 2012). Further, positive affect, which is an aspect of hedonic well-being, has been associated with reduced inflammatory and cardiovascular responses to acute mental stress, and a reduction in inflammatory markers (Steptoe et al., 2012). Moreover, PWB is associated with attaining and maintaining higher physical activity levels (E. S. Kim et al., 2017) and has a significant effect on mental health (Salsman et al., 2014). PWB can therefore impact physical health both directly and indirectly through the effects of positive or negative mental health states.

1.3 Psychological Well-Being and Cognition

PWB has a broad influence on cognition across various domains. PWB may influence attention processes, as evidenced by a meta-analysis reporting that attention is related to positive aspects of mental health, including well-being (Irie et al., 2019). Further, mindfulness, which is characterized by purposeful control of attention (Brown et al., 2007), is highly positively correlated with PWB and negatively correlated with psychological distress (Huang et al., 2021). PWB also has links to memory processes, specifically semantic self-images (which refers to autobiographical knowledge about the self) and this correlation grows stronger over the lifespan (Rathbone et al., 2015). Semantic self-images are suggested to play a crucial role in supporting the self, providing a link between semantic memory and eudaimonic processes of PWB (Rathbone et al., 2015). Studies have also suggested that PWB has a positive correlation with adaptive decision-making strategies in adolescents, particularly subjective aspects of PWB (Páez-Gallego et al., 2020). Higher levels of PWB are associated with a preference for adaptive decision-making strategies, emphasizing life satisfaction and self-realization (Páez-Gallego et al., 2020). Likewise, cognitive flexibility has been found to predict PWB, where it is considered a mediator in the relationship between self-confidence and PWB (Malkoç & Mutlu, 2019). Importantly, a significant relationship has been observed between PWB and aging, particularly in health outcomes at older ages (Steptoe et al., 2015). PWB may contribute to longer life expectancies and promote active aging by serving a protective role (McFarquhar & Bowling, 2009), and attitudes toward aging may moderate the relationship between PWB and subjective age (Mock & Eibach, 2011). Therefore, the impact of PWB on behaviour and cognition is far reaching and may have profound effects on mental and physical health outcomes.

1.4 Psychological Well-Being and Positive Emotional Stimuli

Positive emotions have been suggested to play a significant role in higher PWB outcomes, where they form the experiential foundation for mental health (Fredrickson, 2001). Not only are positive affect and feelings of happiness two of the components comprising PWB, but cheerfulness, optimism, and freedom from negative thoughts are considered indicators of higher PWB (Satici, 2019). Further, positive emotions mediate the relationship between positive psychological capacities and PWB (Avey et al., 2011) and the importance of positive emotions has been emphasized in the creation of psychological resources and the promotion of higher PWB levels (Santos et al., 2013). Further, higher levels of PWB are associated with reduced affective reactivity to positive events in daily life (Grosse Rueschkamp et al., 2020), demonstrating the complex relationship between high PWB and positive emotions. Contrarily, lower levels of PWB have been associated with less frequent positive emotions, as negative affect and the reduction in positive emotions are two of the components comprising low PWB. Low PWB is associated with assigning negative context to stimuli, suggesting that the interpretation of positive events may be affected by negative context (Pedale et al., 2017). Low positive affect, a component of low PWB, may be related to encoding ambiguity as less emotionally extreme (Pury, 2004), suggesting that positive events will be experienced with less intensity in individuals with low PWB.

1.5 Psychological Well-Being and Negative Emotional Stimuli

Negative emotions have a complex bidirectional relationship with lower PWB outcomes, with negative affect being a primary component of low PWB. Negative emotions are negatively correlated with several domains of well-being, including quality of life (Geng et al., 2020) and positive life experiences (Kuan et al., 2020), and can decrease general PWB through lower psychological flexibility (Wąsowicz et al., 2021). The perceived impact of life events is also a strong predictor of wellbeing (Burns & Machin, 2013), suggesting that individuals with lower PWB may interpret ambiguous events more negatively. Further, higher emotional inertia, the degree to which emotional states are resistant to change (Kuppens et al., 2010), is associated with lower levels of PWB, and this effect becomes more pronounced with negative emotions (Koval et al., 2016). In contrast, higher PWB is associated with a reduction in negative emotions. While high PWB does not require constant positive emotions, or the complete absence of negative emotions, individuals with high PWB are typically able to manage negative emotions more effectively (Iani et al., 2019). Further, higher PWB is associated with less negative interpretation of negative events and less affective reactivity to positive events (Grosse Rueschkamp et al., 2020), suggesting that individuals with high PWB profit less from the joy of a positive event in daily life, whereas positive events may act to increase the mood of individuals with low PWB.

1.6 Neuroimaging Studies on Psychological Well-Being

1.6.1 Structural MRI

While an abundance of neuroimaging studies have investigated the neural correlates of PWB, there is a large degree of variability in the literature. Several neuroimaging techniques have been used to investigate the neural correlates of PWB, including structural MRI. Lewis et al. (2014) investigated whether regional gray matter volume was associated with eudaimonic aspects of PWB and found that eudaimonic PWB was positively correlated with right insular cortex gray matter volume. Other structural MRI studies have found that trait happiness is positively correlated with gray matter density of the rostral anterior cingulate cortex (ACC; Matsunaga et al., 2016), subjective happiness is associated with gray matter volume in the right precuneus (Sato et al., 2015), and regional gray matter volume in the left rostrolateral prefrontal cortex (PFC) and dorsal ACC are negatively associated with quality of life (Takeuchi et al., 2014). The variability observed in structural MRI studies investigating the neural correlates of PWB emphasizes the need to delve into the domain of functional MRI (fMRI) studies to gain a more comprehensive understanding of PWB in the brain.

1.6.2 Functional MRI

In attempt to build a model of PWB in the brain, fMRI studies have been conducted investigating the neural correlates of PWB. Luo et al. (2016) investigated the neural correlates of happiness, a subjective component of PWB, using resting-state functional connectivity analysis. They found that unhappy people, when compared to happy people, exhibited greater functional connectivity in the bilateral medial prefrontal cortex (mPFC), bilateral posterior cingulate cortex (PCC), and left intraparietal lobule, and the functional connectivity between these regions correlated positively with the inclination to ruminate, which involves repeatedly and passively focusing on symptoms of distress (Nolen-Hoeksema et al., 2008). A resting-state fMRI study by Kong et al. (2015) investigated the neural correlates of self-reported subjective well-being, and found that activation in the bilateral posterior superior temporal gyrus (STG), right thalamus, left postcentral gyrus, and left planum temporale positively predicted cognitive well-being, and only activation in the right amygdala reliably positively predicted affective well-being. Lastly, a resting state fMRI study by Hermes et al. (2011) investigated the neural correlates of extraversion, a component of positive affect, and found that dispositional positive affect is positively associated with activity in the ventral striatum. Despite employing somewhat similar experimental methodologies (i.e., fMRI while participant is at rest), there is a lack of convergence of results, emphasizing the need for further research.

1.6.3 Electroencephalography and Positron Emission Topography

Other neuroimaging domains that have investigated PWB include electroencephalography (EEG) and positron emission topography (PET). EEG studies investigating PWB have implicated several brain regions in PWB. A resting EEG study by De Pascalis et al. (2013) found that optimism, a component of positive affect, was associated with higher activations in the left superior frontal gyrus (SFG) and right posterior cingulate cortex

(PCC). Similarly, another resting EEG study investigating the neural correlates of PWB found that left superior frontal activation was associated with higher PWB (Urry et al., 2004). A PET study by Volkow et al. (2011) investigated the neural correlates of positive emotionality by assessing the correlation between baseline brain glucose metabolism and positive emotionality scores. They found baseline glucose metabolism of the bilateral orbitofrontal cortex (OFC) and ACC were positively associated with higher levels of positive emotionality. Therefore, while PWB has been studied using several different neuroimaging techniques and methodologies, the brain areas associated with PWB varied widely across studies.

1.7 Psychological Well-Being Model

As seen in section 1.6, based on previous research, the neural correlates of PWB still remain elusive. In a systematic review by King (2019), the ACC, PCC, OFC, insula, and thalamus are the regions most consistently reported in association with PWB. However, these are only a small number of the wide range of brain regions suggested to be involved in PWB, and replication of associations across studies is scarce, both in strength and direction (De Vries et al., 2023). Further, it remains unclear what functions these brain regions serve in promoting PWB. As a result, there is an overall lack of understanding of how different levels of PWB impact or are impacted by specific brain regions, and there is no empirically validated model of PWB in the brain. As understanding the neural basis of PWB has large implications for mental and physical health, novel experimental paradigms should be implemented to determine a model of PWB in the brain.

1.8 Naturalistic Stimuli

One source of stimuli that show promise for characterizing how specific personality traits modulate neural activity are naturalistic stimuli. Naturalistic paradigms use rich, multimodal dynamic stimuli that represent our daily lived experience, such as audiovisual films, podcasts, gaming environments, and virtual reality (Sonkusare et al., 2019). Consequently, naturalistic stimuli can evoke brain responses that are highly reproducible within and across subjects (Hasson et al., 2004). Indeed, naturalistic stimuli can engage a broader set of brain regions, resulting in more diverse network interactions than task or resting-state paradigms (Zhang et al., 2021). Intersubject correlation analyses (ISC) have been proposed as a technique to analyze fMRI data acquired in a naturalistic environment (Hasson et al., 2010). Over the time course of a stimulus, ISC examines correlations in hemodynamic responses to identify neural activity that is shared between subjects, referred to as neural synchrony (Pajula et al., 2012). Ultimately, it provides maps of neural synchrony, which represent regions of the brain that consistently synchronize among a large group of participants in response to a naturalistic stimulus, providing insight on how neural responses can change based on different traits, despite processing the same stimulus (Hasson et al., 2010).

1.9 Naturalistic Cognitive Processing

While viewing a naturalistic audiovisual stimulus, the narrative of the story influences the neural activity, and higher ISCs are related to the immersiveness of the stimulus. A review by Jääskeläinen et al. (2020) synthesized the findings from neuroimaging studies on how naturalistic stimuli influence ISCs in the brain. A key theme identified by this research was that different regions of the brain have distinct roles when it comes to the processing of a narrative. Specifically, narratives that are attentionally engaging produce more synchronous responses in several regions, including the intraparietal sulcus/superior parietal lobule (SPL) and frontal eye field (FEF). When considering emotional valence, negative emotions during movie watching synchronize both the ventromedial prefrontal cortex (vmPFC) and precuneus, which has several roles in naturalistic processing, including making sense of a narrative. Lastly, due to the processing of an identical audiovisual stimulus, visual and auditory cortices, such as the lateral occipital cortex (LOC) and superior temporal gyrus (STG), show synchronous activity during movie watching. As a result, we can expect to see synchronous responses in the aforementioned brain regions during naturalistic audiovisual movie viewing tasks, highlighting the intricate coordination of these regions in integrating visual and auditory cues, processing different person identities, and enabling the multimodal integration required to construct a coherent, continuous narrative.

Of particular relevance, naturalistic paradigms are valuable for identifying the neural correlates of specific personality traits during more real-world task demands. Finn et al. (2018) used naturalistic stimuli to characterize differences in brain synchrony between participants with low and high trait paranoia. Their results showed patterns of neural synchrony unique to the high paranoia group, where high paranoia is associated with increased neural synchrony in the left temporal pole and right prefrontal cortex, suggesting that personality traits can act as implicit primes and influence the processing of naturalistic stimuli in the brain. Further, Klamer et al. (2023) used naturalistic stimuli to characterize differences in neural synchrony between participants with comparative low and high baseline somatic arousal levels using the NIH Toolbox Fear-Somatic Arousal questionnaire (Gershon et al., 2013), and found that there was a significant difference in the processing of an audiovisual stimulus, with higher levels of somatic arousal being associated with heightened neural synchrony throughout wide expanses of the cortex. Together, these studies support the idea that personality traits can bias how complex audiovisual stimuli are processed in the brain. As experimental paradigms employing naturalistic stimuli have demonstrated that personality traits influence how the brain processes complex audiovisual stimuli, naturalistic paradigms may be an effective tool for examining how PWB modulates neural activity and may help create a model of PWB in the brain.

1.10 Current Research

The current study seeks to examine differences in neural synchrony related to comparative low and high levels of PWB in a more "true-to-life" paradigm. We further aim to determine how PWB influences real-world processing in two different contexts: in response to positive valence stimuli and negative valence stimuli. To do so, we used open-source data from the Naturalistic Neuroimaging Database (NNDb; Aliko et al., 2020; v2.0) from 38 participants, 20 who watched a positive valence full length audiovisual movie while undergoing fMRI, and 18 who watched a negative valence full length audiovisual movie while undergoing fMRI. PWB for each participant was quantified using the NIH Toolbox 2.0 Psychological Well-Being Instrument (Gershon et al., 2013). Our general hypothesis was that PWB impacts naturalistic processing, serving as an implicit prime for how we perceive the world, which would be reflected by unique patterns of neural synchrony in response to a complex, audiovisual film.

Over the course of four experiments, we sought to examine the relationship between neural synchrony and low- and high-levels of PWB in response to complex, audiovisual stimuli. The first experiment focused on identifying differences in neural synchrony between individuals with comparative low and high levels of PWB in response to a positive valence audiovisual film. The second experiment assessed differences in neural synchrony between individuals with comparative low and high levels of PWB in response to a negative valence audiovisual film. The third experiment examined differences in how participants with lower levels of PWB process positive and negative emotional stimuli by examining differences in neural synchrony between two films. The final experiment examined the differences in positive and negative valence stimulus processing associated with higher levels of PWB by examining differences in neural synchrony between two films. Overall, this thesis investigated the relationship between varying levels of PWB and neural synchrony, with particular emphasis on the modulation of neural synchrony by the emotional valence of the incoming stimulus. By investigating the role of emotional valence in how differing levels of PWB modulate neural synchrony, we aim to determine how different contexts alter the modulation of neural synchrony associated with comparative low and high levels of PWB. This thesis further aims to disentangle the inherent variability in the extant literature on PWB and provide a starting point for developing a model of how PWB influences neurological processing by contributing to our understanding of cognitive mechanisms associated with PWB. The findings of this thesis can further shed light on the effects of PWB on mental and physical health and can be used to inform targeted treatments for PWB related cognitive impairments, such as mental health disorders.

CHAPTER 2: Examining neural synchrony associated with comparative low and high levels of PWB in response to audiovisual films of differing emotional valence using fMRI

Experiment 1

2.1.1 Introduction

In Experiment 1, we sought to identify unique patterns of neural synchrony associated with both low and high levels of PWB in response to a complex positive valence audiovisual movie. To achieve this, we used fMRI data from the NNDb (Aliko et al., 2020; v2.0) of 20 participants who watched a full-length feature film with positive emotional valence. *500 Days of Summer* (Webb, 2009) was chosen due to its positive valence and sample size (n=20) within the database. PWB was quantified using the NIH Toolbox Psychological Well-Being Instrument (Gershon et al., 2013) and we used a median split analysis to separate participants into a low PWB group and high PWB group. We then performed pairwise correlations for all pairs of participants, both within and between PWB groups. Next, we determined the average neural synchrony in the low PWB and high PWB groups in response to the film. We then investigated differences in neural synchrony between the two groups. Lastly, we compared within group ISCs to between group ISCs to identify areas of neural synchrony most strongly associated with each PWB trait level. Thus, Experiment 1 aimed to identify patterns of neural synchrony associated with comparative low and high levels of PWB in response to a positive valence, complex audiovisual stimulus.

As there are profound differences in the behavioural response to positive emotional stimuli based on varying levels of PWB, as outlined in introduction section 1.4, we expect this to be reflected in differences in neural synchrony associated with low and high comparative levels of PWB in response to a positive valence audiovisual film. Thus, we generally hypothesize that

PWB will act as an implicit prime during positive valence naturalistic processing, altering how incoming stimuli is perceived. More specifically, we hypothesize that, as higher levels of PWB are associated with more prevalent positive emotions, participants with higher levels of PWB will process the positive film more similarly, demonstrated by increased neural synchrony in regions associated with narrative processing, including the bilateral LOC and STG, and in regions previously associated with higher PWB, including the bilateral OFC and ACC.

2.1.2 Methods

Participants and Data Acquisition

We used fMRI data from the publicly available NNDb (v2.0; Aliko et al., 2020). We selected 20 participants (10 females/10 males, aged 19-53, mean age of 27.7 years) who watched the feature-length audiovisual film *500 Days of Summer* (Webb, 2009; duration ~ 95 minutes) during fMRI. All participants were right-handed, native English speakers, with no history of neurological/psychiatric illnesses, no hearing impairments, unimpaired or corrected vision, and did not take medication. Full data acquisition details can be found in Aliko et al., 2020. Briefly, a 1.5T Siemens Magnetom Avanto scanner with a 32-channel head coil was used to acquire the neuroimaging data. A multiband echo planar imaging (EPI) sequence was used to acquire the fMRI data with a repetition time (TR) of 1s, an echo time (TE) of 54.8ms, a flip angle of 75°, and a resolution of 3.2mm isotropic. A T1-Magnetization Prepared Rapid Acquisition Gradient Echo anatomical scan was acquired with a TR of 2.73s, TE of 3.57ms, and a resolution of 1.00mm^3. Noise attenuating headphones were used to ensure optimal audio quality, and the visuals for the films were presented through a mirror-reversing LCD projector. Participant attention was monitored using a camera fixated on their eyes. The films were played with minimal breaks, however, due to the limitations of the EPI sequence and software, the films were played in 40-50 minute segments. To maintain the naturalistic viewing experience, these breaks were intentionally timed to occur during scenes that did not have relevant plot information or dialogue.

Data Preprocessing

Data preprocessing was carried out by Aliko et al. (2020). We used version 2.0 of the NNDb (Aliko et al., 2020) which, in comparison to v1.0, has improved normalization and standardization of the data, resulting in the better alignment of data to an MNI template and the efficient transformation of voxel intensities to a common baseline across participants. This ultimately results in 'cleaner' preprocessed data and more robust statistics. First, the time series were concatenated using time correction preprocessing as the films were obtained in separate runs using AFNI's '*3dTproject*'. Next, version 2.0 of the NNDb used the afni_proc.py pipeline from AFNI (Cox, 1996; Cox & Hyde, 1997) for the following preprocessing steps: correcting for slice-timing differences, despiking, detrending with regressors (e.g., for motion), volume registration, mask time-series, spatial smoothing, spatially aligning the data to an MNI template with a resampling size of $3x3x3mm^3$, and correcting for timing to align the fMRI time series and the film. This is a standard preprocessing pipeline, and these steps ensure that time delay, sudden fluctuations in the fMRI time series data, and motion artefacts are corrected for. It also spatially aligns the data from different participants to enable comparison. The authors of the NNDb (v2.0; Aliko et al., 2020) obtained approval by the ethics committee of University College London and participants provided written informed consent to take part in the study and share their anonymized data.

Behavioural Questionnaires

Following the MRI imaging session, participants completed the majority of the National Institute of Health (NIH) Toolbox, which validates measures of sensory, motor, cognitive and emotional processing to measure individual differences (Gershon et al., 2013). In this study, we used the Psychological Well-Being (PWB) scores quantified using the NIH Toolbox 2.0 Psychological Well-Being (18+; Gershon et al., 2013) questionnaire. We used a median split analysis to separate participants into low and high PWB groups based on their provided T-score, resulting in 10 participants in each group. The low PWB group had 4 males, 6 females and a mean age of 28.4. The high PWB group had 6 males, 4 females and a mean age of 27. As PWB has a relationship with aging, to ensure age was not a confounding variable, we used SPSS (version 27; IBM Corp., 2020) to run an independent sample *t*-test between participants in each PWB group (i.e., low and high PWB) and age.

Intersubject Correlation Analyses

Pairwise ISC was run for all unique pairs of participants, which produced 190 (n*(n-1)/2, where n = 20) unique ISC maps. ISC is a model-free approach used to analyze complex fMRI data acquired in naturalistic, audiovisual stimulus environments (Kauppi, 2010). It allows us to measure shared content across experimental conditions by filtering out subject-specific signals and revealing voxels with a consistent, stimulus-evoked response time series across subjects (Nastase et al., 2019). It does this by calculating pairwise correlation coefficients between all pairs of participants for each voxel throughout the brain. A visualization of ISC analysis can be found in Figure 2.1. We separated the resulting 190 ISC maps into three groups based on PWB grouping (i.e., low-low PWB pairwise correlations grouped, high-high pairwise correlations grouped, low-high pairwise correlations grouped). This resulted in 45 (n*(n-1)/2, where n = 10) unique ISC maps for both the low (i.e., low-low) and high (i.e., high-high) PWB groups, and 100 between group pairs (i.e., low-high).

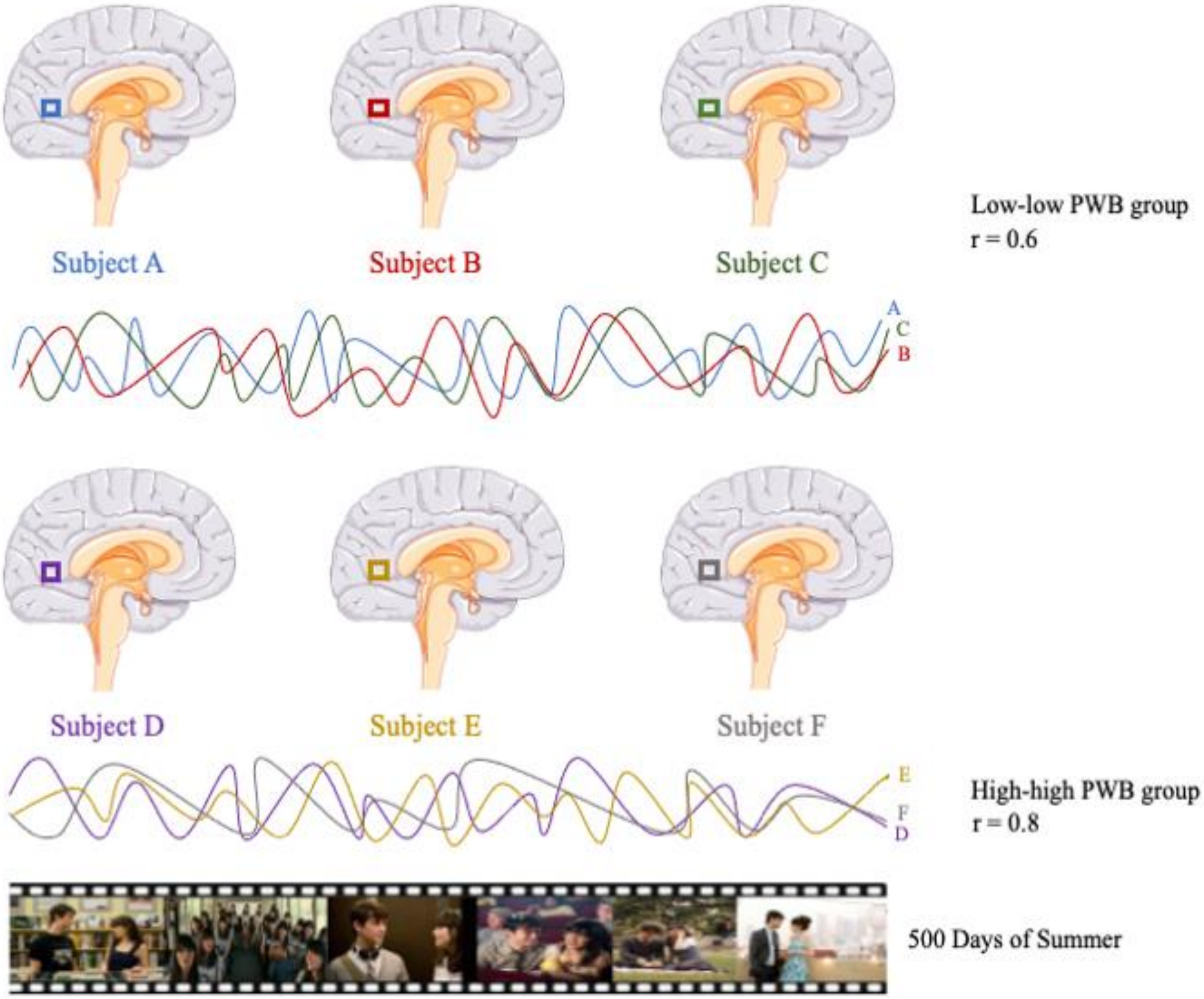

Figure 2.1 Intersubject Correlation Analysis. A representation demonstrating the ISC function for a single voxel over the time course of the film. This process is repeated for all participants in the analysis and all voxels in the brain. Participants are then separated into low-low and high-high PWB groups where their ISC maps can be compared. Figure partly generated using Servier Medical Art ("SMART - Servier Medical ART," n.d.), provided by Servier, licensed under a Creative Commons Attribution 2.0 unported license.

FMRI Analysis

After running ISCs on all pairs of participants, we used the Linear Mixed Effects Model (LME) implemented via the *3dISC* module in AFNI (Cox, 1996; Cox & Hyde, 1997; described by Chen et al., 2020) to identify regions of significant synchrony for each contrast. LME is a parametric method based on the general linear model (GLM) and is used to model the relationship between the fMRI time series data and the experimental conditions at each voxel, accounting for the complex covariance structure of ISC data. As LME accounts for variability in the data due to random effects, it allows for more precise estimation of fixed effects (Koerner & Zhang, 2017). We modeled the following contrasts: average ISC in the low PWB group (low-low PWB), average ISC in the high PWB group (high-high PWB), average ISC between the low and high groups (low-high PWB), differences in ISC between the low and high groups (low-low vs. high-high PWB), differences in ISC between the low group and between group ISC (low-low vs. low-high), and differences in ISC between the high group and between group ISC (low-high vs. high-high). Significant ISCs for the group average contrasts (i.e.., high-high PWB, low-low PWB, low-high PWB), were defined using a voxelwise false discovery rate (FDR) of $q < 0.001$, which indicates that 0.1% of the voxels identified as statistically significant are expected to be false positives. Significant ISCs for the group comparisons contrasts (i.e., low-low PWB vs. high-high PWB; low-low PWB vs. low-high PWB; low-high vs. high-high PWB) were defined using a voxelwise FDR of $q < 0.05$. Clusters with less than 5 voxels were excluded for all contrasts. Significant results were transformed into surface space for visualization purposes only.

2.1.3 Results

Behavioural Questionnaires

We used SPSS (version 27; IBM Corp., 2020) to run an independent samples *t*-test between participants in the low and high PWB groups to determine whether age differed between the two groups. No significant differences were found *t*(18) = .388, *p* = .703.

Group Averages

Full results for the low-low PWB group average can be found in Figure 2.2 and Table 2.1, and full results for the high-high PWB group average can be found in Figure 2.3 and Table 2.2. Results from the low-low PWB and high-high PWB group average ISC showed significant widespread synchrony in regions associated with visual processing, auditory processing, and the processing of a narrative, which is in line with previous research (Güçlütürk et al., 2018). These regions included the bilateral LOC, bilateral STG, bilateral SPL, bilateral TPJ, bilateral precuneus, bilateral occipital pole, bilateral lingual gyrus, bilateral intracalcarine cortex, and bilateral fusiform gyrus. We also found significant clusters of neural synchrony in the bilateral postcentral gyrus and the bilateral right and left crus of the cerebellum. The high-high PWB group showed larger clusters of widespread neural synchrony than the low-low PWB group throughout the cortex.

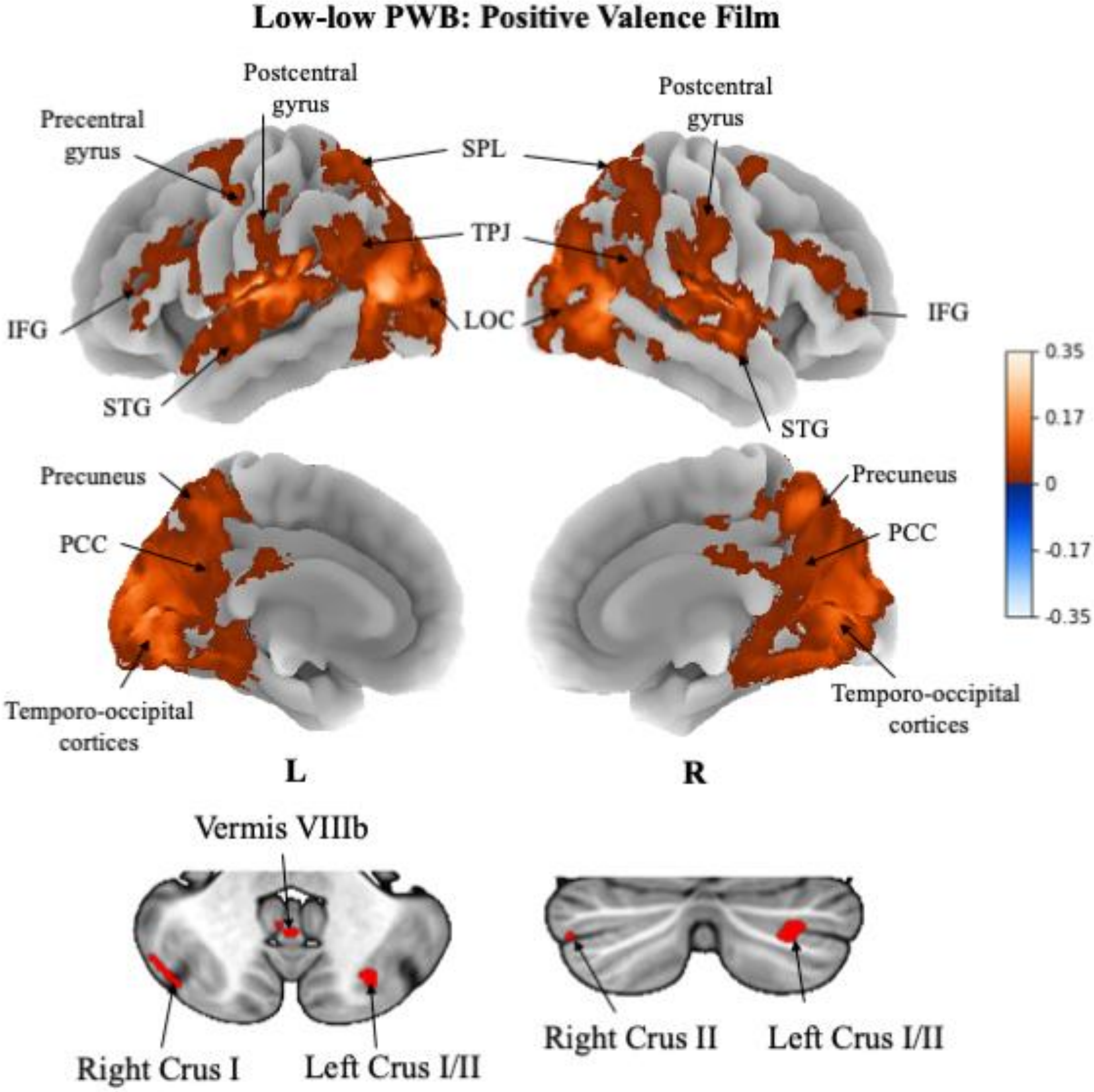

Figure 2.2. Positive Valence Film: Low-low PWB Neural Synchrony. Clusters showing significant ISC within participants in the low-low PWB group across the time course of the audiovisual stimulus. Results are displayed as a voxelwise false-discovery rate (FDR) threshold of $q < 0.001$. Only clusters with five or more voxels reported.

Table 2.1. Positive Valence Film: Low-low PWB average synchrony cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Lateral Occipital Cortex, inferior division	Left	6237	0.296	-52.5	-73.5	7.5
Central Opercular Cortex	Left	568	0.407	-61.5	-16.5	10.5
Precentral Gyrus	Right	132	0.0584	40.5	10.5	28.5

Middle Frontal Gyrus	Left	130	0.0687	-46.5	10.5	31.5
Superior Frontal Gyrus	Left	60	0.0468	-25.5	-1.5	61.5
Cingulate Gyrus, posterior division	Left	35	0.0384	-4.5	-31.5	25.5
Left Crus I	Left	21	0.0408	-28.5	-85.5	-34.5
Precuneous Cortex	Right	17	0.0578	13.5	-40.5	49.5
Superior Frontal Gyrus	Right	14	0.0486	25.5	1.5	64.5
Temporal Pole	Left	12	0.0668	-52.5	16.5	-22.5
Supramarginal Gyrus, anterior division	Left	11	0.0575	-58.5	-28.5	46.5
Middle Temporal Gyrus, temporooccipital part	Right	10	0.0329	64.5	-40.5	-13.5
Right Crus II	Right	9	0.0257	16.5	-85.5	-31.5
Frontal Pole	Left	9	0.0335	-52.5	37.5	-4.5
Vermis VIIIb	Right	8	0.0137	1.5	-61.5	-37.5
Precentral Gyrus	Left	7	0.119	-55.5	-7.5	49.5
Right Crus II	Right	6	0.0148	46.5	-67.5	-43.5
Cingulate Gyrus, posterior division	Right	5	0.0264	7.5	-19.5	43.5
Temporal Pole	Left	5	0.0938	-58.5	7.5	-10.5
Planum Polare	Left	5	0.0244	-43.5	-7.5	-10.5

Coordinates in MNI space. Only clusters with 5 or more voxels reported.

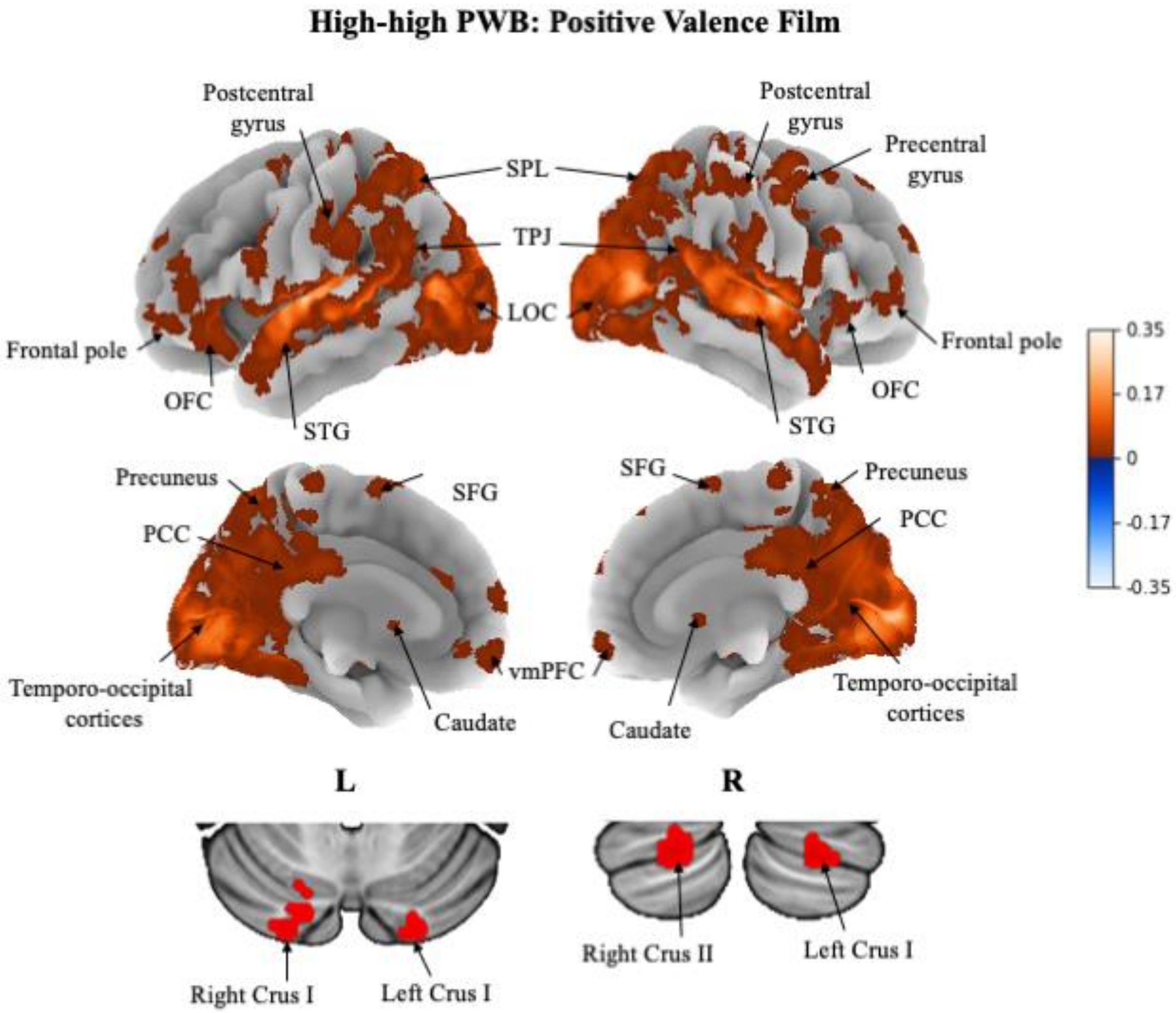

Figure 2.3. Positive Valence Film: High-high PWB Neural Synchrony. Clusters showing significant ISC within participants in the high-high PWB group across the time course of the audiovisual stimulus. Results are displayed as a voxelwise false-discovery rate (FDR) threshold of $q < 0.001$. Only clusters with five or more voxels reported.

Table 2.2. Positive Valence Film: High-high PWB average synchrony cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Superior Temporal Gyrus, anterior division	Right	5900	0.334	64.5	-4.5	4.5
Planum Temporale	Left	567	0.349	-64.5	-13.5	4.5
Superior Temporal Gyrus, posterior division	Left	261	0.199	-58.5	-37.5	4.5
Middle Frontal Gyrus	Right	114	0.0585	49.5	13.5	34.5
Temporal Pole	Right	85	0.0477	55.5	16.5	-4.5

Supramarginal Gyrus, anterior division	Right	79	0.0566	49.5	-34.5	55.5
Precentral Gyrus	Left	79	0.0587	-43.5	1.5	31.5
Middle Frontal Gyrus	Right	73	0.0557	43.5	1.5	55.5
Postcentral Gyrus	Left	67	0.0602	-61.5	-25.5	40.5
Precentral Gyrus	Left	49	0.0471	-28.5	-10.5	61.5
Superior Parietal Lobule	Right	40	0.063	28.5	-52.5	67.5
Right Crus I	Right	36	0.0551	25.5	-85.5	-31.5
Frontal Pole	Left	29	0.0358	-34.5	37.5	-10.5
Frontal Pole	Left	22	0.0298	-49.5	43.5	10.5
Left Crus I	Left	22	0.046	-22.5	-85.5	-31.5
Precentral Gyrus	Right	21	0.0225	40.5	-22.5	67.5
Angular Gyrus	Right	21	0.0349	43.5	-49.5	46.5
Frontal Pole	Left	16	0.0286	-1.5	61.5	-10.5
Juxtapositional Lobule Cortex	Left	16	0.0456	-1.5	1.5	67.5
Precentral Gyrus	Right	15	0.046	13.5	-19.5	43.5
Superior Parietal Lobule	Right	14	0.0739	28.5	-40.5	55.5
Middle Temporal Gyrus, temporooccipital part	Right	13	0.0451	61.5	-55.5	-1.5
Frontal Pole	Left	12	0.0239	-40.5	46.5	22.5
Frontal Pole	Right	11	0.0295	46.5	46.5	1.5
Frontal Pole	Right	10	0.024	46.5	52.5	7.5
Left Caudate	Left	10	0.018	-7.5	7.5	1.5
Frontal Pole	Left	10	0.0239	-46.5	52.5	-7.5
Postcentral Gyrus	Right	10	0.0215	43.5	-19.5	58.5
Frontal Pole	Right	10	0.0259	13.5	58.5	31.5
Temporal Pole	Right	10	0.0402	49.5	22.5	-28.5
Precentral Gyrus	Right	9	0.104	58.5	-1.5	46.5
Superior Frontal Gyrus	Right	8	0.0235	28.5	22.5	58.5
Precentral Gyrus	Right	8	0.0192	1.5	-31.5	70.5
Central Opercular Cortex	Left	7	0.0207	-37.5	-4.5	16.5
Paracingulate Gyrus	Left	6	0.0136	-7.5	34.5	22.5
Precentral Gyrus	Right	6	0.021	10.5	-31.5	73.5
Frontal Pole	Left	6	0.0229	-4.5	64.5	19.5
Postcentral Gyrus	Left	6	0.0204	-31.5	-25.5	67.5
Right Caudate	Right	6	0.0167	10.5	13.5	4.5
Right Amygdala	Right	6	0.0134	19.5	-1.5	-13.5
Superior Temporal Gyrus, posterior division	Right	6	0.0622	52.5	-16.5	-7.5
Paracingulate Gyrus	Left	6	0.0181	-1.5	46.5	-7.5
Frontal Pole	Right	6	0.0191	10.5	37.5	55.5
Left Amygdala	Left	6	0.0135	-19.5	-7.5	-13.5
Right Crus I	Right	5	0.0225	16.5	-73.5	-25.5
Frontal Pole	Left	5	0.0159	-40.5	61.5	-4.5

Frontal Pole	Left	5	0.0161	-28.5	61.5	-1.5
Precuneous Cortex	Left	5	0.0477	-10.5	-46.5	55.5
Central Opercular Cortex	Left	5	0.0159	40.5	1.5	13.5
Central Opercular Cortex	Left	5	0.0141	-43.5	-13.5	19.5
Frontal Pole	Left	5	0.0256	-16.5	58.5	28.5
Postcentral Gyrus	Left	5	0.0202	-25.5	-28.5	73.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

Low-low PWB vs. High-high PWB contrasts

Results for the low-low PWB vs. high-high PWB contrasts can be found in Figure 2.4 (warm colours) and Table 2.3. Results for the low-low PWB > high-high PWB contrast demonstrates regions of the brain that had higher synchronization in the low-low PWB group compared to the high-high PWB group. This contrast found clusters of heightened neural synchrony in regions including the bilateral precuneus, bilateral parietal operculum, Wernicke's area (left planum temporale), right middle frontal gyrus (MFG), left SPL, and bilateral lingual gyrus.

Results for the high-high PWB > low-low PWB contrast can be found in Figure 2.4 (cool colours) and Table 2.4. This contrast demonstrates regions of the brain that had higher synchronization in the high-high PWB group compared to the low-low PWB group. This contrast found clusters of heightened neural synchrony in regions including the right TPJ, right planum temporale, left OFC, bilateral STG, and bilateral occipital pole.

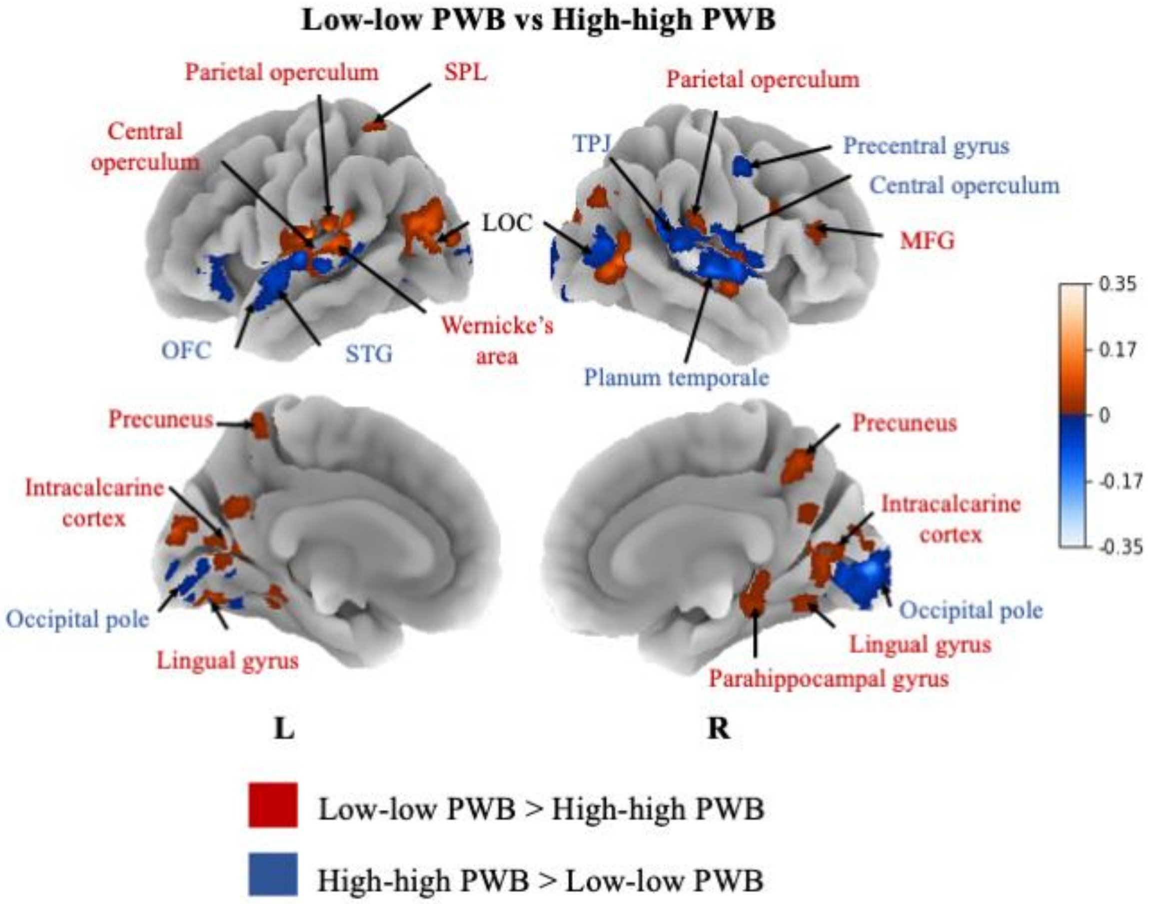

Figure 2.4. Positive Valence Film: Low-low PWB vs High-high PWB Neural Synchrony. Red refers to clusters showing higher ISC within participants in the low-low PWB group compared to the high-high PWB group across the time course of the audiovisual stimulus. Blue refers to clusters showing higher ISC within the high-high PWB group compared to the low-low PWB group across the time course of the audiovisual stimulus. Results are displayed as a voxelwise false-discovery rate (FDR) threshold of *q* < 0.05. Only clusters with five or more voxels reported.

Table 2.3. Positive Valence Film: Low-low PWB > High-high PWB cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Central Opercular Cortex	Left	102	0.326	-61.5	-16.5	10.5
Lateral Occipital Cortex, inferior division	Left	82	0.201	-49.5	-79.5	13.5
Lateral Occipital Cortex, inferior division	Right	64	0.202	43.5	-61.5	4.5
Superior Temporal Gyrus, anterior division	Right	60	0.122	61.5	-7.5	-7.5

Occipital Fusiform Gyrus	Left	48	0.137	-25.5	-76.5	-13.5
Parahippocampal Gyrus, posterior division	Right	24	0.0752	22.5	-37.5	-13.5
Intracalcarine Cortex	Right	22	0.0922	10.5	-76.5	7.5
Supramarginal Gyrus, posterior division	Right	21	0.0697	43.5	-43.5	19.5
Precuneous Cortex	Left	21	0.0514	-16.5	-61.5	7.5
Superior Parietal Lobule	Left	21	0.0849	-34.5	-52.5	67.5
Parietal Operculum	Left	17	0.16	-43.5	-37.5	19.5
Precuneous Cortex	Right	15	0.0874	1.5	-58.5	52.5
Occipital Pole	Right	14	0.11	13.5	-88.5	28.5
Planum Temporale	Right	12	0.114	61.5	-25.5	16.5
Precentral Gyrus	Right	11	0.0402	34.5	10.5	28.5
Precuneous Cortex	Right	10	0.0847	22.5	-55.5	19.5
Temporal Occipital Fusiform Cortex	Right	10	0.0626	28.5	-61.5	-16.5
Occipital Pole	Left	10	0.146	-4.5	-91.5	16.5
Lingual Gyrus	Left	9	0.0593	-19.5	-43.5	-13.5
Lateral Occipital Cortex, superior division	Right	9	0.0598	40.5	-76.5	31.5
Occipital Pole	Left	8	0.122	-34.5	-94.5	10.5
Lateral Occipital Cortex, superior division	Right	8	0.0665	28.5	-76.5	28.5
Superior Temporal Gyrus, posterior division	Left	7	0.0961	-61.5	-19.5	-1.5
Temporal Occipital Fusiform Cortex	Left	7	0.0875	-31.5	-49.5	-4.5
Precuneous Cortex	Left	7	0.0755	-4.5	-61.5	28.5
Middle Frontal Gyrus	Right	5	0.043	43.5	34.5	16.5
Intracalcarine Cortex	Right	5	0.067	10.5	-64.5	10.5
Lateral Occipital Cortex, superior division	Left	5	0.0611	-25.5	-76.5	46.5
Precuneous Cortex	Left	5	0.0651	-4.5	-49.5	64.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

Table 2.4. Positive Valence Film: High-high PWB > Low-low PWB cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Occipital Pole	Right	121	0.31	10.5	-91.5	1.5
Superior Temporal Gyrus, anterior division	Right	71	0.334	64.5	-4.5	4.5

Inferior Frontal Gyrus, pars triangularis	Left	65	0.0871	-52.5	25.5	-4.5
Lateral Occipital Cortex, inferior division	Right	49	0.269	52.5	-70.5	10.5
Supramarginal Gyrus, posterior division	Right	37	0.146	61.5	-43.5	16.5
Superior Temporal Gyrus, anterior division	Left	27	0.234	-64.5	-4.5	-1.5
Supramarginal Gyrus, posterior division	Right	21	0.158	67.5	-34.5	10.5
Planum Temporale	Right	20	0.136	40.5	-28.5	16.5
Superior Temporal Gyrus, posterior division	Left	13	0.199	-58.5	-37.5	4.5
Precentral Gyrus	Right	10	0.104	58.5	-1.5	46.5
Temporal Occipital Fusiform Cortex	Right	10	0.119	31.5	-52.5	-4.5
Superior Temporal Gyrus, anterior division	Left	9	0.349	-64.5	-13.5	4.5
Superior Temporal Gyrus, posterior division	Left	8	0.169	-67.5	-22.5	-1.5
Occipital Fusiform Gyrus	Left	8	0.0761	-31.5	-64.5	-13.5
Intracalcarine Cortex	Left	7	0.0796	-13.5	-67.5	1.5
Occipital Pole	Left	7	0.102	-16.5	-97.5	-1.5
Occipital Fusiform Gyrus	Right	6	0.0943	31.5	-76.5	-7.5
Occipital Fusiform Gyrus	Left	6	0.0906	-13.5	-88.5	-10.5
Superior Temporal Gyrus, anterior division	Right	6	0.214	61.5	4.5	-1.5
Occipital Fusiform Gyrus	Left	5	0.0865	-31.5	-76.5	-10.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

Comparing low and high group ISC with between group ISC

Low-low vs. Low-high PWB

Full results for this contrast can be found in Figure 2.5 (warm colours) and Table 2.5. Results for the low-low PWB > low-high PWB contrast demonstrates regions of the brain that had higher synchronization in the low-low PWB group compared to the low-high PWB group. This contrast found three clusters of heightened neural synchrony, located in Wernicke’s area, the left lingual gyrus, and the right MFG.

Full results for the low-high PWB > low-low PWB contrast can be found in Figure 2.5 (cool colours) and Table 2.6. This contrast demonstrates regions of the brain that had higher synchronization in the low-high PWB group compared to the low-low PWB group. This contrast found 2 clusters of heightened neural synchrony, located in the right planum temporale and left occipital pole.

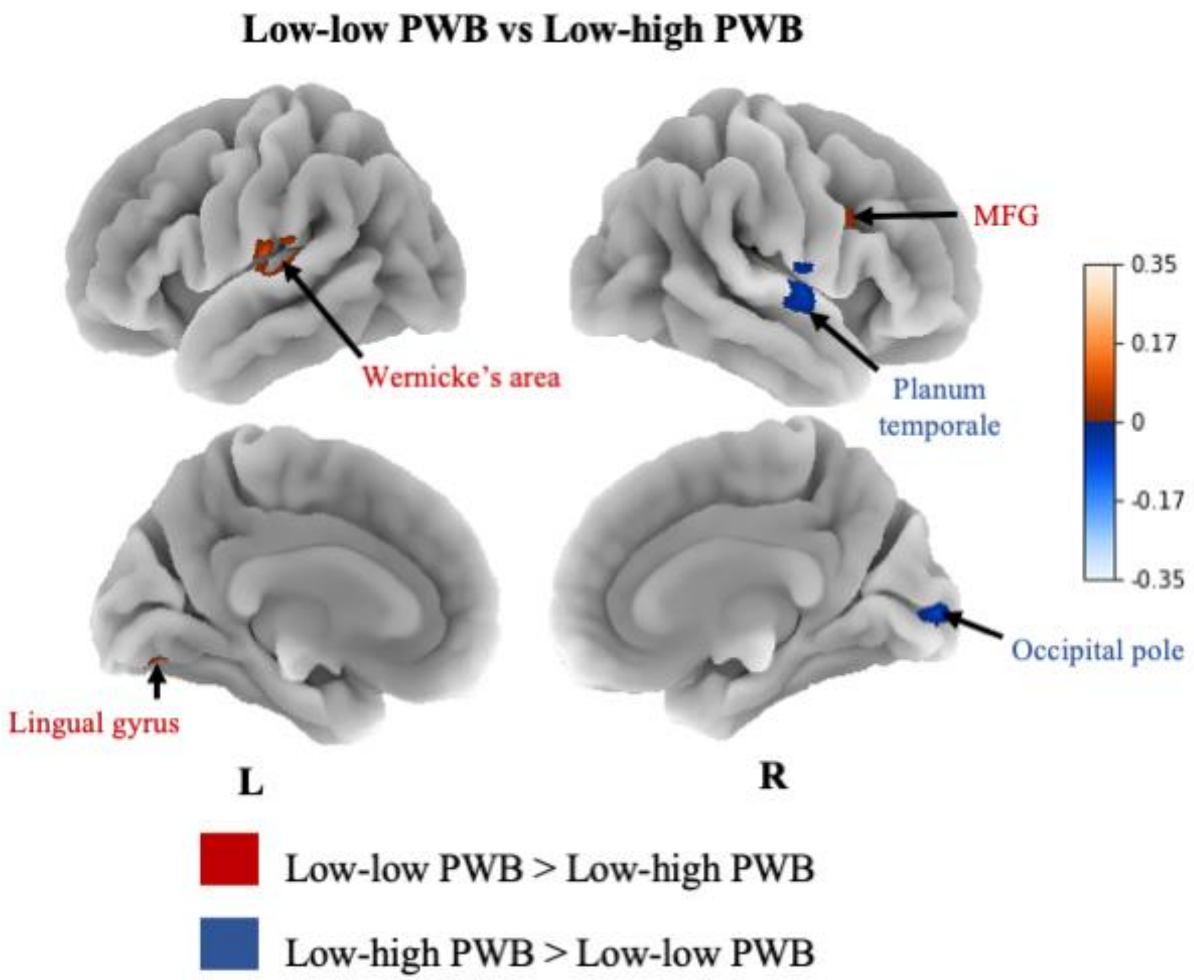

Figure 2.5. Positive Valence Film: Low-low PWB vs Low-high PWB Neural Synchrony. Red refers to clusters showing higher ISC within participants in the low-low PWB group compared to the low-high PWB group across the time course of the audiovisual stimulus. Blue refers to clusters showing higher ISC within the low-high PWB group compared to the low-low PWB group across the time course of the audiovisual stimulus. Results are displayed as a voxelwise false-discovery rate (FDR) threshold of $q < 0.05$. Only clusters with five or more voxels reported.

Table 2.5. Positive Valence Film: Low-low PWB > low-high PWB cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Planum Temporale	Left	26	0.177	-64.5	-25.5	13.5
Lingual Gyrus	Left	5	0.0858	-16.5	-76.5	-16.5
Middle Frontal Gyrus	Right	5	0.0476	34.5	10.5	28.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

Table 2.6. Positive Valence Film: Low-high PWB > Low-low PWB cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Planum Temporale	Right	13	0.233	64.5	-7.5	4.5
Occipital Pole	Right	9	0.197	10.5	-91.5	1.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

Low-high vs High-high PWB

Full results for this contrast can be found in Figure 2.6 (warm colours) and Table 2.8. Results for the low-high PWB > high-high PWB contrast demonstrates regions of the brain that had higher synchronization in the low-high PWB group compared to the high-high PWB group. This contrast found clusters of heightened neural synchrony in regions including the left SPL, Wernicke's area, right precuneus, bilateral lingual gyrus, and right parahippocampal gyrus.

Results for the for high-high PWB > low-high PWB contrast can be found in Figure 2.6 (cool colours) and Table 2.7. This contrast demonstrates regions of the brain that had higher synchronization in the high-high PWB group compared to the low-high PWB group. This contrast found clusters of heightened neural synchrony in regions including the right planum temporale, bilateral STG, left OFC, right TPJ, right central operculum, and right occipital pole.

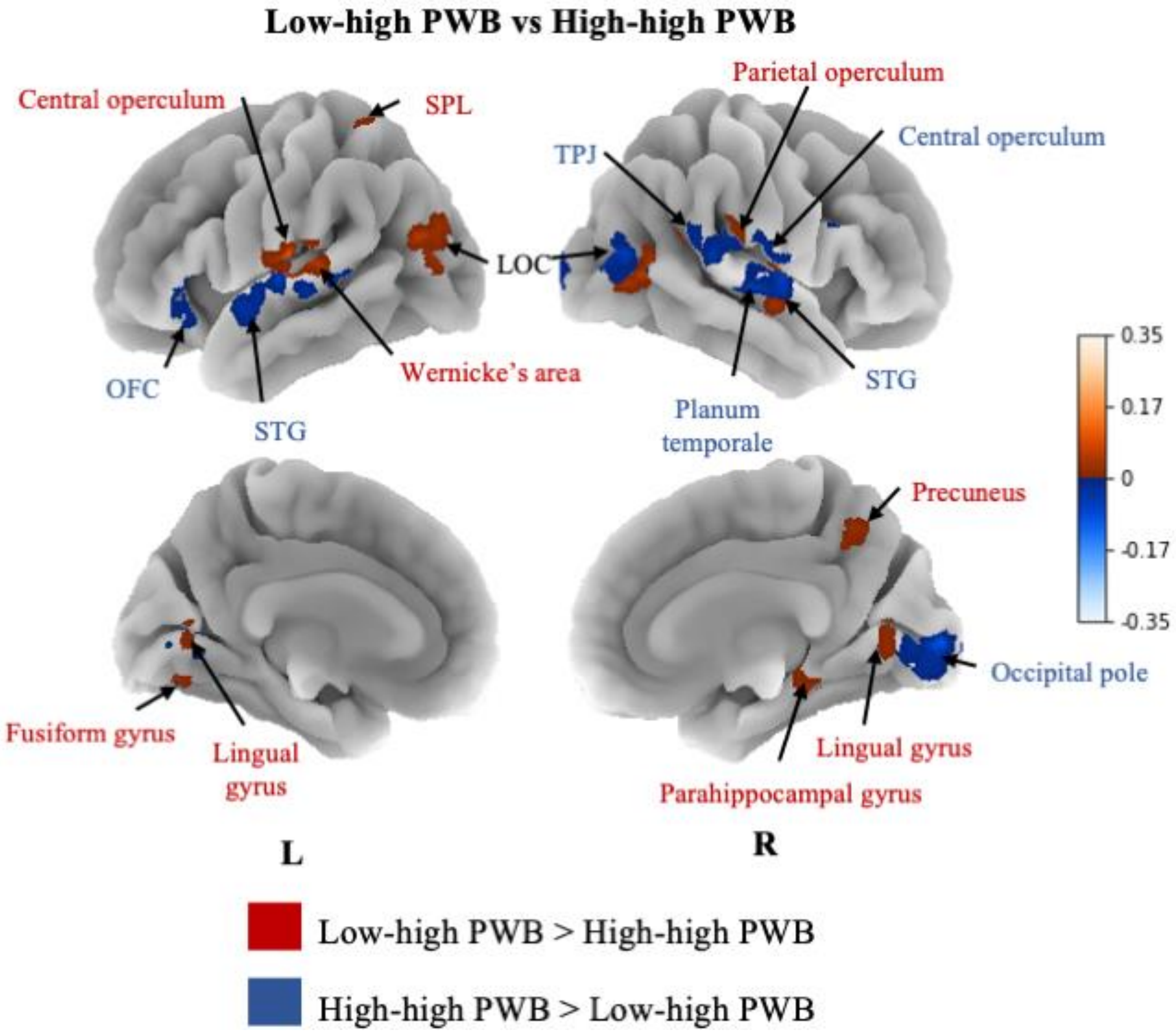

Figure 2.6. Positive Valence Film: Low-high PWB vs High-high PWB Neural Synchrony. Red refers to clusters showing higher ISC within participants in the low-high PWB group compared to the high-high PWB group across the time course of the audiovisual stimulus. Blue refers to clusters showing higher ISC within the high-high PWB group compared to the low-high PWB group across the time course of the audiovisual stimulus. Results are displayed as a voxelwise false-discovery rate (FDR) threshold of *q* < 0.05. Only clusters with five or more voxels reported.

Table 2.7. Positive Valence Film: High-high PWB > Low-high PWB cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Occipital Pole	Right	59	0.31	10.5	-91.5	1.5
Frontal Orbital Cortex	Left	44	0.0871	-52.5	25.5	-4.5
Lateral Occipital Cortex, inferior division	Right	42	0.269	52.5	-70.5	10.5

Superior Temporal Gyrus, anterior division	Right	41	0.334	64.5	-4.5	4.5
Planum Temporale	Right	15	0.136	40.5	-28.5	16.5
Angular Gyrus	Right	12	0.142	64.5	-46.5	19.5
Superior Temporal Gyrus, anterior division	Left	12	0.234	-64.5	-4.5	-1.5
Intracalcarine Cortex	Left	8	0.0796	-13.5	-67.5	1.5
Inferior Frontal Gyrus, pars triangularis	Right	7	0.0492	55.5	16.5	31.5
Superior Temporal Gyrus, posterior division	Left	6	0.199	-58.5	-37.5	4.5
Superior Temporal Gyrus, posterior division	Right	5	0.158	67.5	-34.5	10.5
Planum Temporale	Left	5	0.349	-64.5	-13.5	4.5
Middle Temporal Gyrus, posterior division	Left	5	0.162	-67.5	-25.5	-1.5
Occipital Fusiform Gyrus	Left	5	0.0865	-31.5	-76.5	-10.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

Table 2.8. Positive Valence Film: Low-high PWB > High-high PWB cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Central Opercular Cortex	Left	40	0.169	-61.5	-16.5	10.5
Lateral Occipital Cortex, inferior division	Left	36	0.0976	-49.5	-79.5	13.5
Lateral Occipital Cortex, inferior division	Right	29	0.104	43.5	-61.5	4.5
Occipital Fusiform Gyrus	Right	16	0.069	-25.5	-76.5	-13.5
Planum Polare	Right	11	0.0593	49.5	-1.5	-1.5
Parahippocampal Gyrus, posterior division	Right	8	0.0348	22.5	-37.5	-13.5
Heschl's Gyrus	Left	7	0.0459	-46.5	-13.5	4.5
Precuneous Cortex	Right	7	0.0385	22.5	-55.5	19.5
Parietal Operculum Cortex	Right	7	0.0562	58.5	-28.5	19.5

Precuneous Cortex	Right	7	0.0479	4.5	-55.5	49.5
Superior Parietal Lobule	Left	6	0.0386	-34.5	-49.5	67.5
Superior Temporal Gyrus, anterior division	Right	5	0.063	61.5	-7.5	-7.5
Lingual Gyrus	Right	5	0.0475	1.5	-70.5	7.5
Supramarginal Gyrus, posterior division	Right	5	0.0344	43.5	-43.5	19.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

2.1.4 Discussion

This study sought to examine differences in how individuals with comparative low and high levels of PWB respond to a complex, positive valence audiovisual stimulus, as demonstrated by differences in neural synchrony between the two groups. To do so, we separated participants into two groups. The first consisted of individuals with lower levels of PWB and the second consisted of individuals with higher levels of PWB. We ran ISC analysis and used LME modelling to visualize how neural synchrony differs between each group. Neural activity has been shown to be sensitive to the nature of the stimulus, and results from this study provide support that individual differences in PWB result in substantial variations in neural synchrony in response to a positive valence naturalistic stimulus. Consistent with our hypothesis, differential neural synchrony was found in association with varying levels of PWB in regions associated with PWB and narrative processing.

We predicted that as participants were watching the same stimulus, they would have heightened neural synchrony in regions associated with narrative processing. As expected, the group averages for participants with low and high PWB, respectively, showed heightened neural synchrony in the bilateral SPL, bilateral TPJ, bilateral precuneus, bilateral LOC, and bilateral STG, consistent with previous reports (Jääskeläinen et al., 2021). Participants with higher PWB showed more widespread neural synchrony in several regions in the bilateral frontal lobe of the brain, including the bilateral OFC and bilateral vmPFC, suggesting that these regions behaved more similarly during the positive valence film.

While watching the positive valence stimulus, individuals with comparative low PWB showed heightened neural synchrony in the bilateral precuneus and left SPL when compared to individuals with comparative high PWB, regions previously associated with narrative processing. The precuneus is involved in narrative-sense making, suggesting that individuals with lower PWB made sense of the narrative more similarly. While the precuneus has not been previously associated with PWB, individuals with lower PWB typically have higher emotional inertia, suggesting they are resistant to change in emotional states (Kuppens et al., 2010). Therefore, heightened synchrony in the precuneus in individuals with lower PWB may suggest that they were resistant to emotional changes throughout the film, and as a result may have made sense of the narrative more similarly. However, more research should be done on the role of the precuneus in mediating the brain's response to positive valence stimuli in individuals with low comparative PWB.

The SPL has been shown to have higher synchronization during narrative processing of attentionally engaging narratives (Jääskeläinen et al., 2021). This may indicate that individuals with low comparative PWB found the narrative more attentionally engaging than individuals with higher levels of PWB. Previous research has suggested that low PWB is associated with higher attentional engagement towards emotional stimuli through its associations with low self-esteem. Low self-esteem is related to several psychiatric disorders (Silverstone & Salsali, 2003) and is therefore associated with low PWB outcomes, and there is an attention bias for negative stimuli among individuals with low self-esteem (Li et al., 2011) with the greater mobilization of attentional resources toward emotional stimuli (Li & Yang, 2013). Taken together, it is possible that individuals with lower levels of PWB may have assigned a more negative interpretation to negative events during the film, and therefore exhibited greater attentional engagement throughout the film, however further research is necessary to investigate this claim.

Wernicke's area, the left lingual gyrus, and right MFG were found to have higher synchronization in individuals with lower PWB when compared to individuals with higher PWB. The right MFG is a key region in reorienting attention to exogenous stimuli (Japee et al., 2015). Further, the right MFG shows increased activation in response to fearful expressions in individuals with high negative cognitive bias (Feng et al., 2015), a trait that is associated with lower levels of PWB (Schweizer et al., 1999). Therefore, higher synchronization in the right MFG in individuals with lower PWB may indicate that due to a high negative cognitive bias, they had a more similar response to fearful expressions. However, as the right MFG has not been studied in association with PWB, more research is needed to determine the role of the right MFG in differential PWB outcomes.

The lingual gyrus is generally involved in visual processing, specifically global shape processing and visual word processing (Mechelli et al., 2000; Sohn et al., 2008). Higher synchronization in the left lingual gyrus in individuals with lower PWB may indicate that they process lower-level visual stimuli more similarly than individuals with higher PWB. More specifically, this may suggest that during the audiovisual film they processed visual words, such as subtitles or text on screen more similarly, as well as shapes within the film. Wernicke's area has been previously associated with cognitive well-being (Kong et al., 2015), however its role in cognitive well-being remains unknown. It further may play a crucial role in the processing of a narrative, as Wernicke's area is an important conduit to language comprehension (Tanner, 2007), which is necessary to form a mental representation of a narrative. Higher synchronization associated with lower levels of PWB indicates that participants with lower PWB may have comprehended language in the film more similarly.

As individuals with higher PWB typically experience more frequent positive emotions, we hypothesized that individuals with higher PWB would process the positive valence film more similarly, as demonstrated by heightened neural synchrony in regions associated with narrative processing and PWB. Consistent with our hypothesis, heightened neural synchrony was found in the right TPJ, bilateral STG, and left OFC in individuals with higher PWB when compared to individuals with lower PWB. During narrative processing, the TPJ is centrally associated with higher synchronization during suspenseful narratives (Jääskeläinen et al., 2020). Therefore, higher synchronization in this region may indicate that individuals with higher levels of PWB found the narrative more suspenseful. Higher attentional bias has been associated with a narrower attentional focus during the interpretation of narratives with more suspense (Bezdek & Gerrig, 2017), and previous research has found that shifts in attentional bias toward both threatening and pleasant cues after happy mood induction were associated with small increases in PWB over time (Cavanagh et al., 2011). If we apply these findings to our results, this could indicate that participants with higher PWB had greater attentional bias to suspenseful events during the audiovisual film, leading to higher synchronization in the right TPJ.

The left OFC was also found to have higher synchronization in individuals with higher levels of PWB. The OFC is a region that has been previously associated with PWB, with gray matter volume of the left OFC being associated with increased optimism (i.e., a component of positive affect; Dolcos et al., 2016). Further, the OFC is a key brain area in the representation of reward value (Rolls et al., 2020), providing a direct link to subjective components of PWB. Higher synchronization of this region suggests that it behaved more similarly in participants with higher PWB throughout the audiovisual film, emphasizing previous reports that associate the OFC with higher PWB outcomes.

The regions that consistently showed higher synchronization in individuals with higher levels of PWB are the right planum temporale and right occipital pole. The right planum temporale serves as a computational hub for complex sounds (Griffiths & Warren, 2002), and the right planum temporale is involved in stimulus-driven auditory attention (Hirnstein et al., 2013). Higher synchronization in this region suggests that individuals with higher PWB had similar stimulus-driven auditory attention throughout the film. However, as this region has not been previously associated with PWB, more research is needed to fully elucidate the role of the right planum temporale in mediating differential PWB outcomes in response to complex audiovisual stimuli. The right occipital pole is involved in lower level visual processing, however, as this region has not been previously associated with PWB, more research is needed to elucidate the role of this region in PWB.

Together, results from Experiment 1 provide evidence of differential neural synchrony in individuals with comparative low and high levels of PWB during a positive valence, complex audiovisual film. Individuals with comparative low levels of PWB had heightened neural synchrony in the left SPL, a region associated with attentional engagement, and the precuneus, a region involved in narrative sense-making. Regions that consistently had higher neural synchrony in individuals with lower PWB were the left lingual gyrus and Wernicke's area, areas involved in narrative/language processing. Individuals with comparative high levels of PWB had heightened neural synchrony in regions previously associated with PWB, including the left OFC, and regions associated with narrative processing, including the right TPJ. Regions that consistently had higher neural synchrony in individuals with higher PWB were the right planum temporale and the right occipital pole. These patterns of synchrony suggest that variations in PWB may modulate neural synchrony during positive-valence movie watching, and these effects may be the result of changes in narrative processing and affective processing.

Experiment 2

2.2.1 Introduction

While Experiment 1 revealed significant unique patterns of neural synchrony associated with varying levels of PWB in response to a positive valence audiovisual film, it did not examine if these patterns of neural synchrony are altered when processing a negative valence stimulus. Thus, the objective of Experiment 2 was to identify differences in neural synchrony associated with comparative low and high levels of PWB in response to a negative valence film, shedding light on how the valence of the incoming stimulus can modulate neural synchrony associated with PWB. To achieve this, we used fMRI data from 18 participants who watched the full-length audiovisual film *CitizenFour* (Poitras, 2014). This film was chosen due to its sample size (n=18) and its negative valence. Thus, Experiment 2 aimed to identify patterns of neural synchrony associated with comparative low and high levels of PWB in response to a negative valence, complex audiovisual stimulus.

As individuals with lower PWB typically experience more frequent negative emotions and may interpret ambiguous events more negatively, we expect this to be reflected in differences in neural synchrony associated with low and high comparative levels of PWB in response to a negative valence audiovisual film. We generally hypothesize that PWB will act as an implicit prime during negative valence naturalistic processing, causing individuals with lower PWB to process the negative valence audiovisual film more similarly. More specifically, we hypothesize that individuals with lower PWB will show heightened neural synchrony in the TPJ and SPL in response to the negative audiovisual film, reflecting higher attentional engagement towards emotional stimuli and the more suspenseful interpretation of the narrative.

2.2.2 Methods

The methods for Experiment 2 were the same as Experiment 1, with the following exceptions.

Participants

For this study, we used preprocessed fMRI data from the NNDb (Aliko et al., 2020; v2.0) for 18 participants (9 male/9 female, mean age = 27) who watched the full-length documentary *Citizenfour* (Poitras, 2014). Participants were split into a low PWB group and a high PWB group using a median split from their NIH Toolbox Psychological Well-Being scores (Gershon et al., 2013). The low PWB group consisted of 4 males and 5 females with a mean age of 26.6. The high PWB group consisted of 5 males and 4 females with a mean age of 27.4. All participants were right-handed, native English speakers, had no history of neurological/psychiatric illnesses, had no hearing impairments, had unimpaired or corrected vision, and did not take medication.

Data Analysis

For this experiment, we ran ISC for all unique pairs of participants (*n* = 18) who watched *Citizenfour* (Webb, 2009), resulting in 152 (*n**(*n*-1)/2) unique ISC maps. The remainder of the data analysis was the same as Experiment 1.

2.2.3 Results

Behavioural Questionnaires

We used SPSS (version 27; IBM Corp., 2020) to run an independent sample t-test between participants in the low-low and high-high PWB groups to determine whether age differed between the two groups. No significant differences were found $t(16) = -.174$, $p = .864$.

Group Averages

Results for the low-low PWB group average can be found in Figure 2.7 and Table 2.9, and results for the high-high PWB group average can be found in Figure 2.8 and Table 2.10.

Results from the low-low PWB and high-high PWB group averages found significant widespread synchrony consistent across both groups in areas associated with visual processing, auditory processing, and the processing of a narrative, which is in line with previous research (Güçlütürk et al., 2018). These regions included the bilateral LOC, bilateral STG, bilateral SPL, bilateral TPJ, bilateral precuneus, bilateral occipital pole, bilateral lingual gyrus, bilateral intracalcarine cortex, and bilateral fusiform gyrus. We also found significant clusters of neural synchrony in both groups in areas including the bilateral postcentral gyrus and left crus I of the cerebellum. The low-low PWB group showed larger clusters of neural synchrony than the high-high PWB group.

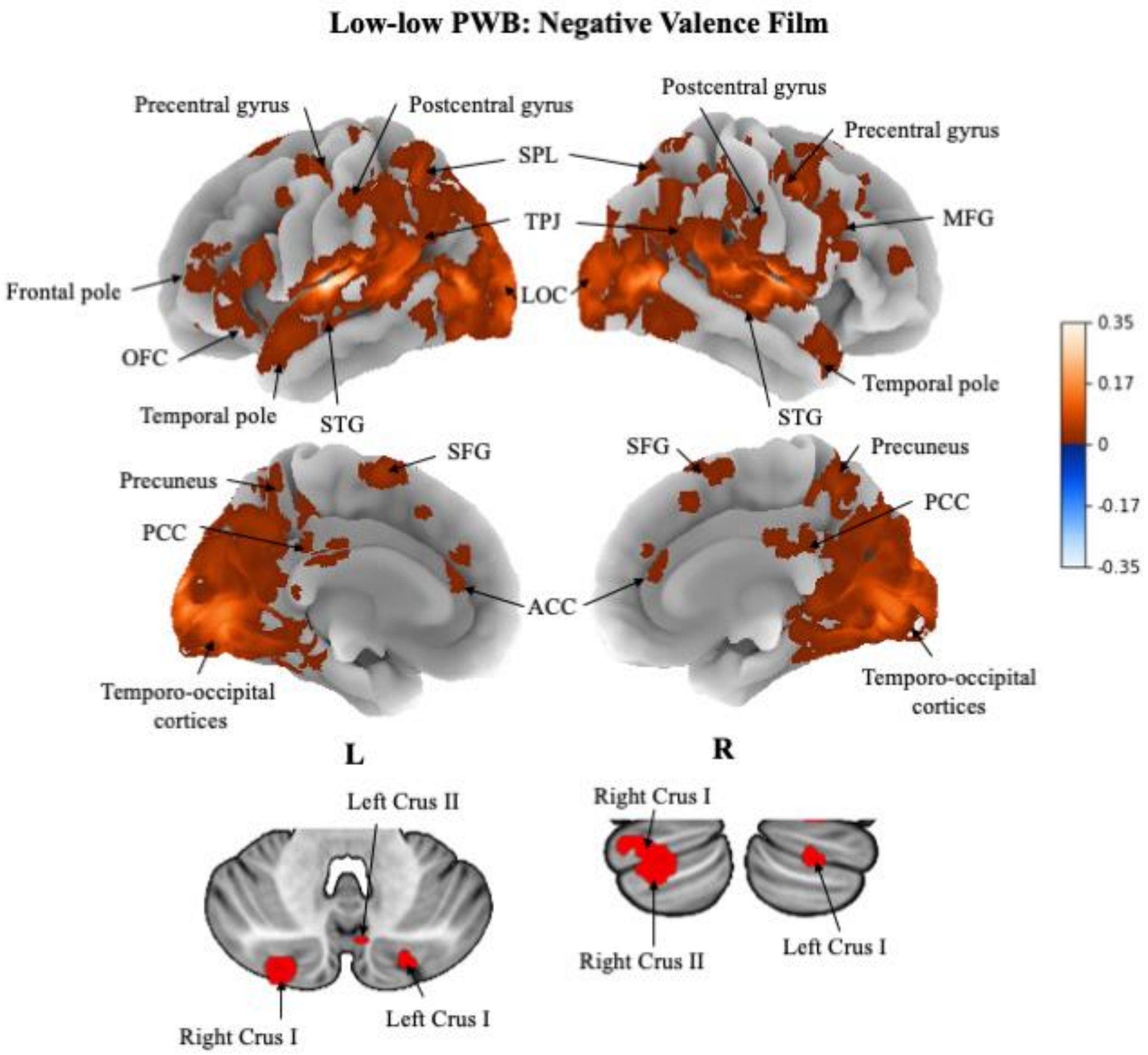

Figure 2.7. Negative Valence Film: Low-low PWB Neural Synchrony. Clusters showing significant ISC within participants in the low-low PWB group across the time course of the audiovisual stimulus. Results are displayed as a voxelwise false-discovery rate (FDR) threshold of $q < 0.001$. Only clusters with five or more voxels reported.

Table 2.9. Negative Valence Film: Low-low PWB average synchrony cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Planum Temporale	Left	5789	0.453	-64.5	-13.5	4.5
Planum Temporale	Right	650	0.299	58.5	-10.5	4.5
Precentral Gyrus	Right	217	0.111	55.5	1.5	46.5
Inferior Frontal Gyrus, pars opercularis	Left	184	0.0496	-58.5	19.5	10.5
Temporal Pole	Left	75	0.0658	-55.5	7.5	-16.5
Precentral Gyrus	Left	44	0.0607	-46.5	-4.5	55.5

Right Crus II	Right	37	0.0476	28.5	-85.5	-34.5
Juxtapositional Lobule Cortex	Left	37	0.0539	-1.5	-1.5	64.5
Temporal Pole	Right	31	0.0564	55.5	10.5	-16.5
Superior Parietal Lobule	Right	22	0.0318	31.5	-52.5	43.5
Cingulate Gyrus, anterior division	Left	19	0.0188	-1.5	34.5	22.5
Superior Parietal Lobule	Right	17	0.0537	28.5	-52.5	67.5
Precentral Gyrus	Left	17	0.0262	-16.5	-37.5	43.5
Supramarginal Gyrus, anterior division	Right	17	0.0227	61.5	-19.5	40.5
Cingulate Gyrus, posterior division	Right	15	0.0237	4.5	-25.5	28.5
Superior Frontal Gyrus	Left	15	0.0277	-13.5	13.5	67.5
Middle Frontal Gyrus	Right	13	0.0191	46.5	31.5	34.5
Precentral Gyrus	Right	12	0.035	28.5	-10.5	61.5
Precentral Gyrus	Left	10	0.0165	-22.5	-28.5	67.5
Paracingulate Gyrus	Right	10	0.0188	1.5	19.5	46.5
Frontal Pole	Right	9	0.0257	43.5	49.5	13.5
Middle Frontal Gyrus	Right	9	0.0243	28.5	31.5	49.5
Frontal Pole	Left	8	0.0187	-34.5	40.5	-10.5
Middle Temporal Gyrus, posterior division	Left	8	0.0379	-52.5	-19.5	-10.5
Superior Frontal Gyrus	Right	7	0.0245	28.5	10.5	61.5
Middle Frontal Gyrus	Left	7	0.0203	-25.5	-1.5	58.5
Precentral Gyrus	Right	7	0.0158	40.5	-13.5	49.5
Precentral Gyrus	Left	7	0.0445	-37.5	7.5	28.5
Postcentral Gyrus	Right	7	0.0211	64.5	-19.5	22.5
Precentral Gyrus	Left	6	0.0229	-43.5	-13.5	49.5
Cingulate Gyrus, posterior division	Right	6	0.0178	4.5	-37.5	25.5
Precuneous Cortex	Left	5	0.0235	-10.5	-58.5	55.5
Left Crus I	Left	5	0.0251	-25.5	-82.5	-34.5
Left Crus II	Left	5	0.0191	-7.5	-76.5	-37.5
Precentral Gyrus	Right	5	0.0188	34.5	-25.5	61.5
Superior Frontal Gyrus	Right	5	0.0241	4.5	19.5	64.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

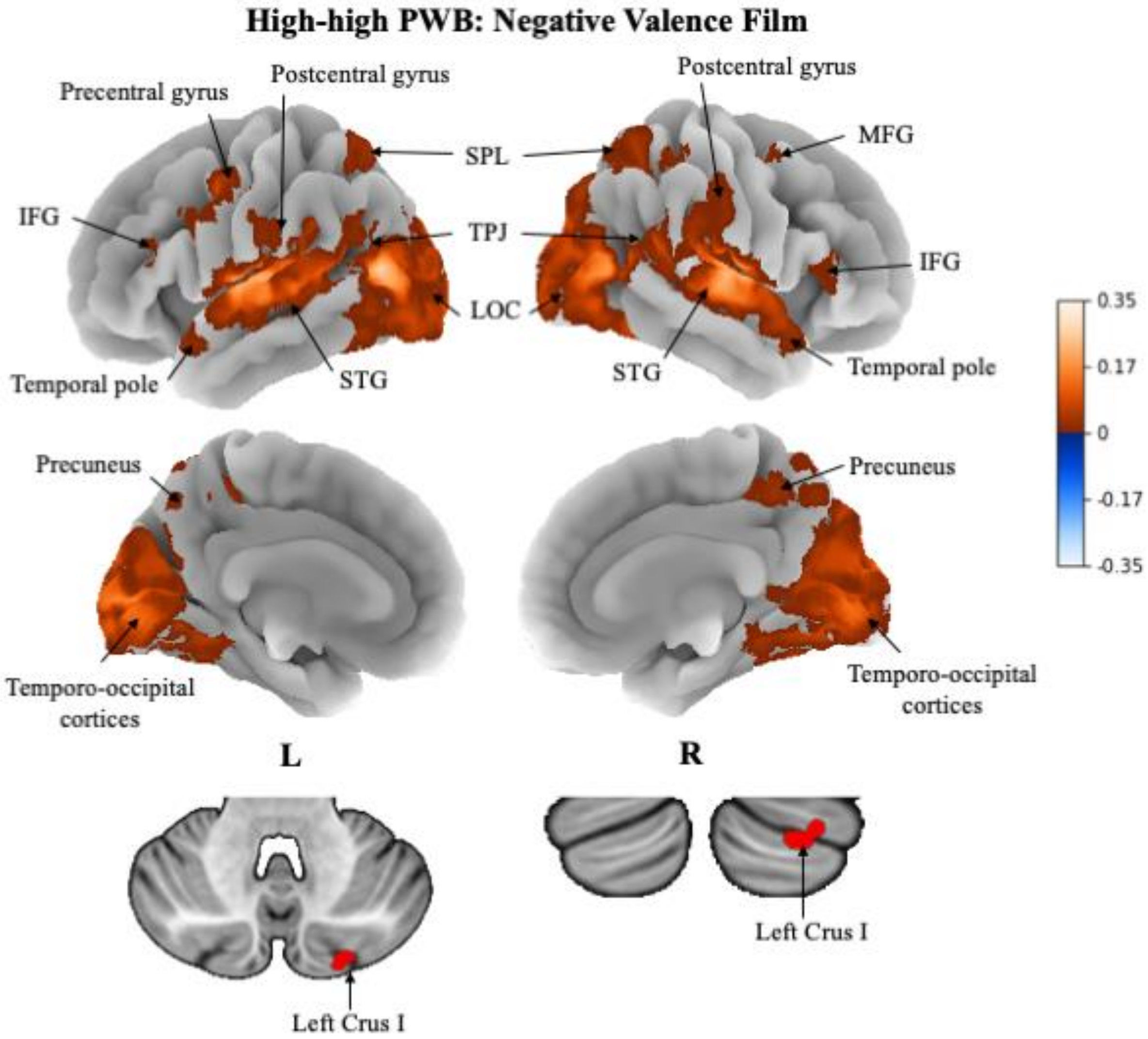

Figure 2.8. Negative Valence Film: High-high PWB Neural Synchrony. Clusters showing significant ISC within participants in the high-high PWB group across the time course of the audiovisual stimulus. Results are displayed as a voxelwise false-discovery rate (FDR) threshold of $q < 0.001$. Only clusters with five or more voxels reported.

Table 2.10. Negative Valence Film: High-high PWB average synchrony cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Planum Temporale	Left	3462	0.336	-64.5	-10.5	4.5
Planum Temporale	Right	729	0.301	61.5	-7.5	4.5
Temporal Occipital Fusiform Cortex	Left	174	0.109	-28.5	-61.5	-7.5
Lateral Occipital Cortex, superior division	Left	45	0.0532	-16.5	-70.5	61.5
Precentral Gyrus	Left	42	0.105	-55.5	1.5	43.5

Inferior Frontal Gyrus, pars opercularis	Right	25	0.028	52.5	25.5	7.5
Precuneous Cortex	Right	16	0.0681	4.5	-52.5	49.5
Postcentral Gyrus	Left	16	0.0422	-64.5	-22.5	22.5
Inferior Frontal Gyrus, pars opercularis	Left	14	0.0424	-43.5	10.5	28.5
Superior Parietal Lobule	Right	13	0.0433	31.5	-40.5	55.5
Precuneous Cortex	Right	11	0.037	1.5	-67.5	46.5
Temporal Pole	Left	11	0.0528	-55.5	13.5	-13.5
Middle Frontal Gyrus	Right	11	0.0504	46.5	1.5	55.5
Precuneous Cortex	Left	10	0.0376	-13.5	-46.5	52.5
Precuneous Cortex	Right	8	0.0296	4.5	-61.5	61.5
Precuneous Cortex	Right	6	0.0236	13.5	-40.5	49.5
Left Crus I	Left	6	0.0286	-25.5	-85.5	-34.5
Inferior Frontal Gyrus, pars triangularis	Left	5	0.0301	-52.5	31.5	16.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

Low-low PWB vs. High-high PWB contrasts

Results for low-low PWB > high-high PWB contrast can be found in Figure 2.9 (warm colours) and Table 2.11. Results for the low-low PWB > high-high PWB contrast demonstrates regions of the brain that had higher synchronization in the low-low PWB group compared to the high-high PWB group. This contrast found clusters of heightened neural synchrony in regions including the left SPL, right planum temporale, bilateral TPJ, left IFG, left precuneus, and bilateral lingual gyrus.

Results for the high-high PWB > low-low PWB contrast can be found in Figure 2.9 (cool colours) and Table 2.12. This contrast demonstrates regions of the brain that had higher synchronization in the high-high PWB group compared to the low-low PWB group. This contrast found clusters of heightened neural synchrony in regions including the bilateral STG, left precentral gyrus, right parietal operculum, and right LOC.

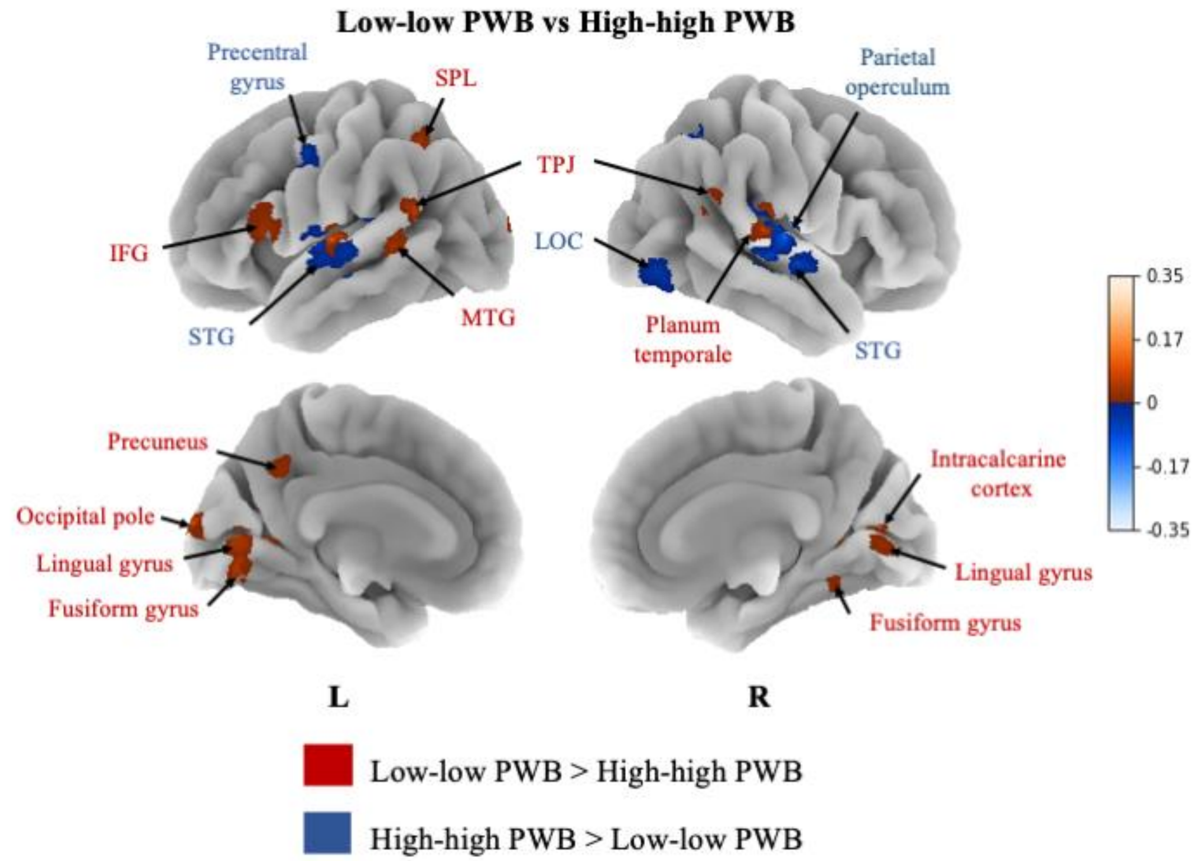

Figure 2.9. Negative Valence Film: Low-low PWB vs High-high PWB Neural Synchrony. Red refers to clusters showing higher ISC within participants in the low-low PWB group compared to the high-high PWB group across the time course of the audiovisual stimulus. Blue refers to clusters showing higher ISC within the high-high PWB group compared to the low-low PWB group across the time course of the audiovisual stimulus. Results are displayed as a voxelwise false-discovery rate (FDR) threshold of $q < 0.05$. Only clusters with five or more voxels reported.

Table 2.11. Negative Valence Film: Low-low PWB > high-high PWB cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Planum Temporale	Right	26	0.142	64.5	-25.5	10.5
Intracalcarine Cortex	Left	23	0.056	-25.5	-67.5	7.5
Inferior Frontal Gyrus, pars opercularis	Left	19	0.0369	-55.5	19.5	4.5
Middle Temporal Gyrus, temporooccipital part	Left	18	0.0808	-58.5	-46.5	4.5
Lingual Gyrus	Left	17	0.121	-10.5	-76.5	-7.5

Lateral Occipital Cortex, superior division	Left	13	0.0645	-28.5	-76.5	22.5
Intracalcarine Cortex	Right	12	0.066	19.5	-73.5	7.5
Superior Parietal Lobule	Left	11	0.0549	-28.5	-55.5	46.5
Occipital Pole	Left	10	0.117	-10.5	-100	10.5
Lingual Gyrus	Right	7	0.0554	28.5	-58.5	4.5
Planum Temporale	Left	7	0.193	-61.5	-13.5	4.5
Angular Gyrus	Left	7	0.0879	-64.5	-52.5	16.5
Temporal Occipital Fusiform Cortex	Right	6	0.0551	28.5	-49.5	-7.5
Occipital Fusiform Gyrus	Left	5	0.0847	-25.5	-79.5	-7.5
Angular Gyrus	Right	5	0.0728	58.5	-49.5	22.5
Precuneous Cortex	Left	5	0.0304	-4.5	-52.5	40.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

Table 2.12. Negative Valence Film: High-high PWB > low-low PWB cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Superior Temporal Gyrus, posterior division	Right	29	0.28	67.5	-13.5	7.5
Lateral Occipital Cortex, superior division	Right	17	0.101	31.5	-64.5	52.5
Superior Temporal Gyrus, posterior division	Left	15	0.177	-70.5	-19.5	-1.5
Superior Temporal Gyrus, anterior division	Left	15	0.294	-64.5	-7.5	4.5
Lateral Occipital Cortex, inferior division	Right	9	0.109	46.5	-76.5	-7.5
Superior Temporal Gyrus, posterior division	Right	9	0.187	64.5	-10.5	-4.5
Parietal Operculum Cortex	Right	9	0.0913	37.5	-28.5	19.5
Heschl's Gyrus	Right	8	0.222	49.5	-19.5	7.5
Precentral Gyrus	Left	7	0.0997	-55.5	-1.5	43.5
Planum Temporale	Left	6	0.146	-34.5	-31.5	16.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

Comparing low and high group ISC with between group ISC

Low-low vs Low-high PWB

Full results for the low-low > low-high PWB contrast can be found in Figure 2.10 (warm colours) and Table 2.13. Results for the low-low > low-high PWB contrast demonstrates regions of the brain that had higher synchronization in the low-low group compared to the low-high group. This contrast showed heightened neural synchrony in regions including the left IFG and right planum temporale.

Full results for the low-high > low-low PWB contrast can be found in Figure 2.10. This contrast demonstrates regions of the brain that had higher synchronization in the low-low group compared to the low-high group. This contrast showed no regions of heightened neural synchrony.

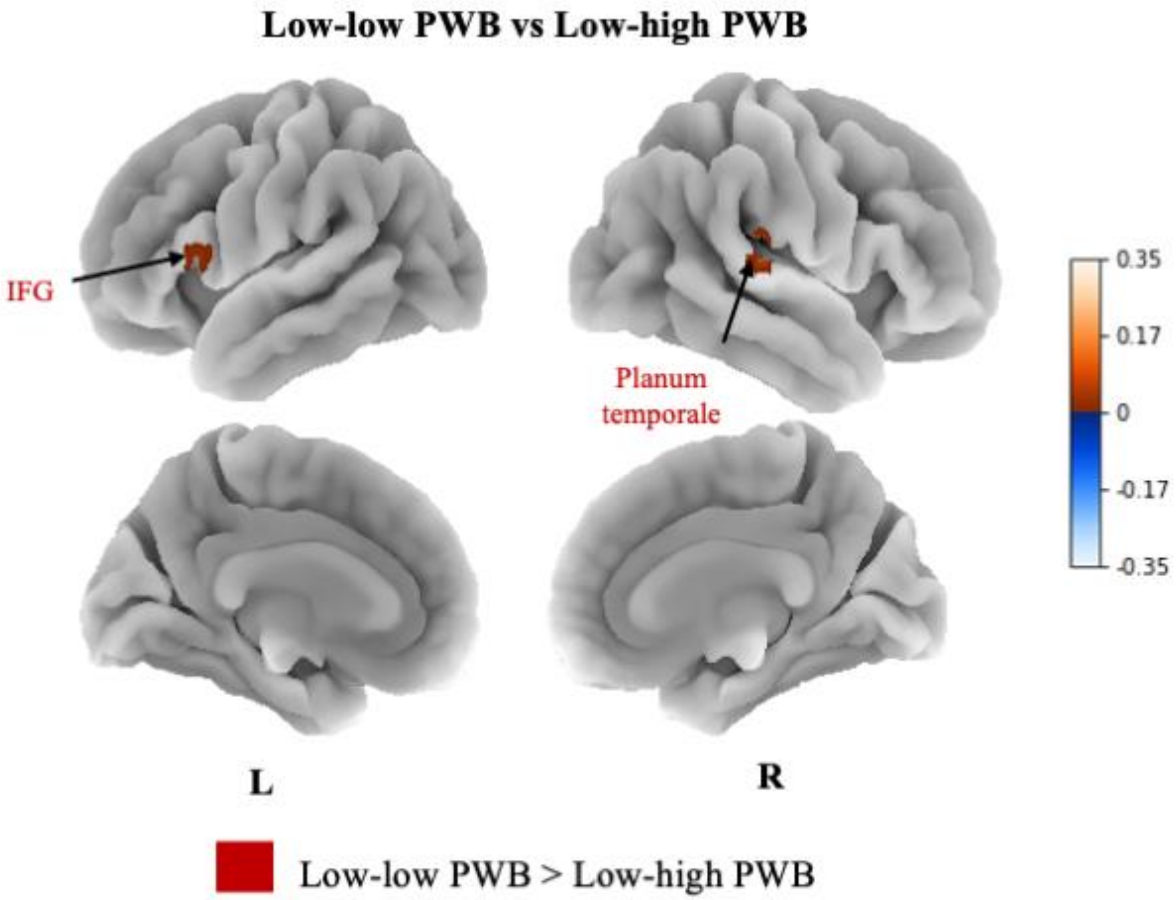

Figure 2.10. Negative Valence Film: Low-low PWB vs Low-high PWB Neural Synchrony. Red refers to clusters showing higher ISC within participants in the low-high PWB group compared

to the high-high PWB group across the time course of the audiovisual stimulus. Results are displayed as a voxelwise false-discovery rate (FDR) threshold of $q < 0.05$. Only clusters with five or more voxels reported.

Table 2.13. Negative Valence Film: Low-low PWB > low-high PWB cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Inferior Frontal Gyrus, pars opercularis	Left	9	0.0494	-58.5	16.5	7.5
Superior Temporal Gyrus, posterior division	Right	5	0.13	67.5	-25.5	10.5
Planum Temporale	Right	5	0.0969	55.5	-28.5	13.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

Low-high vs High-high PWB

Results for the low-high > high-high PWB contrast demonstrates regions of the brain that had higher synchronization in the low-high group compared to the high-high group. This contrast showed no regions of heightened neural synchrony.

Results for the high-high > low-high PWB contrast demonstrates regions of the brain that had higher synchronization in the low-high group compared to the high-high group. This contrast showed no regions of heightened neural synchrony.

2.2.4 Discussion

This study sought to examine differences in how individuals with comparative low and high levels of PWB respond to a complex, negative valence audiovisual stimulus, as demonstrated by differences in neural synchrony between the two groups. To do so, we separated participants into two groups. The first consisted of individuals with lower levels of PWB and the second consisted of individuals with higher levels of PWB. We ran ISC analysis and used LME modelling to visualize how neural synchrony differs between each group. Neural activity has been shown to be sensitive to the nature of the stimulus, and results from this study have provided support that individual differences in PWB result in substantial variations in neural synchrony in response to a negative valence naturalistic stimulus. Consistent with our hypothesis, differential neural synchrony was found in association with varying levels of PWB in regions associated with PWB and narrative processing.

We predicted that as participants were watching the same stimulus, they would have heightened neural synchrony in regions associated with narrative processing. As expected, the group averages for participants both with low and high PWB, respectively, showed heightened neural synchrony in the bilateral SPL, bilateral TPJ, bilateral precuneus, bilateral LOC, and bilateral STG, consistent with previous reports (Jääskeläinen et al., 2021). Participants with lower PWB showed more widespread neural synchrony in several regions in the bilateral frontal lobe of the brain, including the bilateral OFC and bilateral vmPFC, suggesting that these regions behaved more similarly during the negative valence film.

We hypothesized that individuals with lower PWB would show heightened neural synchrony in regions associated with narrative processing, including the TPJ and SPL. These results confirm our hypothesis, as while watching the negative valence stimulus, individuals with comparative low PWB showed heightened neural synchrony in the left precuneus, left SPL, and bilateral TPJ. During narrative processing, the TPJ is centrally associated with higher synchronization during suspenseful narratives and negative emotional narratives (Jääskeläinen et al., 2020). Therefore, higher synchronization in this region may indicate that individuals with lower levels of PWB found the narrative more suspenseful and interpreted it more negatively. Previous research has demonstrated that psychological distress, which is in part defined by low PWB, is associated with perceiving stressful events as a negative turning point (Sutin et al., 2010). Further, as the film is negative valence, individuals with lower PWB having limited capacity to transition to different emotional states (Kuppens et al., 2010) may prolong experiences of stress in the narrative, whereas individuals with higher levels of PWB may be quicker to shift their emotional state from suspense to a different emotion. If we extend this finding to our result, this could indicate that individuals with lower levels of PWB interpreted stressful events during the film as a negative turning point, causing the more suspenseful and negative interpretation of the narrative.

The precuneus is involved in narrative-sense making, and thus it is possible that individuals with lower PWB processed the narrative more similarly than individuals with higher PWB. Individuals with lower PWB typically have higher emotional inertia, suggesting they are resistant to change in emotional states (Kuppens et al., 2010). Therefore, heightened synchrony in the precuneus in individuals with lower PWB may suggest that they were resistant to emotional changes throughout the film, and as a result may have made sense of the narrative more similarly. However, more research should be done on the role of the precuneus in mediating the brain's response to positive valence stimuli in individuals with low comparative PWB.

The SPL has been shown to have higher synchronization during narrative processing during attentionally engaging narratives (Jääskeläinen et al., 2021). This may indicate that individuals with low comparative PWB found the narrative more attentionally engaging than individuals with higher levels of PWB. Previous research has suggested that low PWB is associated with higher attentional engagement towards emotional stimuli through its associations with low self-esteem. Low self-esteem is related to several psychiatric disorders (Silverstone & Salsali, 2003) and is therefore associated with low PWB outcomes, and there is an attention bias for negative stimuli among individuals with low self-esteem (Li et al., 2011) with the greater mobilization of attentional resources toward emotional stimuli (Li & Yang, 2013). Taken together, these results suggest that individuals with lower levels of PWB may have assigned a more negative interpretation to stressful events during the film, and therefore exhibited greater attentional engagement throughout the film.

Areas that consistently showed higher synchronization in individuals with lower PWB in response to a negative valence film include the right planum temporale and left IFG. The right planum temporale serves as a computational hub for complex sounds (Griffiths & Warren, 2002), and the right planum temporale is involved in stimulus-driven auditory attention (Hirnstein et al., 2013). While the right planum temporale has not been previously associated with PWB, higher synchronization in this region suggests that individuals with lower PWB had more similar stimulus-driven auditory attention throughout the negative valence film. The left IFG plays a crucial role in language processing as it is associated with semantic integration and cognitive control during sentence comprehension (Zhu et al., 2013). Individuals with lower PWB showing heightened neural synchrony in this region may suggest that they processed the language in the film more similarly. Specifically, individuals with lower PWB may have had more similar semantic integration during sentence comprehension than individuals with higher PWB in response to the negative valence film.

Areas that had higher synchronization in individuals with higher PWB include the bilateral STG and left precentral gyrus. The precentral gyrus has previously been shown to play a role in movie watching paradigms, as looking at someone performing a motor action modifies the brain activity of the observer, specifically in the precentral gyrus (Babiloni et al., 2002). It has further been suggested higher synchronization in the precentral gyrus may indicate more attention to the narrative content (Andreu-Sánchez et al., 2017). Therefore, it is possible that individuals with higher PWB showing higher synchronization in the left precentral gyrus may indicate more attention paid to the narrative content. Further, stimulation of the precentral gyrus modulates the processing of decontextualized action words and sentences, suggesting that language comprehension may rely on brain circuits mediating the bodily experiences evoked by verbal material (Birba et al., 2020). Therefore, it is possible that higher synchronization in this region may reflect more bodily experiences evoked as a response to the verbal material throughout the negative valence film. However, this is purely speculative, and more research is needed to determine the role of the left precentral gyrus modulating the response to a negative valence audiovisual stimulus based on varying levels of PWB. The STG is a region that has been previously broadly associated with PWB, as it is involved in various high-level processes and is therefore theoretically likely to play a role in PWB (King, 2019). The STG has also been implicated in narrative processing, being involved in higher-level auditory processing (Strittmatter, 2011) and in semantic activation, integration, and selection (Benedetti et al., 2015). These results therefore suggest that in response to a negative valence audiovisual film, participants with higher PWB may have processed higher-level auditory information more similarly, and higher levels of PWB may reflect an enhanced ability to build a coherent story representation.

Together, results from Experiment 2 provide evidence of differential neural synchrony associated with comparative low and high levels of PWB during a negative valence, complex audiovisual film. Individuals with low levels of PWB had more widespread neural synchrony when compared to individuals with higher levels of PWB. They demonstrated increased neural synchrony in regions associated with narrative processing, including the bilateral TPJ, left SPL and left precuneus. Regions that consistently showed higher synchronization in individuals with lower PWB include the right planum temporale and left IFG. Individuals with higher PWB did not demonstrate heightened neural synchrony in the key regions previously associated PWB but demonstrated heightened neural synchrony in the bilateral STG and left precentral gyrus, areas with implications in narrative processing. These patterns of synchrony suggest that individuals with lower PWB respond more similarly to a negative valence audiovisual film than individuals with higher PWB. Lower PWB may therefore act as an implicit prime which biases individuals to preferentially process negative valence stimuli.

Experiment 3

2.3.1 Introduction

While Experiments 1 and 2 revealed significant unique patterns of neural synchrony associated with comparative low and high levels of PWB in response to a positive and negative valence complex audiovisual stimulus, they did not examine how individuals with lower levels of PWB respond to a positive vs. negative valence film. The objective of Experiment 3 was to examine how individuals with lower levels of PWB differentially process positive and negative valence audiovisual stimuli, shedding light on how low PWB shapes the processing of emotionally valenced stimuli. To achieve this, we used fMRI data from 19 participants: 10 from the low PWB group who watched a positive valence film *(500 Days of Summer*; Webb, 2009), and 9 from the low PWB group who watched a negative valence film (*Citizenfour*; Poitras, 2014). Thus, Experiment 3 aimed to identify patterns of neural synchrony specific to positive valence stimulus processing and negative valence stimulus processing associated with lower levels of PWB.

As individuals with higher PWB experience reduced affective reactivity to positive events in daily life, and individuals with lower PWB experience a resistance to emotional state changes (Kuppens et al., 2010), we expect that individuals with lower PWB will experience an affective reactivity to positive events (Grosse Rueschkamp et al., 2020), and that reactivity will be resistant to change throughout the film. We therefore generally hypothesize that individuals with lower PWB will show heightened neural synchrony in response to the positive valence film. More specifically, we hypothesize that individuals with lower PWB will respond more synchronously in regions associated with narrative processing, including the TPJ, SPL, and bilateral precuneus.

2.3.2 Methods

The methods for Experiment 3 were the same as Experiments 1 and 2, with the following exceptions.

Participants

For this study, we used preprocessed fMRI data from the NNDb (Aliko et al., 2020; v2.0). We used functional datasets of 19 participants (8 males/11 females, mean age = 27.21), 10 of which made up the entirety of the low PWB group in Experiment 1 (4 males/6 females, mean age = 28.4) who watched the full-length feature film *500 Days of Summer* (Webb, 2009), 9 of which made up the entirety of the low PWB group in Experiment 2 (4 male/5 females, mean age = 26.6) who watched the full-length documentary *Citizenfour* (Poitras, 2014). All participants were right-handed, native English speakers, had no history of neurological/psychiatric illnesses, had no hearing impairments, had unimpaired or corrected vision, and did not take medication.

Psychological Well-Being Assessment

We ran an independent sample t-test within SPSS (version 27; IBM Corp., 2020) between participants in each PWB group (i.e., low-low PWB and high-high PWB) across *500 Days of Summer* (Webb, 2009) and *Citizenfour* (Poitras, 2014), and age to ensure the two groups did not differ significantly on age.

Data Analysis

To perform ISC analysis across the two different films, it was necessary to decrease the number of fMRI volumes in *Citizenfour* (Poitras, 2014) (TR = 6804) to match the number of fMRI volumes in *500 Days of Summe*r (Webb, 2009) (TR = 5470), as this film had the fewest acquired volumes. We used *fslroi* (Jenkinson et al., 2012) to reduce the number of volumes in *Citizenfour* (Poitras, 2014), resulting in 5470 final volumes in both films. ISCs were then calculated for all pairs of participants both within and between emotional valence groups. We used LME modelling implemented via the *3dISC* module in AFNI (Chen et al., 2016; Cox, 1996; Cox & Hyde, 1997) where we implemented group comparison modelling to obtain the following ISC and t-statistic files: low-low PWB Positive valence vs. low-low PWB Negative valence. Significant ISC was determined using a voxel-wise FDR threshold of $q < 0.05$. Clusters with less than 5 voxels were excluded for all contrasts. Significant results were transformed into surface space for visualization purposes only.

2.3.3 Results

Behavioural Questionnaires

We used SPSS (version 27; IBM Corp., 2020) to run an independent sample t-test between participants in the low and high PWB groups across *500 Days of Summer* (Webb, 2009) and *Citizenfour* (Poitras, 2014) to determine whether age differed between the two groups. No significant differences were found $t(36) = -.398$, $p = .693$.

Low-low PWB Positive Valence Film vs. Low-low PWB Negative Valence Film

Full results for this contrast can be found in Figure 2.11 (warm colours) and Table 2.14. Results for the low-low PWB positive valence film > low-low PWB negative valence film contrast demonstrates regions of the brain that had higher synchronization for the low PWB group in response to the positive valence film compared to the negative valence film. This contrast showed heightened neural synchrony in regions including the bilateral SPL, bilateral TPJ, bilateral SFG, Wernicke's area, bilateral precuneus, bilateral lingual gyrus, and left crus II of the cerebellum.

Full results for the low-low PWB negative valence film > low-low PWB positive valence film contrast can be found in Figure 2.11 (cool colours) and Table 2.15. This contrast demonstrates regions of the brain that had higher synchronization for the low PWB group in response to the negative valence film compared to the positive valence film. This contrast showed heightened neural synchrony in regions including the right planum temporale, right precentral gyrus, left OFC, bilateral intracalcarine cortex, and left crus II of the cerebellum.

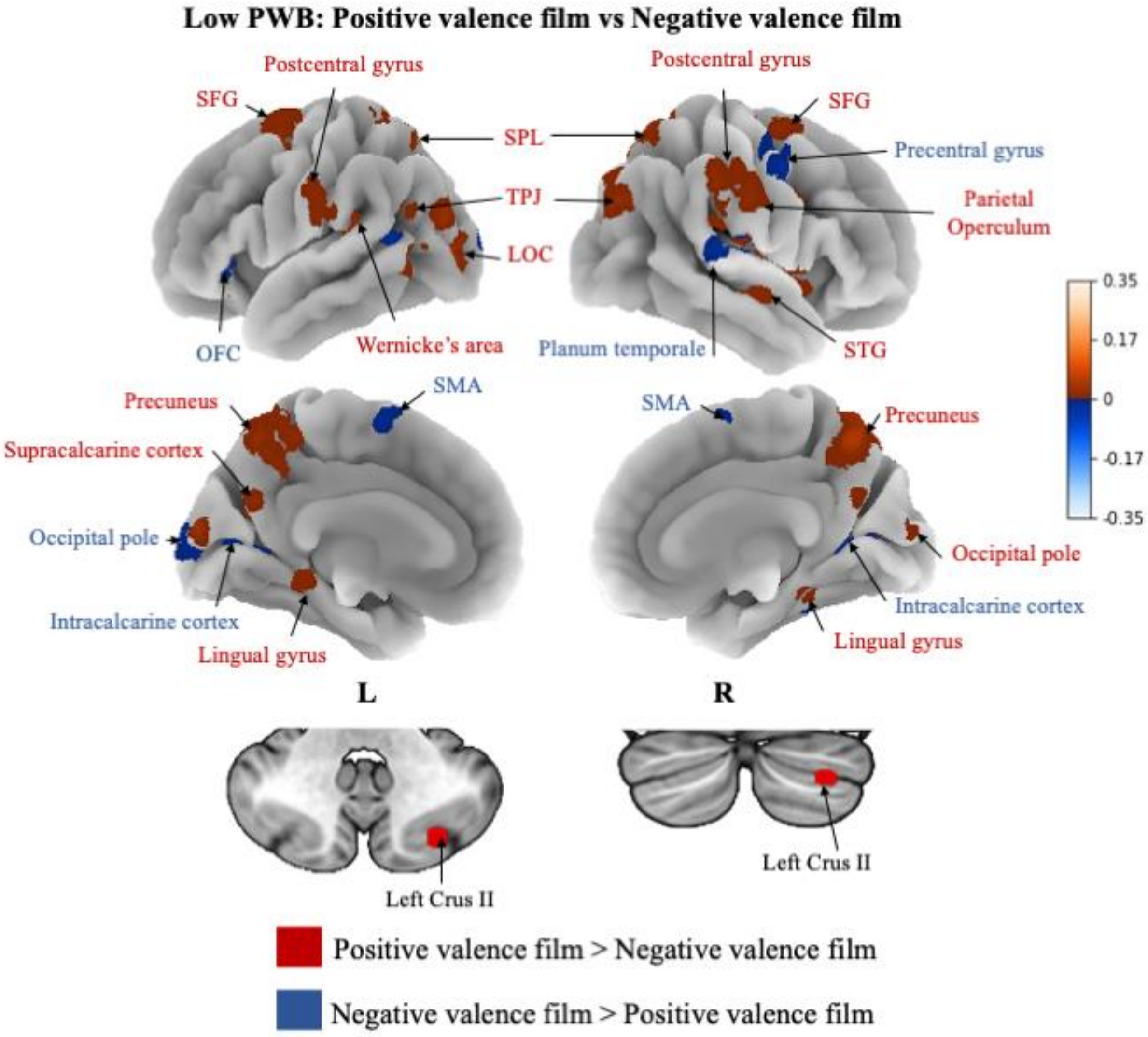

Figure 2.11. Low-low PWB Positive Valence Film vs Low-low PWB Negative Valence Film Neural Synchrony. Red refers to clusters showing higher ISC within participants in the low-low PWB group who watched the positive valence film compared to the low-low PWB group who watched the negative valence film. Blue refers to clusters showing higher ISC within participants in the low-low PWB group who watched the negative valence film compared to the low-low PWB group who watched the positive valence film. Results are displayed as a voxelwise false-discovery rate (FDR) threshold of $q < 0.05$. Only clusters with five or more voxels reported.

Table 2.14. Low-low PWB positive valence film > Low-low PWB negative valence film cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Precuneous Cortex	Right	298	0.0727	1.5	-61.5	52.5
Supracalcarine Cortex	Left	62	0.0489	-22.5	-64.5	19.5
Heschl's Gyrus	Right	51	0.0628	49.5	-7.5	1.5
Superior Frontal Gyrus	Left	50	0.0242	-22.5	1.5	61.5
Precuneous Cortex	Right	45	0.0628	22.5	-58.5	19.5
Postcentral Gyrus	Right	44	0.0264	61.5	-13.5	31.5
Postcentral Gyrus	Left	35	0.0201	-64.5	-19.5	31.5
Occipital Pole	Left	33	0.0739	-31.5	-91.5	1.5
Lateral Occipital Cortex, superior division	Right	31	0.0541	28.5	-79.5	28.5
Precentral Gyrus	Right	25	0.0282	28.5	-7.5	64.5
Lateral Occipital Cortex, superior division	Left	24	0.0583	-46.5	-82.5	16.5
Lateral Occipital Cortex, superior division	Right	19	0.0406	43.5	-79.5	31.5
Lingual Gyrus	Left	19	0.0671	-25.5	-46.5	-7.5
Supramarginal Gyrus, anterior division	Left	18	0.0298	61.5	-31.5	37.5
Planum Temporale	Left	15	0.0994	-40.5	-37.5	16.5
Lateral Occipital Cortex, inferior division	Left	13	0.0529	-52.5	-70.5	4.5
Superior Temporal Gyrus, anterior division	Right	13	0.0732	58.5	-7.5	-7.5
Superior Parietal Lobule	Left	10	0.0326	-25.5	-52.5	70.5
Intracalcarine Cortex	Right	9	0.0893	13.5	-76.5	13.5
Lateral Occipital Cortex, superior division	Right	7	0.0252	37.5	-64.5	58.5
Lingual Gyrus	Left	7	0.0232	-16.5	-43.5	-10.5
Heschl's Gyrus	Right	7	0.0373	40.5	-19.5	10.5
Temporal Pole	Left	7	0.0266	-52.5	22.5	-19.5
Precuneous Cortex	Left	6	0.0345	-1.5	-64.5	28.5
Heschl's Gyrus	Left	6	0.0366	-43.5	-16.5	1.5
Superior Parietal Lobule	Left	6	0.0298	-34.5	-52.5	67.5
Occipital Pole	Left	6	0.0858	-1.5	-91.5	13.5
Precentral Gyrus	Right	5	0.0159	55.5	13.5	34.5
Parietal Operculum Cortex	Right	5	0.0437	46.5	-31.5	19.5

Lingual Gyrus	Right	5	0.0361	22.5	-40.5	-16.5
Parietal Operculum Cortex	Right	5	0.0414	58.5	-31.5	25.5
Left Crus II	Left	5	0.0216	-28.5	-79.5	-37.5
Angular Gyrus	Left	5	0.0338	-49.5	-61.5	25.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

Table 2.15. Low-low PWB negative valence film > Low-low PWB positive valence film cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Intracalcarine Cortex	Right	66	0.0486	16.5	-70.5	7.5
Intracalcarine Cortex	Left	30	0.0362	-25.5	-70.5	7.5
Planum Temporale	Right	22	0.111	58.5	-13.5	10.5
Precentral Gyrus	Right	20	0.0347	43.5	-1.5	52.5
Intracalcarine Cortex	Left	16	0.0395	-16.5	-79.5	7.5
Precentral Gyrus	Right	13	0.0506	55.5	-1.5	46.5
Occipital Pole	Left	12	0.112	-10.5	-100	13.5
Middle Temporal Gyrus, temporooccipital part	Left	9	0.0389	-49.5	-55.5	10.5
Frontal Orbital Cortex	Left	8	0.0195	-43.5	31.5	-4.5
Juxtapositional Lobule Cortex	Left	7	0.0263	-1.5	1.5	64.5
Superior Temporal Gyrus, posterior division	Right	6	0.0883	67.5	-28.5	10.5
Temporal Fusiform Cortex, posterior division	Right	5	0.0169	34.5	-37.5	-22.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

2.3.4 Discussion

This study sought to examine differences in neural synchrony in response to a positive valence and negative valence film in a group of participants with lower levels of PWB. To do so, we separated participants into two groups: one group with low comparative PWB who watched a positive valence film (*500 Days of Summer*; Webb, 2009) and one group with low comparative PWB who watched a negative valence film (*Citizenfour*; Poitras, 2014). We ran ISC analysis and used LME modelling to visualize how neural synchrony differs between each group. Neural activity has been shown to be sensitive to the nature of the stimulus, and results from this study provide support that lower levels of PWB modulate the response to a positive valence and negative valence stimulus differently.

Consistent with our hypothesis, heightened neural synchrony was found in individuals with lower PWB who watched the positive valence film compared to the negative valence film. This includes regions involved in narrative processing, such as the bilateral SPL, bilateral TPJ and bilateral precuneus. The SPL is a region of the brain involved in attention, and attentionally engaging narratives produce synchronous responses in the SPL (Jääskeläinen et al., 2020). This suggests that individuals with lower PWB may have found the positive valence film more engaging than the negative valence film. The TPJ is centrally associated with higher synchronization during suspenseful narratives and negative emotional narratives (Jääskeläinen et al., 2020), and with social, emotional and mental concepts, suggesting that the TPJ modulates semantic concepts related to the characters of the story (Yuan et al., 2018). Higher synchronization in this region in response to a positive valence film could therefore indicate that individuals with lower PWB processed semantic aspects of the characters, such as their traits, development, motivations, and backstory more similarly. It may also indicate that individuals with lower PWB found the positive valence film more suspenseful and with a more negative interpretation. Lower levels of PWB are associated with perceiving stressful events as a negative turning point (Sutin et al., 2010), therefore, it is possible that negative events during the positive valence film were interpreted more negatively than negative events during the negative valence film, especially when considering the resistance to change in emotional states associated with individuals with lower PWB (Kuppens et al., 2010).

The precuneus is associated with narrative sense-making, and negative emotions are associated with stronger ISCs in the precuneus (Jääskeläinen et al., 2021). As individuals with lower PWB had heightened neural synchrony in the precuneus in response to a positive valence film, this may suggest that individuals with lower PWB were able to make more sense of the narrative and may have interpreted it more similarly. Considering the study by Sutin et al. (2010), which suggests individuals with lower PWB may interpret stressful events as a negative turning point, individuals with lower PWB may have interpreted the film more negatively, causing them to have a more coherent, negative representation of stressful events in the film.

Other areas that had higher synchronization in individuals with lower PWB in response to the negative valence film include the right precentral gyrus, right planum temporale, and left OFC. The right precentral gyrus has not been previously associated with PWB, however, it is involved in integrating bilateral body parts, somatic, and visual information, suggesting a role in integrating sensory information and constructing coherent story representations (Iwamura, 1998). Therefore, it is possible that higher synchronization in this area in response to the negative valence film may reflect more bodily experiences evoked as a response to the story representation being constructed.

The right planum temporale serves as a computational hub for complex sounds (Griffiths & Warren, 2002), and is involved in stimulus-driven auditory attention (Hirnstein et al., 2013). Higher synchronization in this region suggests that individuals with low PWB had similar stimulus-driven auditory attention throughout the negative valence film. While the right planum temporale has not been directly associated with PWB, auditory stimuli have a stronger facilitation effect on emotional perception compared to visual stimuli (Asutay & Västfjäll, 2017). Therefore, it is possible that individuals with lower PWB perceived emotional auditory stimuli of the negative valence film more similarly, reflected by heightened neural synchrony in the right planum temporale. However, as this region has not been previously associated with PWB, more research is needed to fully elucidate the role of the right planum temporale in mediating the response to different stimuli in individuals with low PWB.

The left OFC was also found to have higher synchronization in individuals with lower PWB in response to the negative valence film. The OFC is a region typically associated with higher levels of PWB, and is a key brain area in the representation of reward value (Rolls et al., 2020). However, the OFC is also involved in representing negative reward reinforcers, suggesting that during the negative valence film, individuals with lower PWB may have experienced similar negative reward reinforcers, leading to heightened synchrony. Due to the inconsistency in the literature associating the OFC with PWB, more research is needed to determine how the valence of the stimulus modulates synchrony in this area in individuals with lower PWB.

Together, results from Experiment 3 provide evidence that the valence of a complex, audiovisual stimulus modulates the neural response for individuals with low comparative levels of PWB. The positive valence film was associated with increased neural synchrony in regions including the bilateral TPJ, SPL, and precuneus, suggesting that individuals with lower PWB processed several aspects of the narrative more similarly, including how engaging the narrative was, and how suspenseful the narrative was. Individuals with lower PWB processed the negative valence film more similarly in regions including the right precentral gyrus, right planum temporale, and left OFC, suggesting that individuals with lower PWB responded more similarly in higher level auditory emotional processing in response to a negative valence stimulus. Overall, these patterns of synchrony suggest that in individuals with lower PWB, the context of the incoming stimulus (i.e., the valence) has a profound effect on how neural synchrony is modulated.

Experiment 4

2.4.1 Introduction

While Experiment 3 revealed unique patterns of neural synchrony associated with positive and negative valence processing in a group of participants with lower PWB, they did not examine how individuals with higher levels of PWB respond to a positive vs. negative valence film. The objective of Experiment 4 was to identify how individuals with higher levels of PWB process positive and negative valence audiovisual movies, shedding light on how the valence of the incoming stimulus can alter the modulation of neural synchrony in individuals with higher levels of PWB. To achieve this, we used fMRI data from 19 participants: 10 comprised the high PWB group who watched a positive valence film *(500 Days of Summer*; Webb, 2009), and 9 comprised the high PWB group who watched a negative valence film (*Citizenfour*; Poitras, 2014). Thus, Experiment 4 aimed to identify patterns of neural synchrony specific to positive valence stimulus processing and negative valence stimulus processing associated with higher levels of PWB. As the presence of positive emotions is a crucial component of higher PWB outcomes and influences various aspects of cognition (see introduction section 1.3), we hypothesize that higher PWB will bias participants towards positive emotional stimuli, as reflected by heightened neural synchrony throughout wide expanses of the cortex, including regions previously associated with narrative processing, including the SPL and precuneus, and regions previously associated with PWB, including the OFC.

2.4.2 Methods

The methods for Experiment 4 were the same as Experiment 3 with the following exceptions.

Participants

For this study, we used preprocessed fMRI data from the NNdB (Aliko et al., 2020; v2.0). We utilized functional datasets of 19 participants (11 male/8 female, mean age = 27.21), 10 of which made up the entirety of the high-high PWB group in Experiment 1 (6 males/4 females, mean age = 27) who watched the full-length feature film *500 Days of Summer* (Webb, 2009), 9 of which made up the entirety of the high-high PWB group in Experiment 2 (5 males/4 females, mean age = 27.4) who watched the full-length documentary *Citizenfour* (Poitras, 2014). All participants were right-handed, native English speakers, had no history of neurological/psychiatric illnesses, had no hearing impairments, had unimpaired or corrected vision, and did not take medication.

2.4.3 Results

Behavioural Questionnaires

We used SPSS (version 27; IBM Corp., 2020) to run an independent sample t-test between participants in the high-high PWB groups across *500 Days of Summer* (Webb, 2009) and *Citizenfour* (Poitras, 2014) to determine whether age differed between the two groups. No significant differences were found $t(36) = -.174$, $p = .864$.

High-high PWB Positive Valence Film vs. High-high PWB Negative Valence Film

Full results for this contrast can be found in Figure 2.12 (warm colours) and Table 2.16. Results for the high-high PWB positive valence film > high-high PWB negative valence film contrast demonstrates regions of the brain that had higher synchronization for the high PWB group in response to the positive valence film compared to the negative valence film. This contrast showed widespread neural synchrony throughout the brain, including regions such as the bilateral TPJ, right planum temporale, bilateral OFC, bilateral central operculum, and bilateral STG.

Full results for the high-high PWB negative valence film > high-high PWB positive valence film contrast can be found in Figure 2.12 (cool colours) and Table 2.17. This contrast demonstrates regions of the brain that had higher synchronization for the high PWB group in response to the negative valence film compared to the positive valence film. This contrast showed heightened neural synchrony in regions including Wernicke’s area, the left precentral gyrus, and left occipital pole.

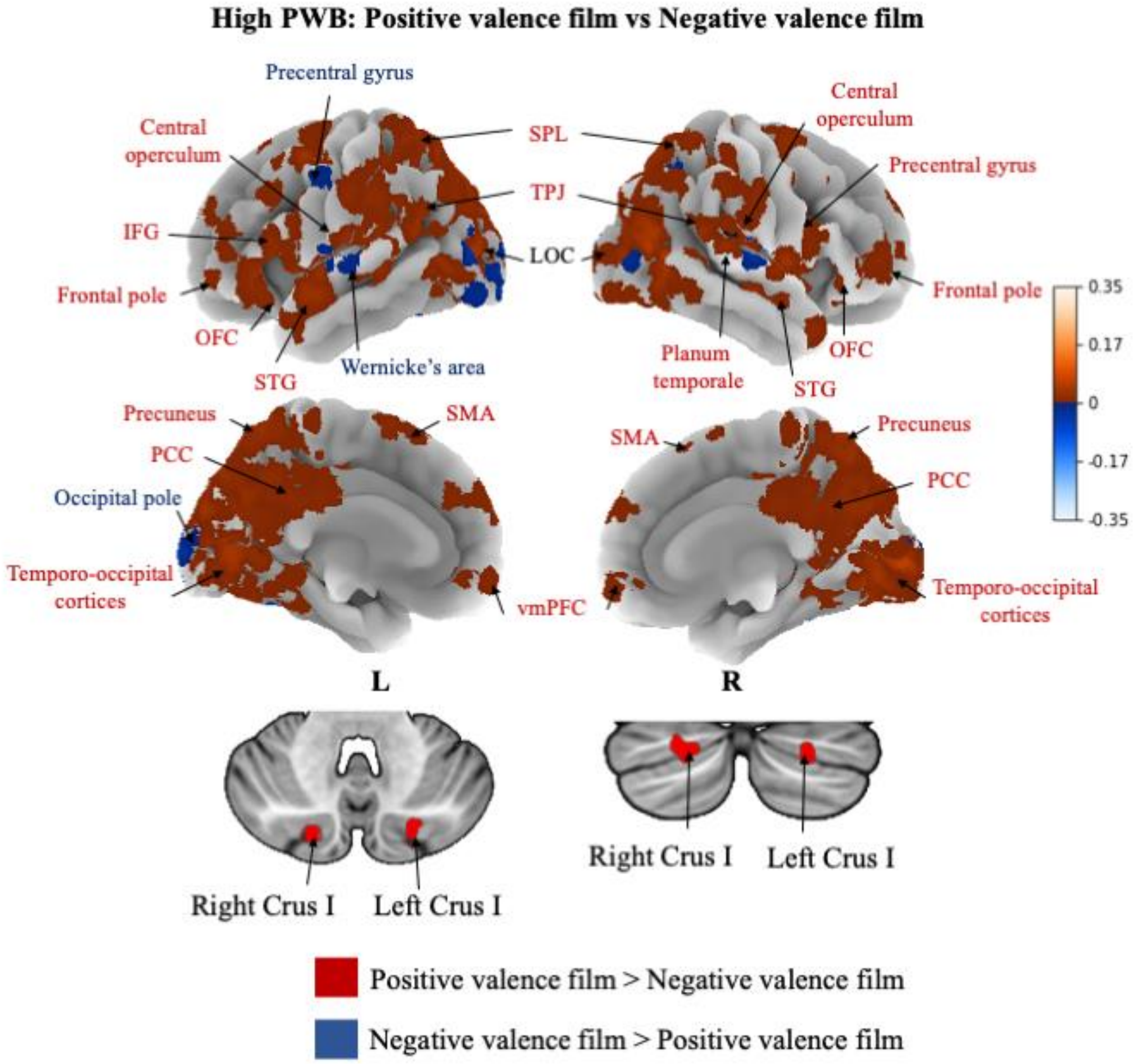

Figure 2.12. High-high PWB Positive Valence Film vs High-high PWB Negative Valence Film Neural Synchrony. Red refers to clusters showing higher ISC within participants in the high-high PWB group who watched the positive valence film compared to the high-high PWB group who

watched the negative valence film. Blue refers to clusters showing higher ISC within participants in the high-high PWB group who watched the negative valence film compared to the low-low PWB group who watched the positive valence film. Results are displayed as a voxelwise false-discovery rate (FDR) threshold of $q < 0.05$. Only clusters with five or more voxels reported.

Table 2.16. High-high PWB positive valence film > high-high PWB negative valence film cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Lateral Occipital Cortex, inferior division	Right	3925	0.146	52.5	-70.5	10.5
Superior Temporal Gyrus, anterior division	Left	490	0.0869	-64.5	-4.5	-1.5
Superior Temporal Gyrus, anterior division	Right	142	0.113	64.5	-4.5	4.5
Lingual Gyrus	Left	130	0.0534	-25.5	-46.5	-7.5
Precentral Gyrus	Left	116	0.0232	-31.5	-7.5	58.5
Superior Frontal Gyrus	Right	86	0.0244	25.5	1.5	61.5
Inferior Frontal Gyrus, pars opercularis	Right	81	0.0282	46.5	10.5	25.5
Angular Gyrus	Left	80	0.0558	-61.5	-52.5	16.5
Temporal Occipital Fusiform Cortex	Right	62	0.0741	28.5	-55.5	-7.5
Lateral Occipital Cortex, inferior division	Left	56	0.0795	-49.5	-76.5	-1.5
Frontal Pole	Right	54	0.0162	46.5	46.5	1.5
Inferior Frontal Gyrus, pars opercularis	Left	51	0.0236	-52.5	7.5	19.5
Frontal Pole	Right	48	0.0141	10.5	64.5	28.5
Precentral Gyrus	Right	40	0.0476	-52.5	-4.5	52.5
Planum Temporale	Right	38	0.0774	43.5	-28.5	13.5
Precentral Gyrus	Right	34	0.0215	13.5	-16.5	43.5
Central Opercular Cortex	Left	34	0.0907	-61.5	-13.5	10.5
Superior Temporal Gyrus, posterior division	Left	33	0.0633	-55.5	-34.5	1.5
Temporal Pole	Right	31	0.0263	49.5	19.5	-28.5
Occipital Pole	Right	27	0.0516	16.5	-91.5	34.5
Frontal Orbital Cortex	Right	22	0.0163	46.5	31.5	-4.5
Frontal Pole	Left	21	0.0174	-28.5	55.5	25.5
Middle Frontal Gyrus	Left	20	0.0139	-43.5	22.5	34.5
Frontal Pole	Left	19	0.0174	-49.5	43.5	10.5
Frontal Pole	Left	16	0.0131	-40.5	49.5	22.5

Juxtapositional Lobule Cortex	Left	15	0.026	-1.5	4.5	67.5
Planum Temporale	Right	15	0.0675	61.5	-25.5	13.5
Frontal Pole	Left	15	0.0137	-1.5	61.5	-10.5
Right Crus I	Right	13	0.0191	22.5	-82.5	-31.5
Frontal Pole	Left	13	0.0133	-43.5	55.5	-4.5
Cingulate Gyrus, posterior division	Left	11	0.0159	-13.5	-19.5	40.5
Precentral Gyrus	Right	11	0.0111	1.5	-31.5	70.5
Supramarginal Gyrus, anterior division	Right	11	0.023	61.5	-31.5	37.5
Superior Temporal Gyrus, posterior division	Right	11	0.0677	70.5	-34.5	10.5
Superior Frontal Gyrus	Left	11	0.0142	-1.5	16.5	64.5
Lateral Occipital Cortex, inferior division	Left	9	0.0455	-49.5	-67.5	-10.5
Superior Frontal Gyrus	Left	9	0.00999	-1.5	43.5	31.5
Superior Frontal Gyrus	Left	9	0.0129	-13.5	28.5	58.5
Superior Temporal Gyrus, posterior division	Left	8	0.0508	-61.5	-25.5	-1.5
Frontal Medial Cortex	Left	8	0.00879	1.5	49.5	-7.5
Left Crus I	Left	7	0.0201	-22.5	-85.5	-31.5
Left Caudate	Left	6	0.00874	-10.5	10.5	7.5
Middle Frontal Gyrus	Left	6	0.0104	-43.5	19.5	52.5
Frontal Pole	Right	6	0.0108	31.5	64.5	7.5
Occipital Pole	Right	5	0.0218	22.5	-97.5	-13.5
Precentral Gyrus	Right	5	0.0118	10.5	-31.5	73.5
Superior Temporal Gyrus, anterior division	Right	5	0.0377	58.5	-1.5	-13.5
Frontal Orbital Cortex	Right	5	0.00857	46.5	25.5	40.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

Table 2.17. High-high PWB negative valence film > high-high PWB positive valence film cluster table.

Anatomical Location	**Hemisphere**	**# of Voxels**	**MAX *r***	**MAX x**	**MAX y**	**MAX z**
Occipital Pole	Left	28	0.0736	-7.5	-100	4.5

Superior Temporal Gyrus, posterior division	Right	17	0.105	67.5	-16.5	4.5
Lateral Occipital Cortex, inferior division	Left	14	0.103	-46.5	-82.5	4.5
Lateral Occipital Cortex, superior division	Right	13	0.0395	28.5	-61.5	52.5
Precentral Gyrus	Left	13	0.039	-55.5	1.5	43.5
Superior Temporal Gyrus, posterior division	Left	12	0.0708	-70.5	-19.5	1.5
Occipital Pole	Left	11	0.0609	-25.5	-97.5	-4.5
Lateral Occipital Cortex, inferior division	Left	10	0.0487	-40.5	-85.5	-13.5
Planum Temporale	Left	10	0.0937	-64.5	-19.5	7.5
Lateral Occipital Cortex, inferior division	Right	10	0.0725	46.5	-82.5	4.5
Occipital Pole	Left	8	0.057	-22.5	-100	-10.5
Occipital Pole	Left	7	0.0442	-16.5	-104	7.5
Temporal Occipital Fusiform Cortex	Right	7	0.0224	46.5	-46.5	-22.5
Superior Temporal Gyrus, anterior division	Left	6	0.142	-64.5	-7.5	4.5
Temporal Occipital Fusiform Cortex	Left	5	0.0137	-40.5	-52.5	-22.5
Occipital Pole	Right	5	0.0432	13.5	-104	13.5

Coordinates in MNI space. Only clusters with five or more voxels reported.

2.4.4 Discussion

This study sought to examine differences in how individuals with comparative high PWB produce neural synchrony in response to a negative valence and positive valence film. To do so, we separated participants into group consisting of individuals with comparative high PWB who watched a positive valence film (*500 Days of Summer*; Webb, 2009) and group consisting of individuals with comparative high PWB who watched a negative valence film (*Citizenfour*; Poitras, 2014). We ran ISC analysis and used LME modelling to visualize how neural synchrony differs between each group. Neural activity is sensitive to the nature of the stimulus, and results from this study provide support that higher levels of PWB modulate the response to a positive valence and negative valence stimulus differently.

Consistent with our hypothesis, we found significantly greater neural synchrony across the frontal, parietal, and temporo-occipital cortices in individuals with higher PWB who watched the positive valence film compared to the negative valence film. Individuals with higher PWB had heightened neural synchrony in several regions involved in narrative processing, including the bilateral TPJ, bilateral SPL, and bilateral intraparietal sulcus, regions that not only have implications alone for narrative processing, but also comprise the dorsal attention network (DAN; Spreng et al., 2017). The DAN is a bilateral network that focuses human attention (Farrant & Uddin, 2015), and may be recruited in individuals with higher PWB, as mindfulness, characterized by purposeful control of attention (Brown et al., 2007), is highly positively correlated with PWB (Huang et al., 2021). ISCs in the SPL are associated with engagement in the film (Jääskeläinen et al., 2020), therefore, individuals with higher PWB may have found the positive film to be more engaging, reflected by heightened synchrony in the SPL. In turn, the DAN showed heightened synchrony, possibly due to the increased attentional capacity in response to the positive valence stimulus. The bilateral precuneus also demonstrated heightened neural synchrony in response to the positive valence film, and as ISC in the precuneus reflects narrative sense-making, this may indicate that individuals with higher PWB process positive valence narratives more coherently. Individuals with higher PWB also had heightened neural synchrony in higher level visual and auditory processing areas, including the bilateral STG, lingual gyrus, right planum temporale and medial temporo-occipital cortices, indicating that individuals with higher PWB processed the higher order visual and auditory components of the positive valence film more similarly than the negative valence film.

When examining regions that showed greater neural synchrony for the negative valence film than the positive valence film, we found that individuals with higher PWB showed heightened neural synchrony in visual areas, including the bilateral occipital pole and LOC. This suggests that individuals with higher levels of PWB processed basic visual components of the negative valence film similarly. Individuals with higher PWB also demonstrated heightened neural synchrony in Wernicke’s area, which has been previously associated with cognitive well-being (Kong et al., 2015). It further may play a crucial role in the processing of a narrative, as Wernicke's area is an important conduit to language comprehension (Tanner, 2007), which is necessary to form a mental representation of a narrative. Higher synchronization in this area may indicate that language during the negative film was processed more similarly in participants with higher PWB, however, more research is needed to determine how the stimulus valence impacts neural synchrony in this region.

Together, results from Experiment 4 provide evidence that the valence of a complex, audiovisual stimulus modulates the neural response for individuals with high comparative levels of PWB. In individuals with higher PWB, positive valence stimulus processing produced widespread neural synchrony throughout frontal, parietal, and temporo-occipital regions, including regions involved in narrative processing and the DAN. In individuals with higher PWB, negative valence stimulus processing produced heightened synchrony in lower-level visual processing areas, including the occipital pole and LOC, as well as Wernicke’s area. Overall, these patterns of synchrony suggest that higher levels of PWB biases individuals to preferentially process positive valence stimuli, as indexed by higher ISCs across the cortex in the positive valence film than the negative valence film for this group.

CHAPTER 3: GENERAL DISCUSSION

This thesis sought to identify differences in neural synchrony related to comparative low and high levels of PWB in a more “true-to-life” paradigm. We were specifically interested in how PWB influences real-world processing in two different contexts: in response to positive valence stimuli and negative valence stimuli. To do so, we examined how neural synchrony was modulated by comparative low and high levels of PWB, and how this differed based on the emotional valence of the stimulus. Our ultimate goal was to provide insight into how PWB levels influence processing in the ‘real-world’, and how PWB influences emotional processing of both negative and positive stimuli. In Experiment 1, we assessed differences in neural synchrony based on comparative low and high levels of PWB in response to a positive valence audiovisual movie. In Experiment 2, we assessed differences in neural synchrony based on comparative low and high levels of PWB in response to a negative valence audiovisual movie. In Experiment 3, we assessed differences in how individuals with lower levels of PWB process to a positive versus negative stimulus. In Experiment 4, we assessed differences in how individuals with higher levels of PWB process a negative versus positive stimulus. Our main findings are highlighted below.

The Neural Correlates of Negative Valence Processing and Low PWB

Experiments 2 and 3 investigated the effect of negative valence stimulus processing in individuals with low comparative PWB. Consistent among Experiments 2 and 3, individuals with low PWB demonstrated heightened neural synchrony in the right planum temporale and bilateral intracalcarine cortex. The intracalcarine cortex forms a part of the primary visual cortex (Dougherty et al., 2003), and the right planum temporale serves as a computational hub for complex sounds (Griffiths & Warren, 2002). Heightened synchrony in these regions indicates that individuals with lower PWB process basic visual and higher-level auditory stimuli similarly when the stimuli have negative valence. Together, these results suggest individuals with lower PWB process basic visual and higher-level auditory components of a negative valence stimulus more similarly and can form a more coherent story representation when the valence of the stimulus is negative.

The Neural Correlates of Positive Valence Processing and Low PWB

Experiments 1 and 3 investigated how individuals with low comparative PWB process a complex, audiovisual positive valence stimulus. Lower levels of PWB were consistently associated with heightened neural synchrony in regions associated with narrative processing, including the left SPL and bilateral precuneus. The precuneus is involved in narrative sense-making, and heightened synchrony in the SPL has been shown to reflect engagement in the film (Jääskeläinen et al., 2020). Together, these results suggest that individuals with lower levels of PWB are more engaged by positive valence stimuli and can form a more cohesive mental narrative when the stimulus is positive.

Consistent among both experiments, individuals with lower levels of PWB showed heightened neural synchrony in Wernicke’s area and the left lingual gyrus in response to the positive valence film. The lingual gyrus is involved in global shape processing and visual word processing (Mechelli et al., 2000; Sohn et al., 2008). Together, our results suggest that individuals with lower PWB may process lower-level visual features more similarly, including shapes and visual words, if the valence of the incoming stimulus is positive. Wernicke’s area has been previously associated with cognitive well-being (Kong et al., 2015), though its role in PWB remains unknown. Wernicke’s area plays a role in language comprehension, and heightened synchrony in this area suggests that individuals with lower levels of PWB comprehend language more similarly if it has positive valence.

The Neural Correlates of Negative Valence Processing and Higher PWB

Experiments 2 and 4 investigated how individuals with higher PWB process negative valence audiovisual stimuli. There were no regions of the brain that had consistently heightened neural synchrony across Experiment 2 and Experiment 4 in association with a negative stimulus. These results suggest that negative valence stimuli may not modulate the neural response for individuals with higher PWB. In other words, higher levels of PWB does not appear act as an implicit prime for audiovisual processing when the incoming stimulus has a negative valence.

The Neural Correlates of Positive Valence Processing and Higher PWB

Experiments 1 and 4 investigated the effect of positive valence stimulus processing associated with higher PWB. Consistent among Experiments 1 and 4, participants with higher PWB showed widespread neural synchrony in frontal, parietal, and temporo-occipital cortices, suggesting that high PWB may act as an implicit prime for how incoming positive valence stimuli is perceived. For regions involved in narrative processing, participants with higher PWB had heightened neural synchrony in the right TPJ. The right TPJ is associated with different capacities to shift attention and to understand other’s mental states. This suggests that when the valence of the stimulus is positive, individuals with higher PWB may have a higher capacity to shift attention to events during the film and may be able to form a better representation of the character’s mental and emotional states (Krall et al., 2015).

For regions previously associated with PWB, individuals with higher PWB had heightened neural synchrony in the left OFC and bilateral STG in response to a positive valence audiovisual film. The left OFC is a region that has been previously associated with higher PWB through its role in providing reward values (Rolls et al., 2020). Results from this study support the hypothesized role of the OFC in higher PWB, however, they suggest that the valence incoming stimulus may modulate its effect, with individuals with higher PWB demonstrating heightened neural synchrony in the OFC in response to positive valence stimuli. The STG is a region that has both been previously associated with PWB (King, 2019) and narrative processing (through its involvement in semantic activation, integration, and selection; Benedetti et al., 2015). These results suggest that higher levels of PWB may reflect an enhanced ability to build a coherent story representation when that story is of positive valence.

Lastly, in individuals with higher PWB, the right planum temporale showed heightened neural synchrony in response to a positive valence film. Of particular interest, across all four experiments, the right planum temporale consistently showed heightened neural synchrony in participants with higher PWB in response to a positive valence film but heightened neural synchrony in participants with lower PWB in response to a negative valence film. These results suggest that the right planum temporale may have a mediating role in the processing of a positive or negative valence stimulus, and this role may be dependent on the level of PWB. The right planum temporale has not been studied directly in association with PWB, and these findings emphasize the need for more research into its role in PWB and narrative processing.

Current Study Findings and Previous PWB Research

This thesis extends research focusing on examining the neural correlates of PWB. Our novel approach of using naturalistic stimuli and examining how valence alters the neurological response to incoming stimuli based on level of PWB offers valuable insight not only into the neural correlates of PWB, but also how context can alter brain responses based on differing levels of PWB. Previous research has generally employed resting-state fMRI (Luo et al., 2016;

Kong et al., 2015) or structural MRI investigating gray matter density (Lewis et al., 2014; Matsunaga et al., 2016; Sato et al., 2015), limiting the ability to apply results to real-life paradigms. In contrast, the experiments in this thesis used a naturalistic paradigm that is more representative of real-life processing. Further, the experiments in this thesis investigated differences in how PWB modulates the brain based on different contexts, taking into account the real-life complexities of stimulus processing.

Our results also have important implications for understanding disorders in part characterized by low levels of PWB, including mental health disorders, such as major depressive disorder. Our research contributes to the understanding of how PWB influences neural processes, potentially providing insights into the underlying mechanism of this disorder. Further, these results have implications for improving physical health outcomes, as higher PWB is associated with reduced cortisol output (Steptoe et al., 2005; Chida & Steptoe, 2008), immune regulation (Winefield et al., 2012), reduction in inflammatory markers (Steptoe et al., 2012), and greater physical activity levels. By contributing to the understanding of the differences in the brain between comparative low and high PWB, this research can provide a foundation for future investigations on the link between PWB and physical health. While these results do not provide evidence of a singular PWB model in the brain, they bridge the gap between the past inconsistent PWB literature and real-world processing, providing a starting point for investigating real-world PWB interventions that could in turn increase physical and mental health outcomes.

Limitations and Future Directions

This thesis aimed at uncovering differential neural synchrony associated with varying levels of PWB levels during movie watching, however, there are several limitations to be discussed. Due to the use of an online database, we were unable to have control over the stimuli that were presented to participants. This introduces a limitation as previous literature suggests that the valence of the stimulus may alter the neural response based on levels of PWB. As the database utilized has only two films with a sample size larger than $n = 6$, we were limited to only two plausible choices when determining which film would be used as our stimulus. Further, while the films used had the largest sample size within the NNDb, the sample sizes in this study are still relatively small and this study should be replicated in a larger sample. The authors of the NNDb additionally did not collect ratings from participants about their subjective experiences during the film, preventing us from incorporating information from participants about their emotions felt during the film. Further, PWB is likely influenced by context beyond the positive/negative valence context discussed here, and it would be beneficial to include a neutral stimulus for comparison. Additionally, the data used in these experiments was collected using a 1.5T MRI, which has a lower signal-to-noise ratio and a lower spatial specificity than MRIs with a stronger field strength. Thus, these findings should be replicated using higher field strengths to acquire such data. Future research should aim at replicating the study but using different positive and negative valence films to rule out movie-specific synchrony. Further, more complex emotions should be studied in association with PWB to further determine the role of contexts in the modulation of neural activity by PWB.

Conclusion

In conclusion, this thesis unveiled distinctive neural patterns distinguishing individuals with comparative low and high PWB and revealed that these neural patterns may be modulated by the valence of the incoming stimulus. Across four studies, distinctive neural patterns emerged in regions previously associated with PWB and narrative processing, and these patterns were modulated by both PWB level and stimulus valence. We further uncovered novel regions of the brain consistently associated with lower PWB, such as Wernicke’s area and the right planum temporale, and concluded that these regions may play a crucial role in the modulation of neural responses by low comparative levels of PWB. Higher PWB may further be associated with heightened neural synchrony across wide expanses of the cortex, including parietal, frontal, and temporo-occipital cortices in response to positive valence stimuli, whereas higher PWB did not show any consistent synchronous regions in response to negative valence stimuli. The findings collectively emphasize that PWB impacts naturalistic processing and serves as an implicit prime for how we perceive the world, with higher levels of PWB biasing individuals to preferentially process positive valence stimuli. By contributing to the understanding of the neurological differences between comparative low and high PWB, as well as how context modulates these differences, this thesis provides a starting point for investigating the neuroprotective role of PWB and for uncovering the links between PWB, physical health, mental health, and cognitive health.

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