About psychotic-like experiences and auditory verbal hallucinations

Transdiagnostic investigations of neurobiological, cognitive, and emotional aspects of a continuous phenomenon

Mag. Isabella Kusztrits, BA

Thesis for the degree of Philosophiae Doctor (PhD)
University of Bergen, Norway
2021

UNIVERSITY OF BERGEN

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Date of defense: 19.03.2021

Year: 2021

Title: About psychotic-like experiences and auditory verbal hallucinations

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Print: Skipnes Kommunikasjon / University of Bergen

Scientific environment

As a PhD candidate, I was employed at the Department of Biological and Medical Psychology at the University of Bergen, and a member of the FLaSH group, which is part of the Bergen fMRI group, University of Bergen. As a student I was part of the International Graduate School of Integrated Neuroscience (IGSIN) at the Faculty of Psychology at the Universiy of Bergen and the NORMENT Norwegian Centre for Mental Health Research, which is part of the University of Bergen and the University Hospital Haukeland.

My supervisor for this project was Professor Marco Hirnstein, who is affiliated with the Department of Biological and Medical Psychology at the University of Bergen, group leader of the FLaSH group, member of the Bergen fMRI group, at the University of Bergen, and also member of the NORMENT Centre of Excellence, University of Oslo. My co-supervisor was Professor Kristiina Kompus, also affiliated with the Department of Biological and Medical Psychology at the University of Bergen, the Bergen fMRI group, the NORMENT Norwegian Centre for Mental Health Research, University of Bergen & University Hospital Haukeland, as well as the Institute of Psychology, at the University of Tartu in Estonia.

For a period of three months, I visited the research lab of Professor Susan Rossell, who is affiliated with the Centre for Mental Health, at Swinburne University of Technology, in Melbourne, Australia.

The research for this project was funded by grants to Marco Hirnstein from the Bergen Research Foundation, Norway (BFS).

Acknowledgements

I am very grateful for all the people I met along the way since my first day here in Bergen.

The biggest thank you goes to Marco, for his constant support and his open ear whenever I needed it. Without him, this thesis would not be as it is now. He always found the right balance between pushing me towards extending my potential and keeping me motivated at the same time. I am very grateful that I had the opportunity to have him as my “Doktorvater”.

The last four years would not have been the same without the rest of the FlaSH team. Thank you, Anne, and Lynn, for the good teamwork in all matters. Especially Lynn, who became not only a colleague, but most of all a friend. Writing our PhD at the same time has made us share a lot of experiences. Thank you for being who you are. Most of our Fridays, we spent at the Radiology department. Thank you to all of you for productive and cheerful session.

I also want to thank Susan and her team in Melbourne, for welcoming me so kindly on the other side of the planet. This research stay made me grow in so many ways.

Another big thank you goes out to my mentors, co-authors, and colleagues, who were involved in all stages of the projects, from planning and data collection to analyzing and writing the articles, and also this thesis. Your feedback was very valuable and highly appreciated.

Working towards this PhD made me aware how important balance is. I want to thank all my friends, here in Bergen, in Austria and the rest of the world. Thank you for being there in times of great challenges. Your joy and support helped me to keep my feet on the ground.

Most importantly I want to thank my family. Danke für eure unendliche Liebe und Unterstützung. Ohne euch würde ich heute nicht hier sein. Ich hab euch lieb!

Abstract

Hallucinations and delusions are known to be key symptoms of psychotic disorders, such as schizophrenia, and have been studied extensively. However, these experiences also occur in other mental disorders, which suggests a transdiagnostic perspective with shared underlying cognitive mechanisms across various psychological illnesses. In addition, hallucinations and delusions are continuous phenomena that occur not only in patients with mental disorders, but also in healthy individuals in the general population, spanning from childhood to adulthood. To understand the development and maintenance of such psychotic-like experiences (PLEs) in general, and auditory verbal hallucinations (AVHs) specifically, neurobiological, cognitive, and emotional factors need to be taken into consideration. The aim of this thesis is to examine these factors by investigating underlying brain mechanisms of inner speech processes, the impact of emotions, and core schemas about the self and others in different groups of individuals along the continuum from healthy individuals to voice hearers with different underlying disorders.

In paper 1, we investigated PLEs in Norway in a sample from the general population, using the screening questions of the Questionnaire for Psychotic Experiences (QPE), an interview that captures the presence and phenomenology of various psychotic experiences separately. Participants with mental disorders reported more frequent lifetime and current hallucinatory experiences than participants without mental disorders, with childhood experiences being rather low. We further replicated findings that young age, illegal drug use, lower level of education, and having parents with a mental disorder are associated with higher endorsement rates of PLEs. Finally, we revealed that the mere presence of PLEs does not discriminate between individuals with and without a mental disorder. Taken together, the findings of paper 1 support existing models that both hallucinations and delusions exist on a structural and phenomenological continuum.

In paper 2, we investigated neurobiological factors of cognitive inner speech processes by using a neurostimulation method called transcranial direct current stimulation

(tDCS) to modulate source monitoring abilities in healthy individuals. We modulated reality monitoring (distinguishing between external and internal sources) and internal source monitoring abilities (distinguishing between two or more internal sources). We found that internal source monitoring abilities were significantly enhanced during active online tDCS, while reality monitoring abilities were unaffected by stimulation. Our findings suggest that there are different brain areas involved in reality and internal source monitoring: Internal source monitoring seems to involve Broca's area. Reality monitoring, however, seems to rely more on the superior temporal gyrus (STG) and the dorsolateral prefrontal cortex (DLPFC) as shown in other studies.

In paper 3, we focused on cognitive and emotional aspects of AVHs, namely the impact of emotions and affect on AVH phenomenology in non-clinical and different clinical populations. Depending on the underlying psychopathology, these phenomena show different phenomenological aspects. Our aim was to determine the mediating roles of anxiety and depression in the relationship between positive and negative core schemas about the self and others, and emotional aspects of AVHs for three groups: non-clinical voice hearers, affective voice hearers, and non-affective voice hearers. Results showed full mediating effects of anxiety in affective voice hearers in the relationship between negative core schemas and all phenomenological aspects, but not in non-affective voice hearers. Depression was not a mediator in any of the groups. These findings suggest different emotional mechanisms for different groups of voice hearers, depending on the underlying psychopathology of individuals with AVHs.

Overall, we conclude that the findings support a continuous and transdiagnostic perspective of PLEs in general, and AVHs specifically. However, more integrative transdiagnostic investigations in different groups of individuals along the continuum are needed as studying AVHs in only one modality or one clinical population is unlikely to bring us closer to understanding how these phenomena develop in the first place.

List of Publications

Kusztrits, I., Larøi, F., Laloyaux, J., Marquardt, L., Sinkeviciute, I., Kjelby, E., Johnsen, E., Sommer, I. E., Hugdahl, K. & Hirnstein, M. (2020). Mapping psychotic-like experiences – results from an online survey. *Scandinavian Journal of Psychology*, DOI: 10.1111/sjop.12683

Kusztrits, I., Marquardt, L., Hugdahl, K. & Hirnstein, M. (2020). Transcranial direct current stimulation (tDCS) enhances internal source monitoring abilities in healthy individuals. Submitted to *Journal of Cognitive Neuroscience*. 21.10.2020

Kusztrits, I., Toh, W. L., Thomas, N., Larøi, F., Hirnstein, M. & Rossell, S. (2020). From core schemas about the self and others to voice phenomenology: anxiety and depression affect voice hearers differently. Submitted to *Psychology and Psychotherapy: Theory, Research and Practice.* 7.9.2020

Reprints of "Mapping psychotic-like experiences – results from an online surve" *are presented with permissions granted through open access publishing.*

List of abbreviations

af-VHs	Affective voice hearers
ANOVA	Analysis of Variance
AVHs	Auditory verbal hallucinations
BAI	Beck Anxiety Inventory
BAVQ-R	Beliefs about Voices Questionnaire - revised
BCSS	Brief Core Schema Scales
BCSS-NS	Brief Core Schema Scales, negative self subscale
BCSS-PS	Brief Core Schema Scales, positive self subscale
BCSS-NO	Brief Core Schema Scales, negative other subscale
BCSS-PO	Brief Core Schema Scales, positive other subscale
BDI-II	Beck Depression Inventory II
CAPS	Cardiff Anomalous Perceptions Scale
CI	Confidence interval
DLPFC	Dorsolateral prefrontal cortex
fMRI	Functional magnetic resonance imaging
naf-VHs	Non-affective voice hearers
nc-VH	Non-clinical voice hearers
PCA	Principal component analysis
PDI	Peters Delusion Inventory

PFC	Prefrontal cortex
PLEs	Psychotic-like experiences
QPE	Questionnaire for Psychotic Experiences
ROC	Receiver operating characteristic curve
RSA	Resilience Scale for Adults
SCS	Self-Compassion Scale
STG	Superior temporal gyrus
tDCS	Transcranial Direct Current Stimulation
TP1	Timepoint 1
TP2	Timepoint 2
TPJ	Temporo-parietal junction

Contents

1. Theoretical Background

In recent years, a transdiagnostic view of mental disorders has gained support, which proposes that different disorders share common underlying processes (Mansell et al., 2008). This has also been suggested for psychotic disorders with key symptoms of hallucinatory and delusional experiences (van Os & Reininghaus, 2016). These experiences are continuous in nature and occur not only in patients with mental disorders, but also in the general population (Reininghaus et al., 2016).

Auditory verbal hallucinations (AVHs) in particular put individuals into a vulnerable state, as they have a huge impact on functioning in everyday life. This is due to the distress caused by negative content of their voices, which can even take the form of commands to harm themselves and others (Larøi, Thomas, et al., 2019).

The aim of this thesis was to examine neurobiological, cognitive, and emotional aspects that are theorized to play a role in AVHs. By investigating this phenomenon from a combined continuous and transdiagnostic perspective, that is, examining different underlying processes of AVHs in different non-clinical and clinical populations, the goal is to gain a more comprehensive understanding of the mechanisms that underlie PLEs in general and AVHs in particular.

First, a continuous and transdiagnostic approach to psychotic-like experiences (PLEs) in general, and AVHs specifically will be introduced. Afterwards, the underlying neurobiological mechanisms of AVHs are described, focusing on local brain activation patterns which can be modulated by a neurostimulation technique called transcranial direct current stimulation (tDCS). This is followed by examining cognitive and emotional aspects that are known to be involved in the development and maintenance of AVHs, including source monitoring, the influence of emotions on AVHs and its phenomenology, and core schemas about the self and others.

1.1. Transdiagnostic approach

The transdiagnostic approach to psychological disorders suggests that cognitive and behavioural processes, which are responsible for maintaining individual symptoms, are shared to various degrees across different disorders (Mansell et al., 2008). This approach has been applied to psychosis as well (van Os & Reininghaus, 2016), and is supported by the fact that a lot of individuals with hallucinatory and delusional experiences have a mental disorder that is not psychotic in nature, for example mood disorders, Alzheimer disease, migraine, hearing loss or borderline personality disorder (Baryshnikov et al., 2018; Linszen et al., 2016; Linszen et al., 2018; Merrett et al., 2016; Vreeburg et al., 2016). Viewing symptoms as separate processes across different disorders can help generalize and transfer knowledge to a broad range of disorders (Mansell et al., 2008). In AVHs for example, most research has been done in patients with schizophrenia. By shifting the focus to a symptom-level and including research in other clinical and also non-clinical populations, we gain a clearer picture of AVHs as a phenomenon per se, since confounding variables, such as comorbidity with other disorders, underlying symptoms and cognitive deficits are prevalent in patients with schizophrenia and prevent a clear assessment of AVHs per se. In addition, this knowledge transfer can inform and extend existing models, that may assist in developing treatment which is effective across several comorbid disorders. This notion is supported, for example, by the observation that when one disorder is treated with cognitive behavioural therapy comorbid disorders also improve (Mansell et al., 2008).

1.2. Continuum hypothesis

The transdiagnostic approach of psychosis shares common ground with the continuum hypothesis, which states that psychotic-like experiences (PLEs) increase in symptom severity and persistence from healthy individuals to patients with a diagnosis of schizophrenia (Baumeister et al., 2017; Linscott & van Os, 2013).

Linscott and van Os (2013) describe three ways in which this continuum can be understood: (1) structural continuity relates to the distribution of psychotic experiences in the general population; (2) temporal continuity refers to the idea that psychotic experiences persist over time; and (3) phenomenological continuity describes the idea that psychotic experiences are independent of disorder and only differ quantitatively from dispositional or personality variables captured by the notion of psychosis-proneness or schizotypy (see also Daalman et al., 2011).

Over time, PLEs have the potential to become persistent and cause a transition to a mental disorder. In the long run, having PLEs predicts greater illness severity and poorer treatment response (van Os & Reininghaus, 2016). However, if the concept of phenomenological continuity is correct, then both individuals with and without mental disorders should exhibit PLEs and the mere presence of PLEs should not allow distinguishing between individuals with and without mental disorders.

But what exactly is a PLE? How often do they occur? And how are they assessed?

1.3. Psychotic-like experiences (PLEs)

1.3.1. Definition

Formally, PLEs are defined as being hallucinations and/or delusions that do not fulfil diagnostic criteria for a mental disorder (Linscott & van Os, 2013). The scientific literature uses many different terms to label them, such as “unusual experiences”, “subthreshold psychotic experiences”, “putative pre-psychotic states”, “subclinical psychotic experiences”, “sub-psychotic experiences” or “putative prodromal states” (e.g. Bourgin et al., 2019; Cella et al., 2012; Jolley et al., 2018; Koyanagi et al., 2016; Liu et al., 2013; Wigman et al., 2011). As these phenomena are known to be present in the general population (i.e., structural continuity) (Kelleher & Cannon, 2011), it is important to reduce the stigma around them (Daalman et al., 2016; Kingdon et al., 2008; Sommer et al., 2010), to make people aware and enable them to share their

experiences, since early detection of a shift from a non-clinical to a clinical state is a key factor in the treatment of psychotic disorders, such as schizophrenia (Sommer et al., 2012). Therefore, in this document the term "psychotic-like experiences" (PLEs) will be used henceforth, as it is also used by most studies in the field and helps to reduce the stigma associated with these phenomena.

1.3.2. Prevalence & predictors

PLEs have been found to have a median lifetime prevalence of 7.2% in the general population (Linscott & van Os, 2013), and are associated with more general medical conditions in adults (e.g., asthma or chronic pain, Scott et al., 2018), as well as several sociodemographic predictors. Being female, young age, unemployment, secondary educational level, low family income, use of alcohol and recreational drugs, stressful and traumatic events, higher level of urbanicity, and a family history of mental disorder increase the odds of having PLEs (Bourgin et al., 2019; Khaled et al., 2019; Linscott & van Os, 2013; Pignon et al., 2018).

The prevalence of PLEs has also been reported in children between 9 and 11 years (66%; Laurens et al., 2012) and adolescents between 16 and 19 years (10.6%; Kompus et al., 2015). Thapar et al. (2012) reported that the frequency of PLEs decreased over time in the transition from childhood (11% at 13 years) to adolescents (5% at 16 years). But while some suggest that PLEs are normal childhood experiences that do not persist into adulthood (Kelleher & Cannon, 2011), other studies found that childhood PLEs can persist into adolescence (Gutteridge et al., 2020), and can create a need for care in the future (Bartels-Velthuis et al., 2016; Maijer et al., 2017; Maijer et al., 2019).

In the literature, usually *either* children/adolescents *or* adults are assessed with respect to PLEs, and longitudinal studies spanning from childhood to adulthood are rare. Moreover, adult participants are often asked to report their lifetime PLEs, but there are no specific instructions whether these include childhood PLEs. Thus, it is unclear whether the PLEs described by adults were "merely" childhood/adolescence

experiences that can be attributed to immaturity or whether they were exclusively experienced during adulthood. To our knowledge, this has not been investigated before.

1.3.3. Assessment of PLEs

Typically, PLEs are assessed with interviews or self-rating questionnaires. However, most instruments do not capture the full spectrum and phenomenology of PLEs. Instruments either focus on only one hallucination modality, like auditory hallucinations (e.g., PSYRATS; Haddock et al., 1999) or on one delusional theme, like paranoia (e.g., Green et al. Paranoid Thoughts Scale; Green et al., 2008); or they provide global scores for hallucinations (e.g., Positive and Negative Syndrome Scale; Kay et al., 1987) and delusions without rating individual themes (e.g., Neuropsychiatric Inventory; Cummings, 1997).

To overcome these shortcomings, the Questionnaire for Psychotic Experiences (QPE; Rossell et al., 2019; Sommer et al., 2018) was developed. It is in line with the continuous and transdiagnostic approach outlined above: It can be applied to assess PLEs not only across different patient populations but also in the general population (for details see Rossell et al., 2019). It aims to cover a wide range of PLEs, including hallucinations in different modalities (auditory, visual, tactile, olfactory) and common types of delusions (persecution, reference, guilt, control, religiosity, grandeur, nihilism, misidentification, and somatic delusions). Moreover, the items of the QPE are phrased openly to capture the scope of individuals' experiences with the aim to reduce the stigma that is connected to PLEs.

The QPE was originally conceived as a full interview. This allows assessing detailed phenomenological information but is also time and resource consuming. For this reason, Sommer and colleagues (2018) provided a short QPE screening questionnaire that only asks about the *presence* of hallucinatory and delusional experiences. However, although the QPE screening questionnaire has already been used as a self-report questionnaire (Begemann et al., 2019) and to group participants in

terms of presence/frequency of PLEs (de Boer et al., 2019), only the full QPE interview has been validated in a patient population so far (Rossell et al., 2019).

1.4. Auditory verbal hallucinations (AVHs)

From all PLEs, AVHs are the most common hallucinatory experiences that occur in psychotic disorders (American Psychological Association, 2013). They are experienced as distressing and have a high impact on affected peoples' lives. The Diagnostic and Statistical Manual of Mental Disorders (DSM 5; American Psychological Association, 2013) describes AVHs as one of the first-rank symptoms of schizophrenia and defines them as verbal "*perception-like experiences that occur without an external stimulus*" (p.87) which are "*usually experienced as voices, whether familiar or unfamiliar, that are perceived as distinct from the individual's own thoughts"* (p.87). These AVHs can differ with regards to their perceived acoustic properties, the number, identity, and frequency of the heard voices. In addition, clarity, content, perceived controllability, distress, and emotional valence (positive vs. negative) can also lead to different AVH experiences that are suggested to form different subtypes (McCarthy-Jones, 2012; McCarthy-Jones et al., 2014). For example, voice experiences can occur on a spectrum from whispering to shouting, they might be perceived as very real or not real at all, individuals might recognize the male or female voices that they hear, with the content being malevolent and negative, or beneficial and supportive (McCarthy-Jones, 2012; Moritz & Larøi, 2008; Nayani & David, 1996). But even though there is a wide phenomenological variation of AVHs between voice hearers with and without mental disorders (McCarthy-Jones, 2012), there are more similarities than differences (Waters & Fernyhough, 2017). While non-clinical voice hearers have less frequent AVHs, with less negative content, more perceived control and fewer affective difficulties (Baumeister et al., 2017), it is likely the experienced distress that accompanies those voices that predicts a transition to clinical mental health difficulties (Baumeister et al., 2017; Garety et al., 2007; McCarthy-Jones, 2012).

To understand the development and maintenance of AVHs entirely, it is important to look at several "levels of explanation", where knowledge from one level informs predictions of another: neurobiological aspects include molecular (e.g., genes, proteins), cellular (e.g., synapses, neurotransmitters), and functional levels (e.g., networks, neuronal systems), that inform cognitive (e.g., perception, language), emotional, clinical (e.g., symptoms, diagnosis), and social explanations (e.g., beliefs, norms, culture) (Hugdahl & Sommer, 2018). In the following sections, neurobiological aspects are outlined with a focus on functional brain activity patterns and supportive evidence from neurostimulation techniques, followed by cognitive and emotional aspects including source monitoring, the influence of emotions and affect, and core schemas about the self and others.

1.4.1. Neurobiological aspects of AVHs

At the molecular and cellular level, neurotransmitter systems for glutamate, gamma-aminobutyric acid (GABA), and dopamine have been shown to be dysfunctional and imbalanced (Lisman, 2012), which forms the basis for antipsychotic medication treatment of AVHs (Sommer et al., 2012). These basic processes are also causing changes on a functional level (Lisman, 2012).

AVHs are connected to a range of network activations in the brain, which involves many areas of left and, to a lesser extent, right hemispheres. These networks are involved in all stages of language from prelexical auditory processing to semantic, syntactic, and articulatory processes of language comprehension on both single-word and sentence levels (Falkenberg et al., 2020; Mody, 2017; Price, 2010; Weber et al., 2020; Zmigrod et al., 2016). In people affected by AVHs, these speech production and speech perception processes are often dysfunctional due to a putative disruption between Broca's area and Wernicke's area. However, as AVHs are phenomena of multiple components a broader brain network is involved (Alderson-Day & Fernyhough, 2015; McCarthy-Jones, 2012) that can also affect motor-sensory areas (Mathalon & Ford, 2008).

In their review, Allen and colleagues (2008) argued that experiencing AVHs is associated with *"reduced grey matter volumes in the temporal cortex, stronger activation in subcortical centres, reduced control by the dorsolateral prefrontal cortex, aberrant activation from emotional attention centres (rostral/ventral anterior cingulate), and attenuated activation of the dorsal anterior cingulate, supplementary motor area and cerebellum which are thought to be involved in monitoring processes."* (p. 187). Therefore, several authors (Allen et al., 2008; Hugdahl, 2009, 2015; Jones, 2010) propose a model of AVHs that involves a cortical and subcortical network including left temporal, parietal and prefrontal areas of the brain. While the left superior temporal gyrus (STG) is known to be involved in speech perception processes in healthy individuals (Obleser & Eisner, 2009), and in both vivid imagery and during AVHs (Kompus et al., 2011; Zvyagintsev et al., 2013), the prefrontal and anterior cingulate cortex are involved in top-down inhibitory control processes (Braver et al., 2002). Within this malfunctioning *hyper*temporal/*hypo*frontal network circuit, spontaneous neuronal activity (Hunter et al., 2006) is hypothesized to prime sensory areas in the temporal cortex to "over-perceptualize" (Allen et al., 2008). These bottom-up driven perceptual phenomena lead to an attentional shift towards AVHs (i.e., that are represented in the cingulate cortex), which in turn contribute to reinforce AVHs over time and create a self-perpetual loop (Hugdahl, 2015). These AVHs cannot be inhibited effectively due to an altered connectivity to *hypo*active prefrontal areas. In clinical voice hearers, both bottom-up and top-down processes are malfunctioning because of a disconnection between these regions (Geoffroy et al., 2014; McCarthy-Jones et al., 2015), therefore making it very difficult to cope cognitively with the salient perceptual experiences. On the other hand, healthy voice hearers have intact prefrontal inhibitory control functions, which allows them to exert top-down control to inhibit bottom-up perceptual impulses and to shift their attention away from the AVHs (Allen et al., 2008; Hugdahl, 2009, 2015). Support for this model also comes from studies using neurostimulation techniques to treat AVHs, which will be introduced in the following section.

1.4.2. Neurostimulation as treatment strategy

Neurostimulation techniques, such as repetitive transcranial magnetic stimulation (rTMS) and tDCS are used to modulate brain activity and are increasingly used as an alternative treatment for medication-resistant AVHs. rTMS uses rapidly changing electrical fields that are created via a ferromagnetic coil which is placed above the scalp. Depending on the frequency of these changes, the induced magnetic field can reduce the excitability of a targeted region (Hoogendam et al., 2010). Slotema et al. (2014) concluded in their review that rTMS is an effective treatment for AVHs, as it reduces their severity also in individuals who are resistant to psychopharmacological treatment. In comparison to rTMS, tDCS uses a constant, electrical current which modulates resting membrane potentials in neurons, resulting in altered cortical excitability and spontaneous cortical activity. Using two electrodes, the anode typically has an excitatory effect on the cortex below, while the cathode typically has an inhibitory effect (Nitsche et al., 2008). Based on the above mentioned hypertemporal/hypofrontal model, the aim of the tDCS treatment is to reverse this behavioural pattern, by increasing cortical excitability in frontal regions and decreasing excitability in auditory cortices (see Figure 1). However, the findings are not consistent. While several randomized control trials have confirmed that real tDCS leads to a decrease in AVHs compared to sham tDCS (Bose et al., 2018; Brunelin et al., 2012; Kantrowitz et al., 2019; Lindenmayer et al., 2019; Mondino et al., 2015), others could not replicate these findings (Fitzgerald et al., 2014; Fröhlich et al., 2016; Koops et al., 2018). In addition, other studies reported a reduction in other symptoms than AVHs (Chang et al., 2018; Gomes et al., 2015; Palm et al., 2016; Smith et al., 2015). These contradictory findings indicate that there is too little evidence for a final conclusion about the effectiveness of tDCS treatment on AVHs (Hasan et al., 2016; Kubera et al., 2015; Mondino et al., 2018; Nathou et al., 2019; Nieuwdorp et al., 2015; Pondé et al., 2017). Furthermore, the excitatory and inhibitory effect of the anodal and cathodal electrode has been challenged (Samani et al., 2019), which adds another level of complexity to the mechanisms of tDCS, as changes in electrode position, current

density, stimulation duration, electrode size, and configuration parameters can lead to different effects (Kuo et al., 2016).

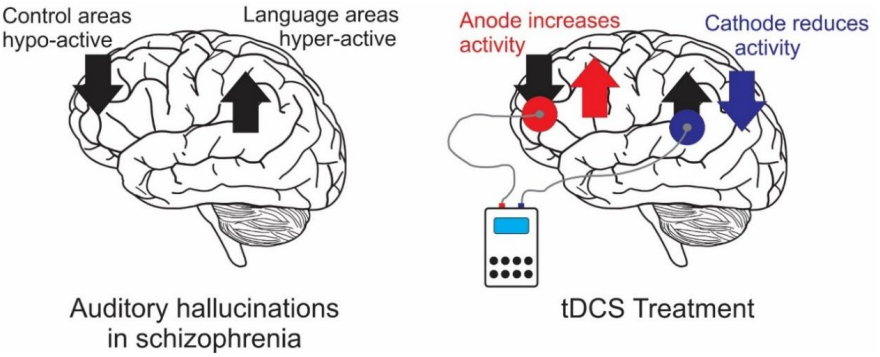


Figure 1. Reversing the hypertemporal/hypofrontal model of AVHs with tDCS (adapted from Hugdahl, 2009)

It has also been suggested that tDCS treatment can correct an abnormality of the so-called corollary discharge mechanism in patients with schizophrenia (Nawani et al., 2014). This process enables us to unconsciously identify and disregard sensations that result from our own actions. According to theoretical views on corollary discharge, when we plan to speak, speech production commands are sent to motor-sensory areas for their execution, and an 'efference copy' of these commands is sent to the auditory cortex to prepare it for the imminent arrival of self-generated sounds. When this plan and the 'efference copy' match, then we identify the produced sounds as coming from ourself (Mathalon & Ford, 2008). However, when the plan and the "efference copy" do not match, inner speech can be misattributed towards external sources (Jones & Fernyhough, 2007b; McCarthy-Jones, 2012). This misinterpretation is also referred to as source monitoring, and can not only be described on a neurobiological, but also on a cognitive level.

1.4.3. Cognitive and emotional aspects of AVHs

Source monitoring. Source monitoring, or source memory, has its roots in inner speech models of AVHs, which suggest that AVHs originate from a deficit in monitoring one's own inner dialogue and thoughts, and recognizing inner speech as not being self-produced (Alderson-Day & Fernyhough, 2015; Larøi & Woodward, 2007; McCarthy-Jones, 2012). This misattribution can be classified in three categories: (1) external source monitoring means distinguishing between two or more external sources (e.g., "I heard that story on the radio, not the TV"); (2) internal source monitoring means distinguishing between two or more internal sources (e.g., "I remember telling you that story, but I actually only thought about telling you."); and (3) reality monitoring means distinguishing between external and internal sources (e.g., "I created that story myself, and did not hear it from someone else.") (Johnson et al., 1993; Johnson & Raye, 1981; Mitchell, 2017; Mitchell & Johnson, 2009).

Both reality and internal source monitoring deficits have been associated with patients with schizophrenia (Brunelin, Combris, et al., 2006). Clinical voice hearers show a tendency to attribute inner speech processes to external sources (i.e., a deficit in reality monitoring) (Waters et al., 2012), and a tendency towards classifying imagined thoughts as verbalized thoughts (i.e., a deficit in internal source monitoring) (Henquet et al., 2005). As an alternative to the corollary discharge model, deficits in both reality and internal source monitoring are also suggested to originate from vivid mental images (Aleman et al., 2003) that are more likely to become misattributed as coming from the outside (Johnson et al., 1993).

The biological basis of source monitoring processes lies in brain areas that are largely overlapping with those involved in AVHs (see section 1.4.1). Sugimori et al. (2014) found that the STG was involved when participants misattributed verbal information as coming from external sources, even though it was internally generated. This activity in the STG was correlated with the tendency to experience AVHs (Sugimori et al., 2014). In healthy individuals, auditory cortical regions, including the STG, showed increased activity when they were listening to speech derived from

external sources, while inner speech did not elicit increased activity in these regions (Allen et al., 2007; Simons et al., 2010). On the other hand, source confusions were associated with reduced activation in the PFC, both in healthy people and in patients with schizophrenia (Simons et al., 2006).

Support for the involvement of these brain areas also comes from treatment studies that use neurostimulation techniques. Brunelin, Poulet, et al. (2006) actively stimulated the left temporoparietal cortex for 5 days, with 2 sessions per day, with rTMS in patients with schizophrenia and found not only a reduction of AVHs, but also an improvement of internal source monitoring abilities *"as attested by patients' increased ability in identifying self-generated items as having come from themselves"* (p. 43). There was also a trend towards the improvement of misattributing imagined words as being spoken aloud. However, this was not significant (Brunelin, Combris, et al., 2006). Using the same task but stimulating with active tDCS, with the anode over the left PFC and the cathode over the temporoparietal cortex, yielded an improvement of these misattribution errors in voice hearers with schizophrenia (Mondino et al., 2015).

In addition, tDCS was also used to study source monitoring processes in healthy individuals (Mondino et al., 2016; Moseley et al., 2018). Mondino and her colleagues (2016) examined the left STG and DLPFC separately, by placing a larger reference electrode on the right occipital cortex which would lead to a more focal stimulation from the smaller electrode (Nitsche et al., 2008). The authors found that anodal tDCS over the left temporo-parietal junction (TPJ; which is part of the STG) resulted in a higher likelihood to misattribute internally generated speech to externally perceived speech. There was no tendency to misattribute self-generated thoughts to self-generated speech. These findings suggest a key role of the left TPJ in reality monitoring, but do not suggest that it is involved in internal source monitoring. Cathodal tDCS over the left PFC did not lead to any modulation of source monitoring abilities, neither internal source monitoring nor reality monitoring (Mondino et al., 2016). However, both regions were stimulated separately, and the hypertemporal/hypofrontal model was not tested directly. Thus, the combined setup of tDCS electrodes seem to be specifically

important. Another study examined the involvement of the right anterior medial PFC with tDCS (Moseley et al., 2018). Participants completed a reality monitoring task three times: real tDCS with the cathode placed over the right medial PFC and the anode over the left STG; sham tDCS with the same montage; and real tDCS with the cathode placed over the right medial PFC and the anode over the left visual area (as a control site). In the first of two separate experiments, participants received tDCS during the encoding stage of the reality monitoring task, when they were asked to remember words. In the second experiment they received tDCS during the testing stage, when they were asked to indicate whether they had heard or imagined a word. Neither experiment found an effect of tDCS as compared to sham on reality monitoring.

While some authors suggest that cathodal tDCS rarely induces inhibitory effects in cognitive tasks (Dedoncker et al., 2016; Jacobson et al., 2012), the different findings of Mondino et al. (2016) and Moseley et al. (2018) might be due to differences in current strength, timing (i.e., whether tDCS was given during encoding or testing stage), or electrode montage (i.e., ipsilateral vs. contralateral hemispheres). Indeed, simulation studies of the electrical field of tDCS suggest that if the distance between electrodes is too close, much of the current is shunted over the scalp (Datta et al., 2008; Miranda et al., 2006). The magnitude of the electrical field was shown to be highest under the anode when electrodes were placed with a certain distance, but the peak shifts towards the cathode as the two electrodes are brought closer towards each other (Miranda et al., 2013). In line with those findings, a simulation study by Mondino et al. (2020) suggested that the peak activation shifted between the electrodes, when stimulating patients with schizophrenia with tDCS with the same electrode setup used in their treatment studies (Brunelin et al., 2012; Mondino et al., 2015). Moreover, a study in healthy individuals could show that simulating the electrical field with the anode over the left temporo-parietal cortex and the cathode over the left DLPFC leads to a peak in electrical field strength between the two electrodes, in the left central sulcus region and Broca's area (Marquardt et al., 2020). As this area is involved in verbal speech processing and inner speech (Alderson-Day & Fernyhough, 2015; Jones & Fernyhough, 2007a; Shergill et al., 2003), an activation in this area might induce a

stimulation of verbal working memory abilities (Chein et al., 2002; Gisselgård et al., 2014; Jenkins et al., 2018), and therefore specifically modulate internal source monitoring abilities.

Another important factor in AVHs and source monitoring is the influence of emotions, as reported misattribution biases have been found to be even bigger for content that is emotionally charged compared to neutral content (Johns et al., 2001; Morrison & Haddock, 1997; Rossell, 2013).

The influence of emotion and affect. Especially negative emotions are known to precede and accompany AVHs (Freeman & Garety, 2003; Oorschot et al., 2012), with voice hearers in clinical populations being more likely to have associated symptoms of heightened depression and anxiety, compared to voice hearers in non-clinical populations (Andrew et al., 2008; Lawrence et al., 2010; Smith et al., 2006).

Negative affect is also an additional predictor of emotional aspects of AVH phenomenology such as emotional valence and distress about voices, and their impact on functioning. More severe depression has been associated with a higher amount and degree of negative voice-content, more voice-related distress, and more disruption to life in clinical voice hearers (Rosen et al., 2018; Smith et al., 2006). However, there seems to be a discrepancy with regards to diagnostic and underlying emotional factors. A recent study by Toh et al. (2020) showed that voice hearers with a depressive or bipolar disorder report that their experience of AVHs leads to moderate disruption of daily psychosocial functioning, compared to voice hearers with schizophrenia and schizoaffective disorder who claimed severe disruption. In contrast, by grouping patients according to their mood state (and not their diagnosis), voice hearers with euthymic and depressive symptoms showed a minimal disruption to life, compared to voice hearers with mania-mixed symptoms who reported severe disruption (Toh et al., 2020). This discrepancy suggests that affect influences voice hearers differently, depending on their current mood states, and advocates for a transdiagnostic examination.

Core schemas about the self and others. Negative voice content and emotional distress in clinical voice hearers also contribute to the maintenance of AVHs through other processes (Garety et al., 2001; Larøi, Thomas, et al., 2019), such as emotion regulation strategies (Badcock et al., 2011) and negative self-concepts (Garety et al., 2007).

These negative self-concepts are also referred to as core schemas about the self and others, which start to form early in life and refer to the developed mental representations of the world (e.g., "The world is a dangerous place."), oneself (e.g., "I am worthless.") and others within it (e.g., "Other people are hostile.") (Young, 1999). They influence current interpretations about our social environment and about ourselves, and shape reactions to daily experiences (Rafaeli et al., 2010; Young et al., 2006). Negative interpretations of social experiences from the environment are thought to feed into the formation of negative core schemas about the self and others by synthesizing past reactions that are influenced by external events, mood, cognitive state, and memory processes (Fowler et al., 2006; Garety et al., 2001). This is especially so after the experience of early social adversity, for example the humiliation and subordination involved in childhood trauma (Appiah-Kusi et al., 2017; Birchwood et al., 2000; Fowler et al., 2006; Scott et al., 2020), which are known to be associated with psychotic symptoms, such as AVHs (for a review see Williams et al., 2018). This social adversity creates an enduring cognitive vulnerability characterized by negative schemas about the self and others that facilitate appraisal biases and low self-esteem, and contribute to the maintenance of these symptoms (Garety et al., 2007; Garety et al., 2001).

Negative core schemas have been shown to be associated with phenomenological aspects of AVHs. Voice-related distress was found to be independently linked to negative social schemas, with voice hearers feeling inferior in relation to their voices, when they perceived a lower social rank of self relative to others (Paulik, 2012). Both the amount and intensity of voice-related distress are positively

associated with negative core schemas about the self (Smith et al., 2006). In addition, the amount and degree of negative content have also been found to correlate positively with negative core schemas about the self in the same study (Smith et al., 2006). Although not consistently found (Thomas et al., 2015), Scott et al. (2020) corroborated this association, and found that negative AVH content was predicted by negative core schemas about the self in a mixed sample of voice hearers with an affective and non-affective mental disorder.

It has been proposed that there is an inter-dependence of negative core schemas about the self and others with negative affect (i.e., anxiety and depression), which is involved in the development of AVHs. However, it is unknown whether this association differs across voice hearers with different diagnoses, and how it affects emotional valence, levels of distress, and the impact on functioning related to voices. It is also unclear how the respective roles of specific affective disturbances (i.e., anxiety and depression) influence voice hearers with different underlying psychopathologies.

1.5. Summary

The literature outlined above indicates that PLEs in general, and AVHs in particular, are continuous multicomponent phenomena that occur across different diagnoses and in individuals without mental disorders.

Neurobiological findings of AVHs show dysfunctional connectivity and functionality within a wide network of involved brain areas. Some findings suggest a *hyper*activation in temporal language areas, with an intercalated attentional shift towards these neuronal signals, that make it difficult for *hypo*active frontal areas to inhibit those experiences. These findings reinforce models that see atypical inner speech processes as critical for the experience of AVHs. The attribution of inner information to internal and external sources is called *source monitoring* and a misattribution bias has been shown in individuals with AVHs, but also in healthy individuals by modulating involved temporal and prefrontal brain regions with tDCS.

Emotionally charged information is aggravating these misattributions and adds to the notion that especially negative emotions, such as depression and anxiety, play an important role in the development and maintenance of AVHs and their phenomenology. When experienced very early in life, these negative emotions can contribute to the development of negative core schemas about oneself and others, and lead to severely negative voices that have an immense impact on individuals functioning in life.

When focusing on neurobiological, cognitive, and emotional processes transdiagnostically, multiple behavioural components of symptoms such as AVHs can give a more fundamental understanding of their aetiology. However, examining those factors in a variety of populations (ranging from healthy individuals to various patients with severe mental disorder) enables us to extend the view towards a continuous perspective and thus seeing these phenomena in their full spectrum.

2. Aims

The purpose of this thesis is to investigate neurobiological, cognitive, and emotional aspects of AVHs at different stages in the continuum, from healthy and non-clinical populations, to affective and non-affective voice hearers as an example of how a combined continuous transdiagnostic perspective towards PLEs in general, and AVHs specifically can work.

2.1. Paper 1: Mapping psychotic-like experiences - results from an online survey

In paper 1, we had several aims. The first aim of the study was to test the psychometric properties of the QPE screening questionnaire. We examined its test-retest reliability, convergent validity, and the internal structure in a convenience sample recruited from the general population via an online survey. Our second aim was to map endorsement rates for both hallucinatory and delusional experiences in this sample in order to determine the frequency of these PLEs and the modalities in which they occur. Additionally, we also aimed to replicate previous findings showing that sex, age, unemployment, level of education, parental mental disorder, and the use of illegal drugs/alcohol predict whether individuals experience PLEs. Thirdly, we wanted to examine how many of the PLEs that adults reported in the present study were "merely" childhood experiences that did not transition into adulthood. Finally, we examined whether the QPE screening items can be used as predictors to distinguish between individuals with PLEs who either had or had not been diagnosed with a mental disorder and to determine the sensitivity and specificity of the QPE screening items. If PLEs really are a phenomenologically continuous phenomenon, we expect that the endorsement of QPE items does not predict the presence of a diagnosed mental disorder.

2.2. Paper 2: tDCS enhances internal source monitoring abilities in healthy individuals

In paper 2, we examined neurobiological and cognitive aspects of AVHs by modulating source monitoring processes with tDCS in healthy adults. The aim of our study was to corroborate and extend the studies of Mondino, et al. (2016) and Moseley, et al. (2018), who also used similar methods but investigated different brain areas. In our study, we placed the anode over the left STG and the cathode over the left DLPFC in healthy individuals – to mimic the hypertemporal/hypofrontal activity pattern that is assumed to underly AVHs and source monitoring deficits in schizophrenia patients. Simulations in another study from our group demonstrated that the electrical field was strongest over Broca's area with this montage (Marquardt et al., 2020). As this area is involved in verbal speech processing, an activation in this area might induce a stimulation of verbal working memory abilities (Chein et al., 2002; Gisselgård et al., 2014; Jenkins et al., 2018) and thus changes in source monitoring abilities. We carried out two experiments: an *offline experiment*, where source monitoring was carried out directly after stimulation with tDCS; and an *online experiment*, where source monitoring was carried out simultaneously with tDCS. This was motivated by findings showing that active stimulation modulates brain activity differently on a neural (Stagg & Nitsche, 2011) and behavioural level (Hummel & Cohen, 2006), when stimulating offline or online. We expected stronger behavioural effects of active tDCS on both internal source monitoring and reality monitoring abilities in the online experiment.

2.3. Paper 3: From core schemas about the self and others to voice phenomenology - anxiety and depression affect voice hearers differently

In paper 3, we investigated the role of emotions in cognitive processes of AVHs in groups of voice hearers who have different underlying psychopathologies or no diagnosed mental disorder. The aim of this study was to examine whether anxiety and

depression mediate the relationship between core schemas about the self and others and emotional aspects of voice phenomenology separately. We hypothesized that voice hearers with an underlying affective psychopathology (i.e., with a diagnosis of major depressive disorder, or bipolar disorder) would be affected differently by anxiety and depression compared to patients with a non-affective psychopathology (i.e., with a diagnosis of schizophrenia, or schizo-affective disorder) or as compared to individuals with no psychopathology at all (i.e., healthy voice hearers).

3. Methods

3.1. Paper 1

3.1.1. Participants

The online survey was taken at two time points, denoted timepoint 1 (TP1) and timepoint 2 (TP2), approximately one week apart. A total of 46,916 participants visited the online survey, with 2,216 of these visiting both sessions. The mean difference, in number of days, was 8.77 (SD = 3.4). After applying exclusion criteria, there were 1439 and 1115 participants at TP1 and TP2, respectively. All 1115 participants from TP2 also completed TP1 (77.5%). Participants at both time points were mostly highly educated and female, with a mean age around 40 years. For more details about participant characteristics, see Table 1.

3.1.2. Questionnaires

We included questions assessing basic demographic and clinical information, the presence/absence of delusional and perceptual anomalies from the Peters Delusion Inventory (PDI; Peters et al., 2004) and the Cardiff Anomalous Perceptions Scale (CAPS; Bell et al., 2005). At the centre of the investigation was the QPE screening questionnaire (Sommer et al., 2018 2018) assessing the general presence/absence of PLEs and whether participants had experienced any of these PLEs in childhood ("Did you experience this only when you were a child?"). We also added questions to ensure the validity of participants' answers (for detailed information see the method section of paper 1).

3.1.3. Procedure

The online survey was administered with the online tool SurveyXact (http://www.surveyxact.no). Participants were recruited via posters, emails, publications on webpages and social media channels, such as Facebook.

At TP1, participants completed demographic questions, the QPE screening questionnaire, PDI, CAPS and clinical questions. At the end, they were asked to voluntarily provide their email address for future research and had the opportunity to comment on the online survey. The total time to complete the online survey was between 20 and 40 minutes. Only participants who gave their informed consent to participate in future research were invited to TP2. Two invitations were sent out via email, seven and nine days after TP1 was completed. At TP2, participants only completed the QPE screening questionnaire, the PDI, and the CAPS.

The study was approved by the regional ethics committee (REK 2017/69) and informed consent was obtained beforehand from all participants at both time points.

3.1.4. Data Analysis

The characteristics of the general sample are presented in Table 1.

Retest reliability of the QPE screening questionnaire was determined with a test/re-test-design and is expressed as the percentage of concordant and discordant answers across TP1 and TP2. For convergent validity, inter-scale concordance rates were calculated between the QPE screening questionnaire and corresponding items of the PDI and CAPS. We chose the items from the QPE, PDI, and CAPS based on their matching content (see Table 6, paper 1). In addition, we provided the mean square contingency coefficient phi (φ). To determine the internal structure of the QPE screening questionnaire, we ran a principal component analysis (PCA) with all 13 items following the recommendations of Neill (2008). Eigenvalues greater than 1 and factor

loadings of greater than 0.4 were retained and considered satisfactory (Mokkink et al., 2010).

To map PLEs, we first report the endorsement rates of lifetime, current, and childhood PLEs at TP1 descriptively, separately for individuals with and without a self-reported mental disorder that had been diagnosed by a psychiatrist or psychologist. Subsequently, we ran a multiple linear regression (not distinguishing between individuals with and without a diagnosed mental disorder) with sex, age, employment status, level of education, parental mental disorder, as well as the consumption of drugs and alcohol as predictors for having PLEs. Unknown answers were treated as missing values and excluded from the analysis. The dependent variable was the total score of lifetime PLEs at TP1, which was calculated as the sum of all QPE items where participants indicated their presence. Finally, a binomial logistic regression model and a receiver operating characteristic curve (Hasan et al., 2016) were computed to assess how well the items of the QPE screening version at TP1 discriminate between individuals with and without a self-reported mental disorder who experience PLEs. In addition, sensitivity, specificity, and positive and negative predictive values were calculated.

Table 1. Participant Characteristics (paper 1)

Variables	*TP 1*	TP 2
n	1439	1115
Age (M ± SD)	39.1 (13 ± 37)	39.62 (13 ± 36)
Sex: female / male [%]	1254:185 [87.1 % / 12.9 %]	975:140 [87.4 % / 12.6 %]
Education:		
Primary	3.8 %	3.5 %
Secondary	27.4 %	24.8 %
Higher	68.9 %	71.7 %
Have parents with a psychiatric diagnosis	8.2% (Unsure: 9.8%)	8.6% (Unsure: 10.5%)
Neurological disorder	3.1%	3.3%
Mental disorder:	32.2%	34.4%
Depression	25%	27.5%
Anxiety	18.8%	20.2%
Schizophrenia	2.2%	2.3%
Bipolar Disorder	3.0%	3.3%
Personality Disorder	3.3%	3.5%
Other	1.7%	1.8%
Consulting a specialist for mental health problems:		
General practitioner	40.7%	43.3%
Psychiatrist	15.6%	16.7%
Psychologist	43.4%	46.3%
Neurologist	3.5%	4.0%
other	3.1%	3.3%

Note: Multiple responses were possible for questions regarding mental disorder and consulting a specialist.

3.2. Paper 2

3.2.1. Participants

In total, we included 61 participants in two separate experiments (offline, n = 34; online, n = 27), with a mean age of 25.13 years (SD = 4.53). Participants in the offline experiment were part of a larger study with the aim to examine the underlying neuronal effects of tDCS on dorsolateral prefrontal and temporo-parietal areas during dichotic listening; these aspects described elsewhere (Marquardt et al., 2020). Participants in the online experiment were recruited separately for the purpose of this study. Chi^2 tests and Mann-Whitney-U tests showed no significant differences regarding gender, handedness, nicotine usage, years of education, and days between session 1 and session 2. Participants in the offline experiment were significantly older than in the online experiment (see Table 2). Exclusion criteria for both experiments can be found in the method section of paper 2. All participants gave written informed consent in accordance with the Declaration of Helsinki (World Medical Association, 2014) and were reimbursed for their participation. The study was approved by the Regional Committee for Medical Research Ethics in Western Norway (REK Vest) #2013/2342.

Table 2. Participant characteristics in both experiments (paper 2)

	Offline experiment (n = 34)	Online experiment (n = 27)		
	M (SD)	M (SD)	U	p
Age	26.47 (4.76)	23.44 (3.65)	252.5	.002
Education in years	15.9 (1.99)	14.78 (2.54)	345.5	.097
Days between tDCS sessions	8.21 (3.29)	7.07 (1.64)	395.5	.334
	Absolute numbers (%)	Absolute numbers (%)	$\chi^2_{(1)}$	p
Gender:			.898	.343
Female	16 (47.1%)	16 (59.3%)		
Male	18 (52.9%)	11 (40.7%)		
Handedness:			.006	.937
Left-handed	4 (11.8%)	3 (11.1%)		
Right-handed	30 (88.2%)	24 (88.9%)		
Daily nicotine users (snuff)	7 (20.6%)	7 (25.9%)	.242	.622

Notes. U = Mann-Witney U-test, χ^2 = Chi-Square test, p = p-value.

3.2.2. Materials

Questionnaires. We collected basic demographic information including years of education and nicotine use. Roughly 88% were right-handed in both experiments, as measured with the Edinburgh Handedness Inventory (Oldfield, 1971). Common adverse side effects (e.g., headache, nausea) were measured with the tDCS Adverse Effects Questionnaire (Brunoni et al., 2011) after both the sham and the active tDCS sessions.

Source Monitoring task. Internal source monitoring and reality monitoring was assessed using two Norwegian source monitoring tasks based on Keefe, Arnold, Bayen, and Harvey (Keefe et al., 1999) as well as Brunelin, Combris, et al. (2006). Words presented in both tasks were contemporary Norwegian words consisting of one syllable and emotional neutral valence. The words for the reality monitoring task (Hear-Imagine) were spoken by a native Norwegian female. For each task, we created two versions (Version A, and Version B), with a different set of 24 words to avoid learning effects between the first and the second tDCS session.

Each task was divided in a presentation phase and a test phase. In the presentation phase, 16 words were presented on a computer screen preceded by an instruction (both the instruction and the word were presented for three seconds). In the internal source monitoring task (Say-Imagine), participants were instructed to either "Say the following word aloud" (eight words) or "Imagine yourself saying the following word aloud" (eight words). In the Hear-Imagine task, participants were

instructed to “Imagine yourself hearing the following word” (eight words) or “Listen to the following word” (eight words). In the test phase, all 16 words were presented again in a randomised order, including eight distractor words that were not included in the presentation phase. In the test phase of the internal source monitoring task (Say-Imagine), participants were asked to indicate via button press for each word whether they had said the word, had imagined saying it, or whether it was a new word. In the reality monitoring task (Hear-Imagine), they indicated whether they had heard the word, imagined hearing the word, or whether it was a new word. Before each task started, there was a training phase with a maximum of four words. In total, both source monitoring tasks lasted approximately ten minutes. Both tasks were administered separately and the type (Hear-Imagine/Say-Imagine) and version (A/B) of the source monitoring tasks were counterbalanced across participants and sessions in both experiments. For more details see the method section of paper 2.

Variables of interest were the number of misattributions of words that participants had imagined saying/hearing but where they indicated later those words were actually said or heard (subsequently referred to as ‘externalization bias’; range: 0-8), the number of misattributions of words that participants had actually said/heard but indicated later they had imagined saying/hearing those words (subsequently referred to as ‘internalization bias’; range: 0-8), and the number of incorrectly identified ‘distractors’ (range: 0-8).

tDCS. In both the offline and online experiment, participants were tested in two sessions, once with real stimulation and once with sham stimulation, in a double-blind design. The order of real/sham stimulation was counterbalanced. A reporting checklist with an overview of the study's design, following the recommendations by Buch et al. (2017) can be found in the supplementary materials for paper 2.

tDCS was delivered with a neuroConn DC-stimulator Plus (neuroConn GmbH, Ilmenau, Germany) and electrode positions were located with EEG caps (EASYCAP GmbH, 82211 Herrsching, Germany), based on the 10/20 system. The cathode and anode were placed over AF3 (left DLPFC) and CP5 (left STG), respectively, and attached to the scalp via a rubber band (see Figure 2). Real stimulation lasted 20 minutes (+30s ramp up and 30s ramp down) at 2mA (current density = 0.057mA/cm^2), and sham tDCS was delivered for 40s, followed by very weak pulses of 110µA lasting 15ms, provided every 550ms as an impedance check. Codes were used to ensure double-blinding. In the offline experiment, rectangular, MR compatible tDCS electrodes made of rubber (5cm x 7cm) were used. Electrodes were coated with conductive paste Ten20 (Weaver and Company, Aurora, United States of America) and a 9mg/ml NaCl solution to decrease impedance. Impedance was kept below 14.2kΩ, which was tested outside the MR scanner. For more details see also Marquardt et al. (2020). In the *online experiment*, we used non-MR rubber electrodes (also 5cm x 7cm), that were placed into saline-soaked sponges. Electrode gel was used to decrease impedance between sponges and the skin.

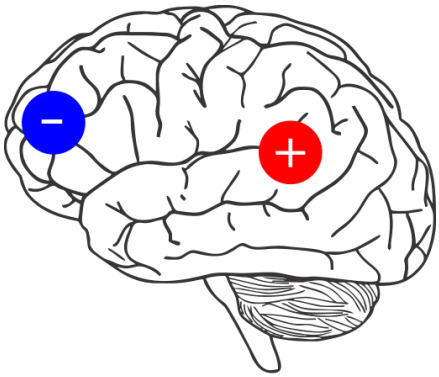


Figure 2. tDCS electrode placement in paper 2

3.2.3. Procedure

Offline experiment*:* Source Monitoring after tDCS. In both sessions, participants completed a questionnaire regarding tDCS safety and functional magnetic resonance imaging (fMRI) safety before the electrodes were mounted and participants entered the scanner. They underwent structural MR, MR spectroscopy, and one fMRI sequence. During fMRI, they received tDCS while simultaneously performing a dichotic listening task. In the beginning of session 1, demographic information was collected, and a hearing test was performed. The whole MR session took approximately 40 min (for more details on the MR experiment see Marquardt, et al. (2020)). Immediately after leaving the MR scanner and removing the tDCS electrodes, participants completed the tDCS adverse effects questionnaire and both source monitoring tasks separately. All participants finished both source monitoring tasks in a time window of 20 minutes after tDCS terminated. After the second source

monitoring task in session 2, participants were asked to guess when they received real tDCS, to control for blinding.

Online experiment: Source Monitoring during tDCS. In Session 1, participants completed questionnaires about demographic information and did a hearing test after giving written consent. In both sessions, participants completed a questionnaire regarding tDCS safety before the electrodes were mounted. Participants began the first source monitoring task five minutes after stimulation had started. All participants finished the tasks before the stimulation terminated and just waited quietly. Afterwards, the tDCS adverse effects questionnaire was completed. At the end of session 2, participants guessed in which session they received active tDCS.

3.2.4. Data Analysis

We compared participants in both experiments (offline vs. online) regarding different characteristics. Gender and handedness were compared using Chi^2 tests. Age, years of education, and the time difference between session 1 and session 2 was compared using Mann-Whitney U tests.

We performed in total six 2 x 2 repeated-measures analyses of variance (ANOVAs) with Stimulation (real vs. sham) as within- and Experiment (online vs. offline) as between-participants factors; one ANOVA for each source monitoring task (Say-Imagine, Hear-Imagine) and each dependent variable (internalization bias,

externalization bias, incorrect distractors) separately. The effect-size partial eta-squared (η_p^2) is provided, with η_p^2 = 0.01 representing a small effect, η_p^2 = 0.06 a medium effect, and η_p^2 = 0.14 a large effect (Maxwell et al., 2017). Post-hoc tests were performed with Bonferroni-adjustment to correct for multiple testing (Maxwell et al., 2017) and descriptive means (instead of estimated marginal means) are given.

A G*Power (Faul et al., 2007) analysis suggested that to obtain a significant Stimulation*Experiment interaction with n = 61, a minimum effect size of η_p^2 = 0.18 was required (with the settings: power = 0.8, α = 0.05, number of groups = 2, number of measurements = 2, correction among repeated measures = 0.5, non-sphericity correction = 1).

We calculated binomial tests with the test proportion 0.5, separately for each experiment, to examine whether the blinding worked. That is, if participants' guesses when they received real stimulation was significantly different from 50% chance level. Adverse effects between real and sham tDCS were compared using Wilcoxon signed rank tests.

All analyses were conducted using IBM SPSS v.25 for Windows (IBM Corporation, Armonk, NY, USA).

3.3. Paper 3

3.3.1. Participants

Participants were recruited as part of a broader study on hallucination phenomenology (Scott et al., 2020; Toh et al., 2020). All 174 participants had voice-hearing experiences and included: 76 non-affective voice hearers (46 females) with a current or past diagnosis of schizophrenia ($n = 50$), or schizoaffective disorder ($n = 26$); 65 affective voice hearers (35 females) with a past or current diagnosis of major depressive disorder ($n = 31$) or bipolar disorder ($n = 34$); and 33 non-clinical voice hearers (18 females) with no past or current diagnosed mental disorder. Inclusion criteria can be found in the method section of paper 3. The majority of clinical participants were outpatients (affective voice hearers: 93.8%, non-affective voice hearers: 78.9%). A Chi^2 test of independence revealed no statistically significant association between females and males and the different groups of voice hearers ($\chi^2(2) = 0.729$, $p = .694$).

3.3.2. Questionnaires

Participants completed questionnaires about basic demographic and clinical information, depression (*Beck Depression Inventory II*, BDI-II; Beck et al., 1996), anxiety (*Beck Anxiety Inventory*, BAI; Beck et al., 1988), core schemas about the self and others (*Brief Core Schema Scale*, BCSS; Fowler et al., 2006), and items that represent emotional aspects of AVH phenomenology (taken from the *Questionnaire*

for Psychotic Experiences, QPE; Rossell et al., 2019): *emotional valence of AVHs* (i.e., the proportion of voices with positive and negative content), *distress due to AVHs* (i.e., the experienced distress and discomfort) and *impact of AVHs on functioning*. Detailed questionnaire descriptions can be found in the method section of paper 3.

3.3.3. Procedure

Participants were recruited from the inpatient and outpatient services of two public and one private psychiatric hospital in Melbourne, Australia, a participant registry associated with a specialist Voices Clinic, and from online and print advertising. Participants provided written, informed consent. Clinical interviews for the original study typically took up to three hours to complete and were conducted by one of three trained researchers using the measures detailed below. Procedures were in line with the Declaration of Helsinki (World Medical Association, 2014).

3.3.4. Data Analysis

All analyses were conducted using IBM SPSS v.25 for Windows (IBM Corporation, Armonk, NY, USA). We performed analyses of variance (ANOVAs) for continuous variables to investigate group differences between non-clinical voice hearers, affective voice hearers, and non-affective voice hearers for demographic and clinical characteristics, and for our variables of interest (i.e., BAI, BDI-II, BCSS subscales, QPE items). As the assumption of homogeneity of variances was not met in

all variables, we reported Welch's ANOVAs. To account for multiple comparisons, we used Dunnet T3 post hoc tests (Lee & Lee, 2018). For categorical variables we conducted Chi^2 tests for independence.

We hypothesized that positive and negative core schemas (X) would predict emotional aspects of AVH phenomenology (Y), mediated by anxiety (M_1) and depression (M_2). Therefore, we first calculated correlations between BAI, BDI-II, BCSS-subscales, and the QPE items *emotional valence, distress,* and *impact on functioning*, using Kendall's τ. As mediators have to be significantly correlated with both the predictor (X) and the outcome variable (Y) (Baron & Kenny, 1986), we only calculated mediation models for significant associations, and omitted non-significant correlations. When one mediator was significantly correlated with both the predictor and the outcome variable, we calculated simple mediation models; when both mediators were significantly correlated with the predictor and the outcome variable, we calculated parallel mediation models using the SPSS macro PROCESS v3.4 by Hayes (Hayes). More details about model specifications can be found in paper 3.

4. Results

4.1. Paper 1

4.1.1. Psychometric Properties.

Test-Retest reliability. Concordance rates between answers at TP1 and TP2 show high consistency of ≥ 85 % in 12 out of 13 items. Only one item (paranoia) is below 78 %.

Convergent validity. Concordance rates between QPE screening questions and related CAPS/PDI items were ranging between 50.4% and 93.6%, with corresponding weak to strong effects (ϕ between .199 and .789; see paper 1, Table 3).

Internal structure. The data screening showed that with 1439 participants for 13 items, we had a satisfactory participant-to-item ratio of approximately 111:1. Several indicators were checked to assess overall suitability for a factor analysis. First, the determinant derived from the correlation matrix was .217 and thus above the recommended value of .00001. Moreover, inter-correlations were well below $r = .80$, suggesting there was no multicollinearity. Second, 8 out of 13 items correlated with at least one other item $r \geq .30$. Third, the Kaiser-Meyer-Olkin measure of sampling adequacy (.83) was above .60, Bartlett's test of sphericity was significant [$\chi^2(78) = 2816.46$, $p \leq .001$], and 11 out of 13 items showed communalities above .30. Based on these indicators, the data including all 13 items was regarded suitable for factor analysis. We carried out a PCA with promax rotation, since we expected that the underlying factors are correlated. Three factors had eigenvalues greater than 1, the first

two explaining 24 % and 11 % of the variance, respectively, while the last factor explained 8 % variance. A two-factor solution seemed most appropriate: first, the characteristic bend in the scree plot as reflected by the eigenvalues occurred after two factors. Second, we compared the observed eigenvalues to randomly generated eigenvalues based on 13 variables, 1439 participants, and 100 replications with the tool "Monte Carlo PCA for parallel analysis" (Watkins, 2000). Only the eigenvalues of the first two observed factors (3.1 and 1.4) were above the randomly generated eigenvalues (1.2 and 1.1), while subsequent observed eigenvalues were level with or below the randomly generated ones. We then re-ran the PCA with the two-factor solution preselected, explaining a total variance of 35 %. Factor loadings higher than .40 are presented in Table 3. As can be seen, Factor 1 represents items about delusions, while Factor 2 only contained items about hallucinations. We therefore called the two factors *delusional experiences* and *hallucinatory experiences*, respectively. In a last step, we analysed the internal consistency for the two factors. Cronbach's alpha for *delusional experiences* and *hallucinatory experiences* were .671 and .645, respectively, suggesting relatively moderate internal consistency.

Table 3. Mean scores of psychotic experiences and factor loadings of the QPE screening questions.

QPE-Item	Mean	Factor 1 delusional experiences	Factor 2 Hallucinatory experiences
1) Auditory hallucinations	0.45		0.71
2) Visual hallucinations	0.40		0.74
3) Tactile hallucinations	0.51		0.63
4) Olfactory hallucinations	0.47		0.68
5) Paranoia	0.57	0.56	
6) Delusions of reference	0.18	0.60	
7) Delusions of guilt	0.24	0.65	
8) Delusions of control	0.16	0.56	
9) Delusions of religiosity	0.06	0.42	
10) Delusions of grandeur	0.18	0.43	
11) Somatic delusions	0.34	0.46	
12) Delusions of nihilism	0.11	0.52	
13) Delusions of misidentification	0.08	0.49	

4.1.2. Mapping PLEs

Endorsement rates of PLEs. In general, hallucinatory experiences were more often reported than delusional experiences (see Table 4). Individuals with a mental disorder experienced more *lifetime* PLEs than those without a mental disorder. Looking at *current experiences*, a similar pattern arises, clustering around roughly ten percent. In general, just a few people reported having experienced PLEs only during *childhood*.

Table 4. Endorsement rates of PLEs in the study sample of paper 1, separately for individuals with and without a mental disorder

	Lifetime		Current		Child	
	With	Without	With	Without	With	without
Hallucinatory experiences						
Auditory	50.10%	42.70%	10.40%	5.60%	2.80%	4.10%
Visual	47.50%	36.80%	9.30%	5.00%	5.80%	4.50%
Tactile	58.30%	47.40%	18.40%	11.80%	2.40%	2.80%
Olfactory	55.70%	43.30%	14.00%	10.60%	0.90%	0.90%
Delusional experiences						
Paranoia	71.30%	50.60%	21.00%	10.00%	2.20%	2.80%
Reference	23.10%	16.30%	6.90%	5.00%	1.30%	0.50%
Guilt	39.50%	16.20%	8.40%	2.90%	4.80%	1.90%
Control	20.70%	13.10%	3.90%	2.00%	1.30%	1.20%
Religiosity	9.50%	4.00%	1.50%	1.60%	1.30%	0.70%
Grandeur	21.40%	16.40%	4.50%	5.60%	5.20%	3.90%
Somatic	43.60%	29.10%	13.40%	6.70%	1.70%	1.10%
Nihilism	17.50%	8.30%	2.20%	1.10%	1.70%	1.20%
Misidentification	10.60%	6.80%	0.40%	0.90%	3.50%	2.50%

Notes: Percentage of individuals with and without a mental disorder diagnosed by a mental health professional, with separate rates for lifetime, current and childhood experiences.

Factors predicting the frequency of PLEs. Using the enter method, the multiple regression model significantly predicted PLEs, $F(7, 1431) = 28.36$, $p < .001$, adj. $R^2 = .12$ (see Table 5). Age, education, parental mental disorder, drug and alcohol consumption were significant predictors of PLEs.

Table 5. Predictors of experiencing PLEs

Variables	B	SE_B	CI_B 95%		β
			Lower	Upper	
Intercept	7.36	0.44	6.51	8.22	
Age	-0.02	0.01	-0.03	-0.01	-.08*
Sex	-0.35	0.20	-0.74	0.05	-.04
Employment status	0.01	0.01	-0.01	0.02	.04
Education	-0.84	0.12	-1.08	-0.59	-.17**
Parental mental disorder	0.01	0.01	0.01	0.02	.16**
Illegal drugs	1.11	0.39	0.34	1.88	.07*
Alcohol	-0.32	0.05	-0.43	-0.22	-.16**

Notes: * $p \leq .005$, ** $p < .001$; B = unstandardized regression coefficient; SE_B = standard error of coefficient; CI_B = confidence intervals of coefficient; β = standardized coefficient;
Variable coding: age (in years), sex (male/female: 1/0), employment status (employed/unemployed: 1/0), education (primary/secondary/higher: 1/2/3), parental mental disorder (yes/no: 1/0), illegal drugs (yes/no: 1/0), alcohol (six-point-scale from "never" to "5 times per week: 0-5);

Discriminating Individuals with and without Mental Disorders based on QPE Screening Questions. The logistic regression model was statistically significant, $\chi^2(13) = 134.76, p \leq .001$. The model explained 12.6% (Nagelkerke R^2) of the variance of discriminating participants with and without a diagnosis and correctly classified 71.4% of cases. Sensitivity was 24.2%, specificity was 92.5%, positive predictive value was 58.8% and negative predictive value was 41.2%. Of the 13 predictor variables, five were statistically significant (in order of descending level of significance): guilt, paranoia, visual hallucinatory experiences, and delusional experiences of religiosity

and nihilism (see Table 6). The area under the ROC curve was .686 with a 95% CI between .656 and .716. According to Hosmer Jr et al. (2013), this represents a poor level of the whole model classifying individuals into the two groups.

Table 6. Logistic regression predicting likelihood of having a diagnosed mental disorder based on the occurrence of psychotic experiences

QPE item	B	SE	Wald	df	odds ratio	95% CI for odds ratio	
						lower	upper
Auditory hallucinations	-0.13	0.14	0.92	1	0.34	0.67	1.15
Visual hallucinations	0.32	0.14	5.74*	1	1.38	1.06	1.79
Tactile hallucinations	0.10	0.14	0.53	1	1.10	0.85	1.44
Olfactory hallucinations	0.23	0.13	2.88	1	1.25	0.97	1.63
Paranoia	0.54	0.14	15.88**	1	1.72	1.32	2.24
Delusions of reference	-0.20	0.17	1.38	1	0.82	0.59	1.14
Delusions of guilt	0.89	0.14	38.65**	1	2.43	1.84	3.22
Delusions of control	-0.05	0.18	0.07	1	0.96	0.68	1.35
Delusion of religiosity	0.57	0.25	5.13*	1	1.77	1.08	2.91
Delusion of grandeur	-0.10	0.16	0.40	1	0.90	0.66	1.24
Somatic delusions	0.19	0.13	2.03	1	1.21	0.93	1.57
Delusions of nihilism	0.38	1.88	4.11*	1	1.46	1.01	2.11
Delusions of mis-identification	0.02	0.22	0.01	1	1.02	.66	1.57
Constant	-1.71	0.13	179.56**	1	0.18		

Notes: * $p = 0.05$, ** $p = 0.01$.

4.2. Paper 2

4.2.1. Hear-Imagine

Externalization bias. There was neither a significant main effect for *stimulation* ($F_{(1,59)}$ = 1.05, p = .31, η_p^2=.02) nor for *experiment* ($F_{(1,59)}$ = .28, p = .60, η_p^2=.01). Also, the interaction effect *stimulation*experiment* was not significant ($F_{(1,59)}$ = 1.32, p = .26, η_p^2 = .02). Means and standard deviations can be found in Table 7.

Table 7. Means and standard deviations of the total number of errors as well as means of the error rates in percent in the Hear-Imagine task.

	externalization bias		internalization bias		incorrect distractors		
	M (SD)	%	M (SD)	%	M (SD)	%	stimulation condition
offline	1.65 (1.41)	20.63	1.09 (0.97)	16.63	0.68 (1.04)	8.50	real
	1.68 (1.53)	21.00	1.12 (1.20)	14.00	0.82 (0.76)	10.25	sham
online	2.07 (1.66)	25.88	1.30 (1.24)	16.25	0.93 (1.11)	11.63	real
	1.56 (1.16)	19.50	1.11 (1.01)	13.88	0.74 (1.06)	9.25	sham

Notes. Maximum possible number of absolute errors was 8.

Internalization bias. There was neither a significant main effect for *stimulation* ($F_{(1,59)}$ = .16, p = .69, η_p^2 = .01) nor for *experiment* ($F_{(1,59)}$ = .23, p = .64, η_p^2 = .01).

Also, the interaction effect *stimulation*experiment* was not significant ($F_{(1,59)}$ = 0.31, p = .58, η_p^2 = .01). Means and standard deviations can be found in Table 7.

Incorrect distractors. There was neither a significant main effect for *stimulation* ($F_{(1,59)}$ = .02, p = .89, η_p^2 < .01) nor for *experiment* ($F_{(1,59)}$ = .15, p = .70, η_p^2 = .01). Also, the interaction effect *stimulation*experiment* was not significant ($F_{(1,59)}$ = 1.48, p = .23, η_p^2 = .02). Means and standard deviations can be found in Table 7.

4.2.3. Say-Imagine

Externalization bias. We found significant main effects for *stimulation* ($F_{(1,59)}$ = 33.33, p < .01, η_p^2 = .36) and *experiment* ($F_{(1,59)}$ = 7.85, p = .01, η_p^2 = .12). Also, the interaction effect *stimulation*experiment* was significant ($F_{(1,59)}$ = 12.71, p = .01, η_p^2 = .18). As can be seen in Table 8, none of the participants in the *online experiment* that received real stimulation made a single mistake (both mean and standard deviation is zero). Post-hoc tests showed significant results between real vs. sham tDCS in the *online experiment* (t = 7.19, p < .01), but not in the *offline experiment* (t = -1.52, p = .14).

Table 8. Means and standard deviations for total number of errors as well as means of error rates in percent in the Say-Imagine task.

	externalization bias		internalization bias		incorrect distractors		
	M (SD)	%	M (SD)	%	M (SD)	%	stimulation condition
offline	1.27 (1.29)	15.88	1.09 (1.33)	13.63	1.06 (0.98)	13.25	real
	1.68 (1.20)	21.00	1.06 (0.85)	13.25	1.06 (1.10)	13.25	sham
online	0.00 (0.00)	0	0.00 (0.00)	0	1.15 (1.13)	14.38	real
	1.74 (1.26)	21.75	1.48 (1.05)	18.50	1.56 (1.37)	19.50	sham

Notes. Maximum possible number of absolute errors was 8.

Internalization bias. We found significant main effects for *stimulation* ($F_{(1,59)}$ = 7.42, p = .01, η_p^2 = .11) and *experiment* ($F_{(1,59)}$ = 9.65, p = .01, η_p^2 = .14). Moreover, the interaction effect *stimulation*experiment* was significant ($F_{(1,59)}$ = 6.68, p = .01, η_p^2 =.10). Again, the interaction arose because participants in the *online experiment* did not commit a single mistake when receiving real tDCS (see Table 8). Post-hoc tests showed significant results between real vs. sham tDCS in the *online experiment* (t = 7.32, p < .01), but not in the *offline experiment* (t = 0.13, p = .90).

Incorrect distractors. Neither the main effects *stimulation* ($F_{(1,59)}$ = .98, p = .33, η_p^2 = .02) and *experiment* ($F_{(1,59)}$ = 1.94, p = .17, η_p^2 = .03), nor the interaction

*stimulation*experiment* became significant ($F_{(1,59)} = .98$, $p = .33$, $\eta_p^2 = .02$). Means and standard deviations can be found in Table 8.

4.2.4. Covariates

Because nicotine has been reported to affect tDCS outcome (Brunelin et al., 2015 Nitsche, & Poulet, 2015), we re-ran the ANOVAs with nicotine consumption as an additional covariate. However, including the covariate did not change the pattern of significant and non-significant effects reported above.

4.2.5. Blinding and adverse effects

In the *offline* and *online experiments*, 47% and 56% of participants guessed correctly when they received real stimulation, respectively. A binomial test found no statistical difference from 50% chance level in either experiment (*offline*: $p = .86$; *online*: $p = .70$).

Wilcoxon signed-rank tests showed no significant difference in the frequency of common adverse side effects between real and sham tDCS in either experiment. Z-scores and p-values can be found in the supplementary materials of paper 2.

4.3. Paper 3

4.3.1. Participants

Welch's ANOVAs revealed group differences between the voice hearing groups in terms of age, duration of illness, number of mood episodes, and the number of hospital stays, and in all variables of interest. Results from the following Dunnett T3 post hoc tests showed differences between the single groups: As an overall observation, affective voice hearers and non-affective voice hearers only differed with regards to anxiety. Affective voice hearers had the highest scores for negative core schemas, and the lowest scores for positive core schemas, but did not differ significantly from non-affective voice hearers.

Mean scores, standard deviations, and results from Welch's ANOVAs and Dunnet T3 post hoc tests are presented in Table 9.

4.3.2. Impact of emotional states

Non-clinical voice hearers. Correlations between our variables of interest are shown in Table 10. Higher positive core schemas about the self correlated with lower scores of emotional valence (i.e., more positive voices), and more positive core schemas about others. Higher levels of anxiety also correlated with more positive voices. More negative core schemas about the self showed a correlation with higher depression scores. As there were no significant correlations between BCSS-subscales,

BAI, or BDI-II, and QPE items with one another, we did not calculate any mediation models.

Affective voice hearers. Correlations between our variables of interest are shown in Table 11. We calculated six parallel mediation models in total (models 1-6), as both BAI and BDI-II were correlated with BCSS-NS and BCSS-NO and the QPE-items. All models were significant ($p \leq .007$; see paper 3, Table 3). Path coefficients revealed that while the indirect path from BCSS-NS/BCSS-NO via BAI to the QPE items were significant in all models and showed a full mediation, the indirect path via BDI was not (see Figure 3 and 4). Coefficients for direct and indirect paths can be found in paper 3, Table 4.

Table 9. Means, standard deviations, Welch's ANOVAs and group differences according to Dunnet T3 post hoc tests for demographic and clinical characteristics of participants and variables of interest (paper 3).

	M (SD)			Welch's ANOVA					Dunnet T3 (p-values)		
	ncVH	afVH	nafVH	F	df1	df2	η^2	p	nc-VH vs. af-VH	nc-VH vs. naf-VH	af-VH vs. naf-VH
Age	29.39 (9.93)	31.14 (12.70)	41.36 (10.98)	20.70	2	90.46	.184	**<.001**	.839	**<.001**	**<.001**
Duration of illness since diagnosis	0.20 (0.56)	9.24 (9.95)	15.56 (10.07)	101.89	2	85.3	.210	**<.001**	**<.001**	**<.001**	**.002**
Number of mood episodes	0.15 (0.87)	11.50 (34.78)	9.81 (19.54)	4.78	2	36.99	.049	**.014**	.203	.054	.994
Number of hospital stays	0.06 (0.35)	1.59 (2.32)	5.98 (9.40)	24.15	2	82.43	.147	**<.001**	**<.001**	**<.001**	**.003**
BAI	9.03 (8.12)	23.91 (15.61)	17.91 (12.14)	21.24	2	101.80	.145	**<.001**	**<.001**	**<.001**	**.039**
BDI-II	6.48 (7.29)	21.34 (15.30)	18.52 (12.09)	30.01	2	105.12	.155	**<.001**	**<.001**	**<.001**	.548
BCSS-NS	2.42 (2.22)	8.83 (6.63)	7.37 (6.30)	35.76	2	112.68	.134	**<.001**	**<.001**	**<.001**	.454
BCSS-PS	15.48 (5.61)	10.83 (5.89)	11.59 (6.49)	7.69	2	89.75	.073	**.001**	**.001**	**.007**	.847
BCSS-NO	5.67 (6.29)	9.42 (6.19)	7.33 (6.26)	4.30	2	86.11	.048	**.017**	**.020**	.501	.140
BCSS-PO	14.03 (5.73)	9.69 (5.12)	11.71 (6.56)	7.03	2	87.01	.067	**.001**	**.002**	.187	.121
QPE – emotional valence	1.21 (2.77)	2.17 (2.56)	2.66 (2.69)	3.18	2	84.90	.039	**.047**	.274	**.042**	.619
QPE – experienced distress	0.39 (0.97)	1.72 (2.34)	2.33 (2.26)	22.22	2	112.37	.101	**<.001**	**<.001**	**<.001**	.322
QPE – impact on functioning	0.18 (0.47)	1.17 (2.18)	2.04 (2.53)	23.40	2	103.31	.096	**<.001**	**.002**	**<.001**	.090

Notes: ncVH = non-clinical voice hearers; afVH = affective voice hearers; nafVH = non-affective voice hearers; BAI = Beck Anxiety Inventory; BDI-II = Beck Depression Inventory II; BCSS-NS = Brief Core Schema Scale – negative self; BCSS-PS = Brief Core Schema Scale – positive self; BCSS-NO = Brief Core Schema Scale – negative other; BCSS-PO = Brief Core Schema Scale - positive other.

Tabelle 10. Kendall's τ (and p-values) between BCSS subscales, BAI, BDI, and QPE-items for non-clinical voice hearers.

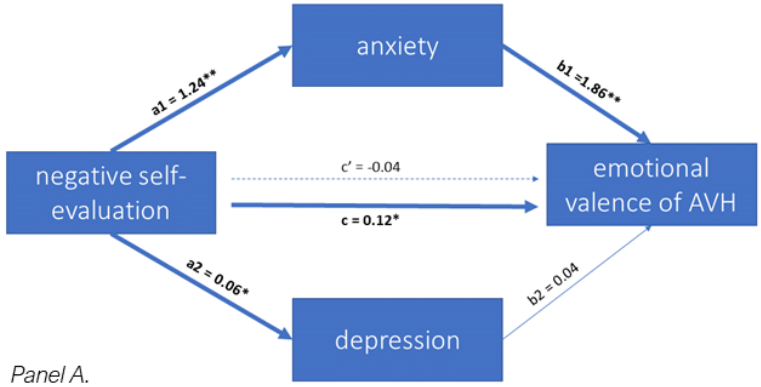
	BAI	BDI-II	BCSS-NS	BCSS-PS	BCSS-NO	BCSS-PO
BDI-II	**.337** (.008)					
BCSS-NS	.175 (.184)	**.336** (.012)				
BCSS-PS	-.038 (.767)	-.097 (.452)	-.242 (.068)			
BCSS-NO	.206 (.109)	.193 (.138)	.071 (.598)	-.086 (.508)		
BCSS-PO	-.061 (.629)	-.247 (.054)	-.145 (.274)	**.383** (.003)	.096 (.459)	
QPE – emotional valence	**-.363** (.011)	-.003 (.983)	.123 (.412)	**-.285** (.049)	-.087 (.551)	-.240 (.096)
QPE – experienced distress	.224 (.120)	.119 (.415)	.107 (.480)	.007 (.963)	-.134 (.361)	-.192 (.185)
QPE – impact on functioning	.173 (.238)	.086 (.563)	.090 (.558)	-.082 (.580)	-.049 (.742)	-.268 (.117)

Notes: BAI = Beck Anxiety Inventory; BDI-II = Beck Depression Inventory II; BCSS-NS = Brief Core Schema Scale – negative self; BCSS-PS = Brief Core Schema Scale – positive self; BCSS-NO = Brief Core Schema Scale – negative other; BCSS-PO = Brief Core Schema Scale - positive other.

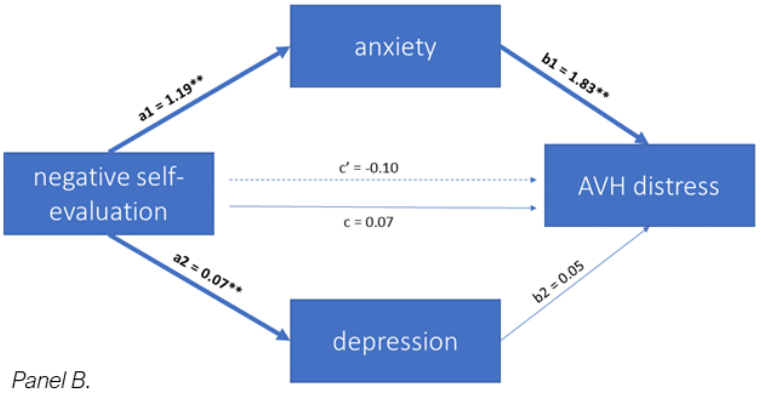
Tabelle 11. Kendall's τ (and p-values) between BCSS subscales, BAI, BDI, and QPE-items for affective voice hearers.

	BAI	BDI-II	BCSS-NS	BCSS-PS	BCSS-NO	BCSS-PO
BDI-II	**.513** (<.001)					
BCSS-NS	**.376** (<.001)	**.623** (<.001)				
BCSS-PS	-.118 (.178)	**-.377** (<.001)	**.421** (<.001)			
BCSS-NO	**.312** (<.001)	**.288** (.001)	**.377** (<.001)	-.115 (.194)		
BCSS-PO	.005 (.959)	-.092 (.297)	-.175 (.051)	**.306** (.001)	-.046 (.604)	
QPE – emotional valence	**.372** (<.001)	**.328** (.001)	**.263** (.006)	-.112 (.245)	**.264** (.006)	-.036 (.710)
QPE – experienced distress	**.443** (<.001)	**.376** (<.001)	**.265** (.006)	-.102 (.287)	**.189** (.049)	-.071 (.459)
QPE – impact on functioning	**.387** (<.001)	**.295** (.003)	**.276** (.005)	-.098 (.319)	**.218** (.027)	-.105 (.209)

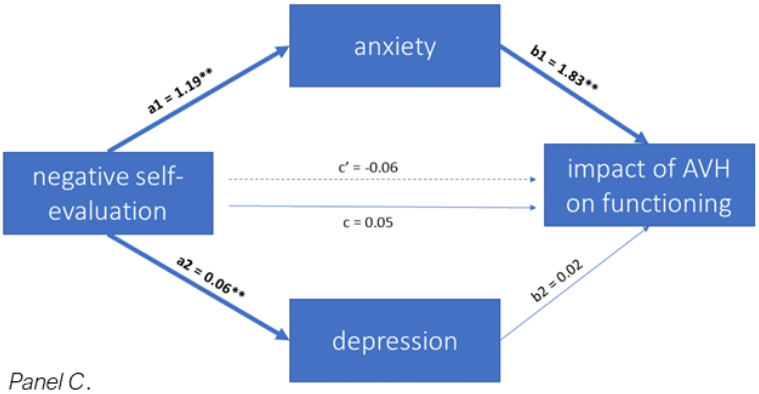
Notes: BAI = Beck Anxiety Inventory; BDI-II = Beck Depression Inventory II; BCSS-NS = Brief Core Schema Scale – negative self; BCSS-PS = Brief Core Schema Scale – positive self; BCSS-NO = Brief Core Schema Scale – negative other; BCSS-PO = Brief Core Schema Scale - positive other.



Panel A.
Model 1 – emotional valence of AVHs

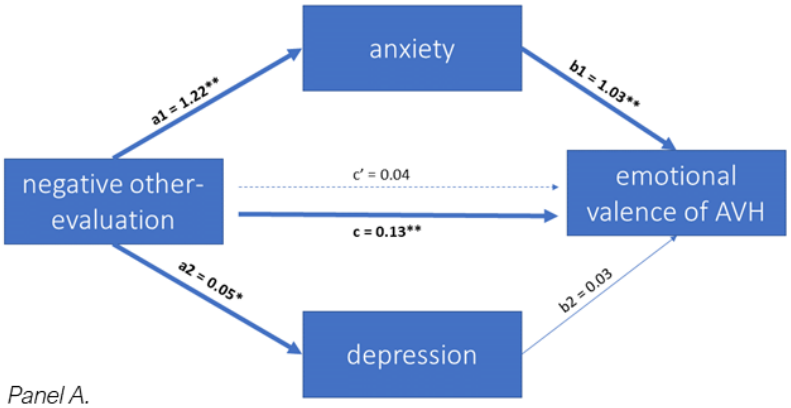


Panel B.
Model 2 – distress due to AVHs

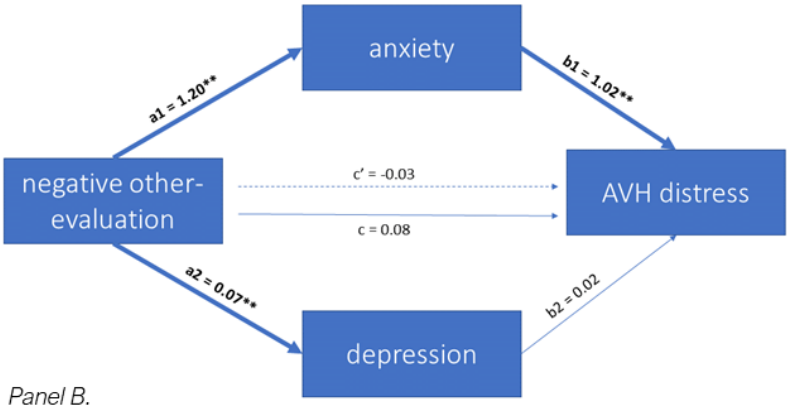


Panel C.
Model 3 – impact of AVHs on functioning

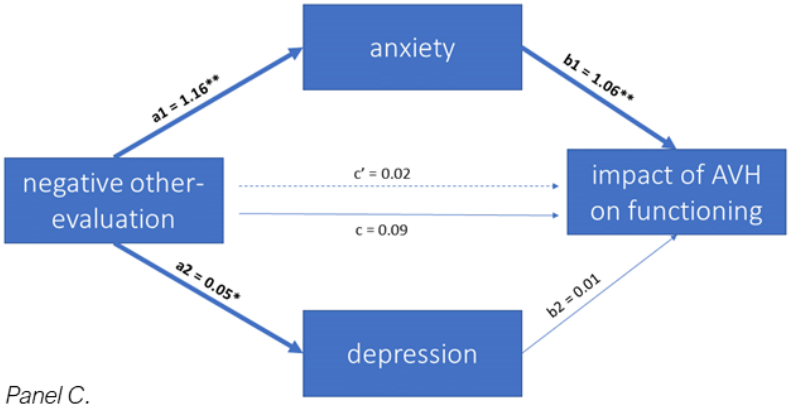
Figure 3.
Parallel mediation models in affective voice hearers between negative schemas about the self and emotional AVH phenomenology, with anxiety and depression as mediator.



Panel A.
Model 4 - emotional valence of AVHs



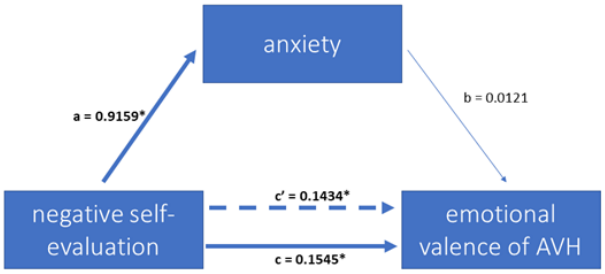
Panel B.
Model 5 – distress due to AVHs



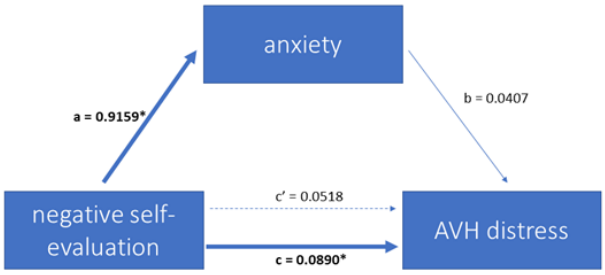
Panel C.
Model 6 – impact of AVH on functioning

Figure 4.
Parallel mediation models in affective voice hearers between negative schemas about others and emotional AVH phenomenology, with anxiety and depression as mediator.

Non-affective voice hearers. Correlations between our variables of interest are shown in Table 12. We calculated three simple mediation models, as only BAI correlated with BCSS-NS/BCSS-NO and QPE-items. Only two models (models 7-8), with BCSS-NS as predictor, were significant ($p \leq .023$; see paper 3, Table 3). While in model 7, the indirect pathway from BCSS-NS via BAI to emotional valence was not significant, model 8 showed a significant indirect pathway from BCSS-NS via BAI to AVH-related distress (see Figure 5). Coefficients for direct and indirect pathways are presented in paper 3, Table 5.



Panel A.
Model 7 – emotional valence of AVHs



Panel B.
Model 8 - distress due to AVHs

Figure 5.
Simple mediation models in non-affective voice hearers between negative schemas about the self and emotional AVH phenomenology, with anxiety as mediator.

Tabelle 12. Kendall's τ (and p-values) between BCSS subscales, BAI, BDI, and QPE-items for non-affective voice hearers.

	BAI	BDI-II	BCSS-NS	BCSS-PS	BCSS-NO	BCSS-PO
BDI-II	**.417** (<.001)					
BCSS-NS	**.329** (<.001)	**.477** (<.001)				
BCSS-PS	-.124 (.123)	**-.282** (.001)	**-.403** (<.001)			
BCSS-NO	**.238** (.004)	**.327** (<.001)	**.421** (<.001)	-.111 (.177)		
BCSS-PO	-.010 (.903)	**-.243** (.003)	-.077 (.346)	**.358** (<.001)	-.118 (.154)	
QPE emotional valence	**.207** (<.001)	.133 (.127)	**.268** (.002)	**-.192** (.028)	**.203** (.023)	.059 (.500)
QPE experienced distress	**.251** (.003)	.163 (.059)	**.172** (.048)	-.088 (.306)	.133 (.128)	.031 (.722)
QPE impact on functioning	**.219** (.011)	.138 (.115)	.095 (.279)	-.058 (.505)	.138 (.120)	.043 (.618)

Notes: BAI = Beck Anxiety Inventory; BDI-II = Beck Depression Inventory II; BCSS-NS = Brief Core Schema Scale – negative self; BCSS-PS = Brief Core Schema Scale – positive self; BCSS-NO = Brief Core Schema Scale – negative other; BCSS-PO = Brief Core Schema Scale - positive other.

5. Discussion

The aim of this thesis was to look at PLEs in general, and AVHs specifically from both a continuous and transdiagnostic perspective, by investigating underlying neurobiological, cognitive, and emotional processes in different populations, ranging from healthy individuals to patients with different underlying psychopathology.

5.1. Paper 1

In paper 1 we examined the psychometric properties of the QPE screening questionnaire (Sommer et al., 2018) in a sample drawn from the general population and investigated the frequency and predictors of PLEs.

5.1.1. Psychometric Properties

Our first aim was to examine the psychometric properties of the QPE screening questionnaire. Measures for retest reliability showed high concordance rates between the answers at the two time points, indicating that the QPE screening questionnaire is a stable measure. Only the item about paranoia had a medium concordance rate. In general, the screening questions are phrased rather broadly. This reduces stigma and lowers the threshold of reporting PLEs but might also lead to higher fluctuations in participants' answers over time even in non-clinical populations (Garety & Freeman, 2013).

Concordance rates between the selected items of the PDI/CAPS and the QPE screening questionnaire showed considerable variation. QPE items were designed to capture a lot of information about PLEs by merging questions of different existing instruments. At the same time, the wording of the QPE items was modified such that they represent one common theme. As a result, there is varying overlap between the phrasing of QPE items and items from other instruments (Rossell et al., 2019). For example, for the QPE screening item that asks about visual hallucinations ('It sometimes occurs that people see a person, animal or object that others cannot see. For some people, this can be a shade or shadow. Have you seen any of those objects, persons or images?'), there are two corresponding items in the CAPS ('Do you ever see shapes, lights or colours even though there is nothing really there?', 'Do you ever see things that other people cannot?'). These modifications might be an explanation for the high variation in effect sizes and the difference in the psychometric properties to the full QPE interview. There were no corresponding items in the PDI or CAPS for delusions of nihilism and misidentification, as these delusions are typically not employed in psychiatric assessments due to their neurological character and the fact that they are very rare (Rossell et al., 2019).

The internal structure revealed two components: hallucinatory experiences and delusional experiences. While a solution with two components is highly intuitive, given that there were items about hallucinatory and delusional experiences, Rossell et al. (2019) found a 3-factor solution in the full QPE interview. That is, one factor each for auditory and visual hallucinations, as well as a unidimensional solution for delusions. Tactile and olfactory hallucinations were not included in the analysis, as there were no

other validation instruments available in a semi-structured interview format. In comparison to our study, however, the authors analysed the follow-up questions of the interview and not the screening questions (Rossell et al., 2019). Cronbach's alpha for the two factors in the present study were moderate. This is not surprising given that it reflects the heterogeneity of hallucinatory and delusional experiences in the clinical reality: For example, while having hallucinatory experiences in one modality increases the odds of having hallucinatory experiences in other modalities, many individuals experience hallucinations in either only a single modality (auditory, visual, tactile, olfactory), or in only a subset of all possible modalities, in various combinations (Larøi, Bless, et al., 2019). This is also true for delusions. Taken together, the QPE screening questionnaire has satisfactory reliability and validity and can be used as a complementary tool for epidemiological studies: It provides less information than the full QPE interview but can be carried out much faster and does not require trained interviewers.

One should also bear in mind that while the low-threshold wording of the screening items invites participants to be more open about their experiences, the phrasing is also likely going to yield rather high endorsement rates of PLEs.

5.1.2. Mapping endorsement rates of PLEs

The second aim of the study was to map PLEs in our sample. The proportion of individuals in our sample with a diagnosed mental disorder was rather high (30%), as compared to an estimated 11% of individuals suffering from any mental health disorder

worldwide, according to the World Health Organization (Ritchie & Roser, 2018). Therefore, we mapped PLEs for participants with and without a diagnosed mental disorder separately.

Both lifetime and current PLEs were consistently reported more often by individuals with a mental disorder. This was to be expected, as PLEs are associated with a wide range of mental disorders and reflect the phenomenological continuity (Linscott & van Os, 2013). The frequency of delusional experiences with religious, grandiose and misidentification content were similar in both groups.

There were some differences between individuals with and without a diagnosed mental disorder with respect to childhood PLEs. While for all modalities of hallucinatory experiences participants without a mental disorder had higher endorsement rates than those with a mental disorder, delusional experiences did not show this pattern, as prevalence of delusional ideas were rather low in both groups. In general, however, childhood PLEs were rather rare, suggesting that when adults report lifetime PLEs they usually do not reflect childhood experiences. Kelleher and colleagues (2012) posited that PLEs are part of normal childhood experiences that decrease over time. While the authors directly tested children and adolescents, we investigated PLEs in adults. This approach might give room for a memory bias that is connected to reporting retrospective life-events (Lalande & Bonanno, 2011; Van den Bergh & Walentynowicz, 2016). Another potential issue is that we did not further define “childhood” when we asked participants about their experiences. We worded our question as “Did you experience this only when you were a child?”. Thus, the

definition of "when you were a child" may have varied between the participants, which might have made it difficult for participants to classify their childhood PLEs as such.

Regardless of individuals with and without a mental disorder, in general, frequencies in lifetime PLEs were rather high. Between 4.0% and 71.3% of participants in our sample reported experiencing PLEs in their life. In comparison, Bourgin and colleagues (2019) reported more than 26% with at least one lifetime PLE, while prevalence rates of lifetime PLEs in Linscott and van Os (2013) ranged between 1.2% to 25.5%. In the present study, hallucinatory experiences in both individuals with and without a mental disorder were reported typically by 40% and more (lifetime perspective). For hallucinatory experiences in the auditory modality, for example, a meta-analysis reported a prevalence rate of below 10% (Maijer et al., 2018). In the present study the rate was 50% and 43% for participants with and without a mental disorder, respectively. For delusional experiences, there was a large variation, with highest endorsement rates for paranoia. The large variation is in accordance with the results of a recent review article, however, that reported rates between 3% to 91% for different delusional experiences (Heilskov et al., 2019). The high PLEs rates in the present study are likely due to the fact that the online survey was advertised as a project to assess PLEs, which probably attracted individuals who have had such experiences. As outlined above, another reason could be the open phrasing of the QPE screening questions. This possibility aligns with the similar high prevalence of endorsement in studies using the full QPE interview (Begemann et al., 2019; de Boer et al., 2019).

5.1.3. Predictive factors of PLEs

Irrespective of whether participants had a diagnosed mental disorder or not, young age, lower education, parental mental disorder, and the use of illegal drugs and alcohol were significantly associated with higher frequency of PLEs. Thus, despite a possible selection bias in our convenience sample, these findings replicate previous studies regarding age, parental mental disorder, and drug consumption effects on PLEs (Bourgin et al., 2019; Linscott & van Os, 2013; Pignon et al., 2018). The results are more inconsistent regarding education: Both Bourgin et al. (2019) and Pignon et al. (2018) found a higher prevalence for 'at least one PLE' in individuals with a secondary education level and higher, but Linscott and van Os (2013) did not find an association between education and PLEs. This discrepancy might arise from the fact that Linscott and van Os (2013) conducted a meta-analysis based on several samples, while Bourgin et al. (2019) and Pignon et al. (2018) had only one sample in their analysis. Counterintuitively, we found that the consumption of more alcohol is associated with fewer PLEs. Possibly, alcohol consumption reflects the social behaviour of participants in our sample, meaning that individuals go out more often and therefore consume alcohol more often per week. The resulting social network might function as a protective factor against the onset and recurrence of mental disorders (Avison, 1996). In general, however, the standardized coefficients did not exceed beta=.17, suggesting that the correlations we found in the present study were weak and their significance was rather the result of the large sample.

5.1.4. Discriminating individuals with and without mental disorders

Finally, we investigated whether PLEs, as assessed with the QPE screening questionnaire, can discriminate between people with and without a mental disorder, to test the assumption of structural continuity (Linscott & van Os, 2013). Five QPE items were found to significantly discriminate between people with and without a mental disorder. These included items assessing (in decreasing order of calculated odds ratios): delusional experiences of guilt and paranoia, visual hallucinatory experiences, and delusional experiences of religiosity and nihilism. The significance levels of both delusional experiences of guilt and paranoia were much higher than those of the other significant items. This is in line with another study that reported delusional experiences of guilt and paranoia to be discriminators between psychotic and non-psychotic patients (Verdoux et al., 1998). However, the highest odds ratio in the present study was 2.4, implying that participants indicating "yes" on the item about delusional experiences of guilt have 2.4 times the odds of having a diagnosed mental disorder. Moreover, the logistic regression model showed a poor level of discrimination between the two groups. Both, the positive and the negative predictive values congregate around 50%, which can also be based on chance. The fact that the presence (or absence) of PLEs appears to be fairly similar in both groups, although the frequency of PLEs is generally higher in individuals with a diagnosed mental disorder, supports the phenomenological aspect of the continuum hypothesis of PLEs (Linscott & van Os, 2013). These data show that the mere experience of a PLE does not provide much information about mental health status, as such experiences are ubiquitous. In the full QPE interview, additional questions are asked regarding the underlying phenomenology of PLEs. This

information is necessary to differentiate between groups with and without mental health issues.

5.1.5. Limitations

The results of our study should be interpreted in the light of some limitations. Firstly, while our online survey was completed by a high number of participants, thus providing good statistical power and the possibility to compare subgroups, it attracted mostly female and highly educated participants, implying that this is not a representative sample of the general population; this makes it difficult to generalize our findings. This is a typical issue with convenience samples in epidemiological research on PLEs and in online surveys in general (Armando et al., 2010). As pointed out above, the sample selection, together with the open phrasing of the QPE items, could account for the relatively high PLE rates. The self-reporting nature of the QPE screening questionnaire could have further contributed to the high frequency. Linscott and van Os (2013) demonstrated a higher prevalence rate of PLEs in studies where researchers only used self-report measures in comparison to interview measures. However, there is also evidence that self-report instruments rather underestimate subthreshold PLEs which speaks for a social desirability bias (DeVylder & Hilimire, 2015). Moreover, while our strategy to use Facebook as a tool to recruit a lot of participants has been used previously and proved to be a viable approach (Kosinski et al., 2015), the downside of this recruitment strategy is that a high number of clicks does not automatically translate into high quality data (Crosier et al., 2016). This made it

necessary to include survey validity items and have a rigid data cleaning procedure. In addition, we did not assess ethnicity, migration status, and the context in which PLEs were occurring, such as in sleep or while intoxicated, which are all relevant factors (Tortelli et al., 2018; Waters & Fernyhough, 2017). Finally, clinical diagnoses were self-reported, and we had to trust participants, as we had no possibility to validate the diagnoses externally.

5.1.6. Summary

Despite the issues with representativeness, the present study allows drawing a couple of conclusions with relevance to the ongoing debate about PLEs in the general population. First, we showed that the QPE screening questions have satisfactory psychometric properties. Researchers need to be aware that because of the open phrasing it is likely to yield higher reported frequencies of PLEs. Still, the open phrasing reduces the risk that participants refrain from reporting PLEs due to social desirability. We also showed that a range of PLEs, especially hallucinatory experiences, are ubiquitous in both individuals with and without a diagnosed mental disorder. Corroborating previous research, PLEs were predicted by young age, being female, use of illegal drugs and parental mental disorder. Finally, the finding that the presence of PLEs discriminates rather poorly between individuals with and without a diagnosed mental disorder further supports the continuum hypothesis, implying a spectrum from subthreshold experiences in healthy individuals to severe symptoms of psychosis in those with mental disorders.

5.2. Paper 2

The focus of paper 2 lay on neurobiological mechanisms of source monitoring processes in healthy individuals. We examined reality monitoring and internal source monitoring abilities with the tDCS anode and cathode placed over the left STG and DLPFC, respectively. While tDCS had no effect on reality monitoring, neither in the offline nor in the online experiment, internal source monitoring was significantly improved with real tDCS as compared to sham in the online experiment. Participants made both fewer externalization and internalization errors, while the number of incorrectly identified distractors was similar.

5.2.1. Reality monitoring

Our main findings are in line with the current literature. Mondino et al. (2016) found a modulatory effect of anodal tDCS in the left STG, where stimulation increased the number of errors (i.e., imagined words were incorrectly recognized as heard) in reality monitoring abilities. While the electrical current of real tDCS (i.e., 2mA) and the timing of the task (i.e., it also started after 5 minutes of stimulation) was similar to our study, the authors used a different electrode setup. The separate anodal/cathodal stimulation of left PFC and left STG, in combination with a contralateral reference electrode over the right occipital lobe in Mondino et al. (2016), might have led to different modulatory effects, as a larger distance between electrodes leads to a different localization of the peak electrical field (Miranda et al., 2013). Moseley et al. (2018) did not find any effects of real tDCS on reality monitoring, but they used a contralateral

frontotemporal electrode setup (not ipsilateral) and a lower electrical current than in the present study (i.e., 1 mA vs. 2 mA). They suggest that the PFC plays a less important role in reality monitoring than previously assumed, as this region shows increased activation during retrieval of source information, with a focus on monitoring self-generated information (Mitchell & Johnson, 2009) and acting as a gateway between task relevant and task independent thought (Burgess et al., 2007). According to Moseley et al. (2018), the activation for related processes that are used during reality monitoring is valid, but it is not causally necessary for encoding or source judgements.

5.2.2. Internal source monitoring

For internal source monitoring, the involvement of the STG is not so clear from the literature. While inhibiting activity in the temporo-parietal cortex with rTMS led to both reduced frequency of AVHs and increased internal source monitoring abilities in patients with schizophrenia (Brunelin, Combris, et al., 2006), Mondino et al. (2016) could not show a modulation of those abilities in healthy people when stimulating this area with anodal tDCS, even though the peak activation of tDCS is suggested to lie within this brain area (Mondino et al., 2020).

A possible explanation for these inconsistent results may be provided by another study from our group (Marquardt et al., 2020) that found (1) no excitatory/inhibitory effect underneath the electrodes in the ipsilateral frontotemporal montage and (2) that the electrical field was strongest in the left central sulcus region/Broca's area – between the two electrodes. Together with the finding of the present study that internal source

monitoring is affected by the frontotemporal montage (but not reality monitoring) this implies that Broca's area might be specifically important for internal source monitoring abilities. This may not be surprising given that Broca's area is also involved in lexical, grammatical, and phonological processing (Sahin et al., 2009), as well as verbal working memory (Chein et al., 2002). In addition, Flinker et al. (2015) reported in their study that Broca's area specifically has a mediating role in speech production processes by sending articulatory codes that originate from temporal areas (where neural representations of words are created) to the motor cortex (where these articulatory codes are turned into gestures). These articulatory codes (which are a combination of semantic, syntactic, and phonological information) have been suggested to be the core elements of inner speech (Alderson-Day & Fernyhough, 2015). The excitation of neurons specialized for speech production in our study might have led to an enhanced ability to differentiate between imagined and spoken words. Thus, while Mondino et al. (2016) and Moseley et al. (2018) seem to have targeted the PFC and STG more directly, as their electrodes were placed further apart, we might have simply not stimulated the same brain areas, leading to different results.

Furthermore, it is important to note that both an externalizing and internalizing bias was induced by tDCS – but no modulation of the distractor words. If the number of distractor words had also been affected, this would have been indicative of a more general effect of tDCS on memory processes. The fact that distractor words were not affected further supports the notion that Broca's area is specifically involved in internal source monitoring processes.

5.2.3. Offline vs. online tDCS

As adverse effects did not differ between the offline and online experiment, and the guessing of whether they received real or sham tDCS was not above chance level, we can assume that the blinding of real and sham stimulation conditions worked, and that participants' expectations regarding real/sham stimulation did not affect the results. Similar results regarding blinding were reported by other authors who specifically investigated the differences between real and sham stimulation in tDCS (Gandiga et al., 2006; Palm et al., 2013).

Another result was that we only found a modulatory effect of source monitoring in the online, but not the offline experiment. This has previously been demonstrated by other authors (Martin et al., 2014; Stagg & Nitsche, 2011), who reported that timing tDCS with motor learning and cognitive training tasks simultaneously (i.e., online tDCS) yielded better performance outcomes than offline tDCS.

5.2.4. Limitations

The results in the offline experiment could have been confounded by the participants being tired after the scanning protocol. Secondly, participants in the offline experiment were performing an acoustic language task (i.e., dichotic listening, Hugdahl, 2009) in the MR scanner while receiving tDCS (Marquardt et al., 2020), which might have led to a different outcome as compared to the online experiment. Thirdly, there was a break between the termination of tDCS and the beginning of the

source monitoring task of roughly 20 minutes, in which two more MR-sequences were applied and electrodes had to be removed from the scalp. This timespan might have reduced the impact of tDCS on source monitoring tasks. Finally, participants in the offline experiment were significantly older than in the online experiment. However, given the means were 26 and 23 years, respectively, we find it hard to believe that this could account for the different outcomes of the experiments.

Another potentially limiting factor in general, is the relatively few discrete responses (16 per source monitoring task, eight per dependent variable) and the relatively few mistakes (range: 0-25%). Thus, our findings rest on relatively few events. As pointed out by Moseley et al. (2018) the difficulty could be increased by introducing a break between the encoding and testing phase. However, that would make it difficult to include both phases in a single tDCS period. For the same reason, increasing the number of trials would make it difficult to complete both tasks in the short stimulation window. As one of our goals was to corroborate the findings of Mondino et al. (2016) we opted for similar tasks and experimental designs. We tried to compensate for the few trials by testing a reasonable number of participants, given that this was a tDCS-study with a repeated design.

5.2.5. Summary

In summary, the current study is in line with previous findings that tDCS over prefrontal and temporo-parietal areas affects source monitoring in healthy participants, in general. Beyond the existing literature, however, it suggests that reality monitoring

and internal source monitoring involve different brain structures: While reality monitoring may be more specifically linked to (left) prefrontal and temporo-parietal areas, internal source monitoring rather seems to involve Broca's area. Still, more studies are needed to look at the potential different contributions of STG and Broca's area in different types of source monitoring, to identify distinctive mechanisms of speech production and speech perception in source monitoring mechanisms.

5.3. Paper 3

In paper 3, we examined the role of core schemas about the self and others in voice hearers with no or different underlying psychopathology and the effect of emotions on AVH phenomenology. The aim was to determine whether core schemas of the self and others predicted emotional aspects of AVH phenomenology, and if this prediction was mediated by anxiety and depression. In non-clinical voice hearers, mediation models could not be calculated, since there were no significant correlations between core schemas, anxiety, depression, and emotional aspects of AVH phenomenology.

5.3.1. Non-clinical voice hearers

Non-clinical voice hearers had the lowest scores for negative core schemas about the self and others, and the highest scores for positive core beliefs about the self and others. In addition, this group had minimal depression levels and very mild anxiety levels (see Table 9). Thus, the lack of significant correlations between all three

concepts might be due to the non-help-seeking status of the group, and possible floor effects of the measures. There was, however, a negative correlation between anxiety and emotional valence of AVHs, meaning that higher anxiety was associated with more positive voices (as indicated by the scoring of the QPE item, where lower scores represent positive voices, and higher scores represent negative voices). That non-clinical voice hearers experienced fewer negative voices is a consistent finding (Baumeister et al., 2017), and might serve as a protective mechanism when experiencing anxiety.

5.3.2. Affective vs. non-affective voice hearers

For affective voice hearers, depression was not a significant mediator between negative core schemas and emotional aspects of AVH phenomenology. Only anxiety served as a significant mediator, with more negative schemas (about both the self and others) predicting greater anxiety, which in turn predicted more negative voices, more AVH-related distress, and a greater impact on functioning. Here, anxiety fully accounted for the association between negative schemas and emotional AVH characteristics as there is no direct impact of core schemas. This can be understood as a reflection of broader anxiety levels. In comparison, for non-affective voice hearers, whilst anxiety and depression were associated with negative schemas, neither appeared to mediate any of the relationships between core schemas and emotional aspects of AVH phenomenology. Especially for the prediction of negative voice content, the absence of a significant indirect effect and presence of a significant direct effect implies

that in non-affective voice hearers, negative voice content directly reflects core schemas independent of emotional symptoms, which has also been suggested by Scott et al. (2020).

In general, this is in line with the main theoretical assumption of the development of core schemas, that negative affect plays a key role (Garety et al., 2001), and also with empirical evidence even though Jaya et al. (2018) did not differentiate between anxiety and depression in their study. This is also in line with Oliver et al. (2012) who found that negative schemas predicted the level of delusional ideation, which was mediated by anxiety, but not depression. It seems that these positive symptoms of psychosis share a common trait here. In addition, Barrowclough et al. (2003) also found that schemas in patients with psychosis were independent of depression.

When differences between affective and non-affective voice hearers were examined, anxiety was the only variable where groups differed from each other. Both groups had moderate levels of anxiety, according to the interpretation scale of the BAI (see Table 9). But while non-affective voice hearers had scores at the lower end of the scale (mean score: 17.91), affective voice hearers had scores at the higher end, at the border to severe anxiety (mean score: 23.91). In our sample, non-affective voice hearers were older, and had a longer duration of illness, but at the same time had fewer mood episodes in the past than affective voice hearers. Solano and Whitbourne (2001) suggest that older individuals with persistent positive symptoms use similar coping strategies as younger individuals, but the perceived efficacy of the strategies employed had increased (i.e., higher perceived efficacy in older individuals). The authors argue

that this was associated with greater levels of acceptance of illness by the older age group (Solano & Whitbourne, 2001). Over the course of their treatment, non-affective voice hearers might have gained more experience in coping with the anxiety that accompanies the experience of AVHs and use more adaptive strategies (El Sheshtawy, 2011) to manage their anxious mood, compared to affective voice hearers.

In affective voice hearers, negative core schemas about the self predicted the emotional valence of AVHs (model 1), distress about AVHs (model 2) and impact of AVHs on functioning (model 3), which were all only mediated by anxiety. The same pattern held true for negative core schemas about others (models 4-6). In all models, the direct path from negative core schemas to AVH phenomenology was not significant, which indicates full mediation of anxiety. For non-affective voice hearers, only negative core schemas about the self showed a direct relationship with the emotional valence of AVHs (model 7), and AVH distress (model 8), both independent of anxiety and depression. This was in line with Smith et al. (2006) who found an association between the amount and degree of negative voices, and negative core schemas about the self in non-affective voice hearers, but this association was not found for negative core schemas about others. It remains unclear, however, why negative evaluations about others are important in affective voice hearers. Garety et al. (2001) suggested that information processing biases, safety behaviours and meta-cognitive beliefs are of importance, as they are traditionally associated with anxiety disorders. These processes might have a greater influence in affective voice hearers compared to non-affective voice hearers.

5.3.3. Limitations

Our study was the first that compared the mediating effects of anxiety and depression in the relationship between core schemas and phenomenological AVH aspects in different groups of voice hearers, using a transdiagnostic approach. However, our study comes with some limitations. First, even though we had a sizeable sample, the number of participants in the different voice hearing groups was not equal. This could have impacted statistical power to detect group differences. Second, our results were based on cross-sectional analyses of the data. Therefore, it is not possible to establish a causal relationship. Third, path coefficients were rather low for indirect paths compared to direct pathways in all the models, suggesting that other factors might be involved in these processes as well, for example, information processing biases. The significance of complete mediation models might also be driven by very strong direct effects between two variables (e.g., model 8: the strong association between negative core schemas about the self and anxiety).

5.3.4. Summary

Taken together, our findings suggest that negative schemas influence emotional aspects of AVH phenomenology differently depending on the underlying psychopathology. In voice hearers with an affective disorder, higher negative schemas predicted higher levels of anxiety (but not depression), which in turn led to more negative voices, more distress, and a greater negative impact on functioning. This indicates a stronger influence of emotional processes in voice hearers with affective

disorders, compared to voice hearers with schizophrenia or schizoaffective disorder, where negative voice content directly reflects core schemas of the self and others. However, future studies are needed to uncover the complex dynamic between negative core schemas and negative consequences of AVHs. Especially longitudinal study designs are encouraged, to further investigate the role of anxiety in the development and maintenance of transdiagnostic AVHs and their effects over time. In addition, negative core schemas about the self and others seem to affect groups of voice hearers differently. A broader study design, that integrates other important factors such as childhood adversity, emotion regulation, and coping strategies, might uncover the mechanisms behind these different aspects of core schemas. These integrative approaches will be useful to reveal the complex influence of emotions and their related processes to reveal potential targets for the treatment of transdiagnostic AVHs arising from different underlying psychopathologies.

6. Conclusion

The main purpose of this thesis was to examine PLEs and AVHs in different populations along a continuum, by looking at underlying neurobiological, cognitive, and emotional processes. The findings support the notion that PLEs in general and AVHs specifically, are distributed on a structural and phenomenological continuum (Linscott & van Os, 2013), as the presence of PLEs does not discriminate between individuals with and without a mental disorder, and individuals with mental disorders reported more frequent lifetime and current PLEs than individuals without a mental disorder. While the endorsement of having had PLEs in life does not give much information about the mental health status, it is rather the severity and intensity of those experiences that distinguishes these groups.

Neurobiological models of AVHs suggest the activation of a broad network of brain areas which are involved in dysfunctional inner speech processes and stretches from *hypo*activated frontal to *hyper*activated temporo-parietal cortices. These are also associated with cognitive processes called source monitoring (Johnson et al., 1993; Mitchell & Johnson, 2009), which can be studied by neuromodulation techniques such as tDCS (Mondino et al., 2016; Moseley et al., 2018), even though the underlying mechanisms of tDCS are still unclear. By modulating the STG and DLPFC and therefore healthy individuals' behaviour, we found that the misattribution of inner speech processes to internal sources (i.e., internal source monitoring) might be related to different areas in the brain than the misattribution to external sources (i.e., reality monitoring). Our findings suggest that internal source monitoring seems to involve

Broca's area, which has a mediating role in speech production processes and is responsible for both articulatory and phonemic information. When neural representations of spoken words are created in sensory areas, they are forwarded to the prefrontal cortex. Broca's area links these representations to an articulatory code that is forwarded to and implemented by motor cortices responsible for the actual act of speaking (Flinker et al., 2015). At the same time, forward models (McCarthy-Jones, 2012) suggest that 'efference copies' from speech production and vocalization areas in the frontal lobe prepare temporal cortices responsible for auditory processing for the arrival of self-generated speech sounds. When spoken words and the predictions of those (i.e., 'efference copies') align, then the activity of the auditory cortex is suppressed, which allows speech to be recognized as self-generated (Mathalon & Ford, 2008). As Broca's area lies within these auditory areas, active tDCS might have put an emphasis on these 'efference copies' by increasing the excitability in neurons responsible for generating articulatory codes, and therefore enable individuals to distinguish between outer and inner speech even better.

Based on these neurobiological mechanisms, and depending on the involvement of other additional cognitive resources, such as working memory (Jenkins et al., 2018), attention focus, and cognitive control (Hugdahl et al., 2013), an imbalance of such aspects of inner speech might determine if hearing an "inner voice" is misattributed (Alderson-Day & Fernyhough, 2015). This is due to a competition for these cognitive resources (Ford & Hoffman, 2013), which may be limited due to information processing biases aggravated by heightened emotions such as anxiety (Garety et al., 2001), or negative core schemas about the self and others that are predicted by adverse

early life experiences (Scott et al., 2020). Negative core schemas are internalized and express themselves as more negative AVHs that are more distressing and have a higher impact on functioning, with affective voice hearers being differently influenced by anxiety than non-affective voice hearers. Even though clinical voice hearers have similar levels of AVH phenomenology, core schemas and depression scores, it is the experienced anxiety in individuals with an underlying affective mental disorder (i.e., major depressive disorder and bipolar disorder) that seems to activate these negative voice experiences. For non-affective voice hearers, on the other hand, negative emotional AVH phenomenology seems to be a direct representation of negative core schemas. In that sense, emotional factors build the bridge between neurobiological mechanisms of inner speech processes and how AVHs are expressed phenomenologically, depending on the emotion that is predominant. These differences in the interplay of neurobiological, cognitive, and emotional aspects serve as an example of how a transdiagnostic continuous approach can benefit the current discourse about AVHs and can also have implications for cognitive behavioural treatment strategies. Even though there are "many roads that lead to Rome", with multiple pathways that therapists and clients can embark on to treat AVHs, a focus on core schemas in non-affective voice hearers and on emotion regulation strategies in affective voice hearers might lead to more effective treatment results, and, hence, improved functioning in everyday life.

Future research is encouraged to continue looking at neurobiological and cognitive aspects of PLEs on a clinical and non-clinical level. Study designs that integrate separate processes on different levels, such as the "levels of explanation"

approach by Hugdahl and Sommer (2018) will help in gaining knowledge and understanding the complexity of PLEs in general and AVHs specifically. Approaching these phenomena with longitudinal designs will help to identify markers of specific processes that help predicting the transition from non-clinical to clinical states and can lead to early treatment. In addition, mixed-methods studies that combine quantitative and qualitative research approaches, such as the study from Toh et al. (2020), will help deepen the understanding of PLEs. From a transdiagnostic perspective, this can also benefit the treatment of other mental disorders. The implementation of new methods such as tDCS as a treatment of AVHs, should, however, be done with care when the underlying mechanisms are not yet fully understood.

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Personality and Social Psychology

Mapping psychotic-like experiences: Results from an online survey

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Suggestions have been made that psychotic-like experiences (PLEs), such as hallucinatory and delusional experiences, exist on a continuum from healthy individuals to patients with a diagnosis of schizophrenia. We used the screening questions of the Questionnaire for Psychotic Experiences (QPE), an interview that captures the presence and phenomenology of various psychotic experiences separately, to assess PLEs in Norway. Based on data from an online survey in a sample of more than 1,400 participants, we demonstrated that the QPE screening questions show satisfactory psychometric properties. Participants with mental disorders reported more frequent lifetime and current hallucinatory experiences than participants without mental disorders. Childhood experiences were rather low and ranged from 0.7% to 5.2%. We further replicated findings that young age, illegal drug use, lower level of education, and having parents with a mental disorder are associated with higher endorsement rates of PLEs. Finally, a binomial regression revealed that the mere presence of PLEs does not discriminate between individuals with and without a mental disorder. Taken together, the findings of the present study support existing models that both hallucinations and delusions exist on a structural and phenomenological continuum. Moreover, we demonstrated that the QPE screening questions can be used by themselves as a complementary tool to the full QPE interview.

Key words: Delusions, Hallucinations, Predictors, Psychosis, Questionnaire for Psychotic Experiences, Transdiagnostic.

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INTRODUCTION

Hallucinatory and delusional experiences occur not only in psychotic disorders, such as schizophrenia (Aleman & Larøi, 2008; Andreasen & Olsen, 1982; Hugdahl & Sommer, 2018; Waters, Badcock, Michie & Maybery, 2006), where they have the status of first-rank positive symptoms (American Psychiatric Association, 2013), but they also occur in other disorders including, mood disorders, Alzheimer disease, migraine, hearing loss or borderline personality disorder (Baryshnikov, Suvisaari, Aaltonen *et al*., 2018; Linszen, Brouwer, Heringa & Sommer, 2016; Linszen, Lemstra, Dauwan, Brouwer, Scheltens, & Sommer, 2018; Merrett, Rossell & Castle, 2016; Vreeburg, Leijten & Sommer, 2016). In addition, *psychotic-like experiences* (PLEs) are defined as being hallucinations and/or delusions (Linscott & van Os, 2013), that do not fulfill diagnostic criteria for a mental disorder and are known to be present in the general population (Kelleher & Cannon, 2011). There are many other terms for not (yet) clinically relevant psychotic experiences in the scientific literature, for instance, "unusual experiences", "subthreshold psychotic experiences", "putative pre-psychotic states", "subclinical psychotic experiences", "sub-psychotic experiences" or "putative prodromal states" (e.g. Bourgin, Tebeka, Mallet, Mazer, Dubertret & Le Strat, 2019; Cella, Vellante & Preti, 2012; Jolley, Kuipers, Stewart, Browning, Bracegirdle Basit & Banerjea, 2018; Koyanagi, Stickley & Haro, 2016; Liu *et al*., 2013; Wigman *et al*., 2011). In this study, we prefer the term "psychotic-like experiences"/"PLEs," because it is used by most studies in the field and aims to reduce the stigma that is connected to psychotic episodes (Daalman, Diederen, Hoekema, van Lutterveld & Sommer, 2016; Kingdon, Vincent, Vincent, Kinoshita & Turkington, 2008; Sommer, Daalman, Rietkerk *et al*., 2010).

Crucially, the term PLEs reflects the essence of the continuum hypothesis, which posits that PLEs increase in symptom severity and persistence from healthy individuals to patients with a diagnosis of schizophrenia (Baumeister, Sedgwick, Howes & Peters, 2017; Linscott & van Os, 2013). It is not only valid for PLEs in general, but also for delusional (Freeman, 2006; Varghese, Scott & McGrath, 2008) and hallucinatory experiences (Aleman & Larøi, 2008; Badcock & Hugdahl, 2012) separately. The hypothesis can be understood in different ways: (1) *structural continuity* relates to the distribution of PLEs in the general population; (2) *phenomenological continuity* describes the idea that PLEs are independent of disorder and only differ quantitatively from dispositional or personality variables captured by the notion of psychosis-proneness or schizotypia (Daalman *et al*., 2011); and (3) *temporal continuity* refers to the idea that PLEs persist over time (Linscott & van Os, 2013).

Looking at both hallucinatory and delusional experiences together, a meta-analysis found a median lifetime prevalence for PLEs of 7.2% in the general population, ranging from 1.2% to 25.5% (Linscott & van Os, 2013). Newer studies support these findings. While a study by Pignon and colleagues (2018b) found

a prevalence rate of 22.5% of PLEs in the French general population, another recent study reports a similar rate of PLEs in a representative sample of non-institutionalized US citizens: more than 26% experienced at least one type of PLE (Bourgin *et al*., 2019).

However, hallucinatory and delusional experiences seem to have different prevalence rates in the general population. The frequency of hallucinatory experiences, for example, is modality specific. While a recent meta-analysis (Maijer, Begemann, Palmen, Leucht & Sommer, 2018) reported a general lifetime prevalence of 9.6% for auditory hallucinatory experiences, the prevalence was 7.3% for visual hallucinatory experiences in adults (Waters *et al*., 2014). The latter study was not a meta-analysis. Of specific interest is the study by Kråkvik *et al*. (2015) who found a prevalence for auditory verbal hallucinations of 7.3% hallucinatory experiences in the Norwegian population. Other modalities have been studied less frequently. Ohayon (2000) reported a frequency of 2.6% tactile (haptic) hallucinations and 1.5% for olfactory hallucinations (Ohayon, 2000). For delusional experiences, a recent review reported a high variability of endorsement for overall delusional experiences, ranging from 3% to 91% (Heilskov, Urfer-Parnas & Nordgaard, 2019).

PLEs have been associated with more general medical conditions in adults, such as asthma or chronic pain (Scott *et al*., 2018), as well as several sociodemographic predictors. Being female, young age, unemployment, secondary educational level, low family income, use of alcohol and recreational drugs, stressful and traumatic events, higher level of urbanicity, and a family history of mental disorder increase the odds of PLEs (Linscott & van Os, 2013). More recent studies support these findings (Bourgin *et al*., 2019; Khaled, Wilkins & Woodruff, 2019; Pignon, Schürhoff, et al., 2018b).

The presence of PLEs are well described in children (Laurens, Hobbs, Sunderland, Green & Mould, 2012), adolescents (Kompus, Løberg, Posserud & Lundervold, 2015 & Lundervold, 2015), and also in the transition from childhood into adolescence (Thapar *et al*., 2012). In children between 5 and 7 years of age, Pignon, Geoffroy, Gharib et al. (2018a) for example, found a prevalence rate of 15.8% for auditory hallucinations. In addition, Kelleher and colleagues (2011), suggest that PLEs are normal childhood experiences that do not persist into adulthood. They found that the prevalence of PLEs in children decreases from 21% at age 11–13 to 7% in adolescents aged 13–16. Yet, other studies found that when PLEs are reported at the age of 9–12, there is an increased risk that PLEs were also reported later in adolescence (Gutteridge, Lang, Turner, Jacobs & Laurens, 2020), and that children/adolescents with persistent PLEs often need care in the future (Bartels-Velthuis, Wigman, Jenner, Bruggeman & Van Os, 2016; Maijer, Palmen & Sommer, 2017; Maijer, Steenhuis, Lotgering, Palmen, Sommer & Bartels-Velthuis, 2019). In adults, participants are often asked to report their lifetime PLEs, but there are no specific instructions whether these include childhood PLEs. Thus, it is unclear whether the PLEs described by adults were “merely” childhood/adolescence experiences that can be attributed to immaturity or whether they were exclusively experienced during adulthood. To our knowledge, this has not been investigated before.

Typically, PLEs are assessed with interviews or self-rating questionnaires. While prevalence rates on self-rating questionnaires tend to be higher than in interviews, self-rating instruments are suggested to have a high degree of accuracy as well (Kelleher & Cannon, 2011). However, most instruments do not capture the full spectrum and phenomenology of PLEs. Instruments either focus on only one hallucination modality, like auditory hallucinations (e.g. PSYRATS; Haddock, McCarron, Tarrier & Faragher, 1999) or on one delusional theme, like paranoia (e.g. Paranoid Thoughts Scale; Green, Freeman, Kuipers *et al*., 2008); or they provide global scores for hallucinations (Positive and Negative Syndrome Scale; Kay, Fiszbein & Opler, 1987) and delusions without rating individual themes (e.g. Neurospsychiatric Inventory; Cummings, 1997).

To overcome these shortcomings, the Questionnaire for Psychotic Experiences (QPE; Rossell, Schutte, Toh e*t al*., 2019; Sommer, Kleijer & Hugdahl, 2018) was developed. It aims to cover a wide range of PLEs, including hallucinations in different modalities (auditory, visual, tactile, olfactory) and common types of delusions (persecution, reference, guilt, control, religiosity, grandeur, nihilism, misidentification and somatic delusions). The QPE was also developed as a transdiagnostic instrument that can be applied to assess PLEs not only in different patient populations but also in the general population (for details see Rossell *et al*., 2019). The QPE was originally conceived as a full *interview*. This allows assessing detailed phenomenological information. However, it is also time consuming. For this reason, Sommer and colleagues (2018) provided a short *QPE screening questionnaire* that only asks about the presence of hallucinatory and delusional experiences. However, although the QPE screening questionnaire has already been used as a self-report questionnaire (Begemann, Linszen, de Boer *et al*., 2019) to group participants in terms of presence/frequency of PLEs (de Boer, Linszen, de Vries et al., 2019), only the full QPE interview has been validated in a patient population so far (Rossell *et al*., 2019).

Therefore, the first aim of the present study was to test the psychometric properties of the QPE screening questionnaire. We examined its test-retest reliability, convergent validity, and the internal structure in a convenience sample recruited from the general population via an online survey. Our second aim was to map endorsement rates for both hallucinatory and delusional experiences in this sample. Third, we wanted to examine how many of the PLEs that adults reported in the present study were "merely" childhood experiences that did not transition into adulthood. Fourth, we aimed to replicate previous findings showing that sex, age, unemployment, level of education, parental mental disorder, and the use of illegal drugs/alcohol predict whether individuals experience PLEs. Finally, if the concept of phenomenological continuity is correct, then the mere presence of PLEs should not be a predictor for whether individuals have a mental disorder or not. To test this notion, we examined whether the QPE screening items can be used as predictors to distinguish between individuals with PLEs who either had or had not been diagnosed with a mental disorder

and to determine the sensitivity and specificity of the QPE screening items.

METHODS

Participants

In total, 46,916 and 2,216 participants visited the online survey at two different time points, respectively: time point 1 (TP1) and time point 2 (TP2) with approximately 1 week in-between. We excluded data from participants who: (1) did not start the survey at all and just consulted the first page; (2) reported an aberrant age or being underaged (≤18 years of age); (3) did not complete at least the QPE, Peters Delusion Inventory (PDI), and Cardiff Anomalous Perception Scale (CAPS); (4) made double entries; and (5) whose answers did not pass a validity check (for more details, please see the material section below). We also screened the comment section for invalid answers. After applying these exclusion criteria (see Fig. 1), there were 1,439 and 1,115 participants at TP1 and TP2, respectively. All 1,115 participants from TP2 also completed TP1 (77.5%).

Materials

QPE screening questionnaire (Sommer et al., 2018). We first created a Norwegian version of the full QPE interview through back-translation. For the online survey, we only included the screening questions assessing the general presence/absence of PLEs (see Table 3) while the follow-up questions were omitted. Participants indicate via "yes"/"no" whether they had any of the hallucinatory or delusional experiences in their life (lifetime experiences) or during the last seven days (current experiences). We adapted the QPE screening questions by additionally asking whether participants had experienced any of these PLEs in childhood ("Did you experience this only when you were a child?") with the same answer format.

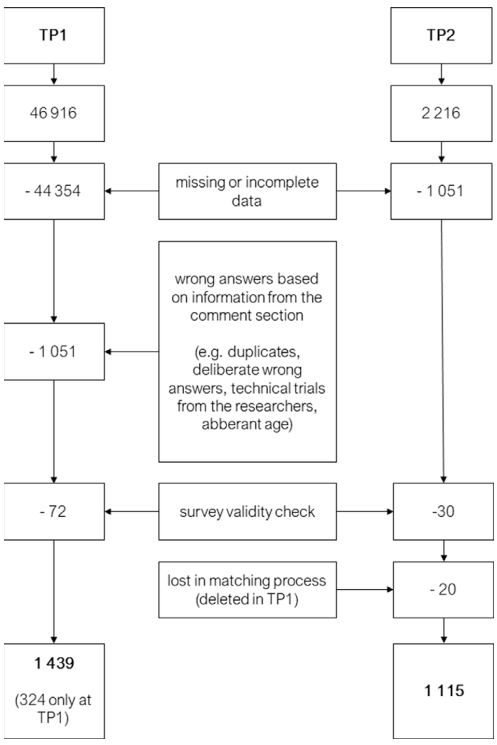

Fig. 1. Flow chart of the data cleaning procedure. There was no possibility for comments at TP2.

Peters Delusion Inventory (PDI; Peters, Joseph, Day & Garety, 2004). The PDI is a self-report questionnaire that was designed to assess delusional ideation multi-dimensionally in the general population. It contains 21 items, such as "Do you ever feel as if people are reading your mind?". In the original PDI, participants indicate the presence of delusional ideation with "yes"/"no" responses. In case they answer "yes", they further indicate on a five-point Likert-scale, how distressing and true this delusion is for them, and how much they think about it. For the present study, we only used the initial question that asks about the presence of delusional experiences, as it aligns with the "yes"/"no" answers from the QPE. The Norwegian translation of the PDI has a Cronbach's alpha of 0.782.

Cardiff Anomalous Perceptions Scale (CAPS; Bell, Halligan & Ellis, 2005). The CAPS is a self-report questionnaire that comprises 32-items and assesses perceptual anomalies on three subscales. In a non-clinical sample these subscales can be interpreted as clinical psychosis, chemosensation, and temporal lobe disturbance (Bell *et al.*, 2005). Participants indicate the presence/absence of anomalous perceptions with "yes"/"no" answers. In case they answer "yes", they are asked follow-up questions regarding the level of distress, intrusiveness, and frequency of those anomalous perceptions. As with the PDI, we adapted the CAPS such that the follow-up questions were not included. Cronbach's alpha for the Norwegian version of the CAPS is 0.901.

Survey validity check. As up to 23% of participants can be unreliable responders (Fervaha & Remington, 2013; Ladea, Szöke, Bran *et al.*, 2020), six items which were already used in another study (Bortolon, Lebrun & Laloyaux, 2020) were distributed across the entire survey to ensure the validity of participants' answers. Two items aimed to detect random completion or attention lapses (i.e., "Please tick "yes," "Please select "2–3 times per week."); two items to detect lies taken from the Eysenck Personality Questionnaire Revised (Eysenck, Eysenck & Barrett, 1985), where participants rated on a seven-point Likert-scale from "all my habits are bad" to "all my habits are good", as well as from "I have never cheated in games" to "I have always cheated in games"; and two items to detect the simulation of psychotic symptoms based on published clichés (Moritz, Van Quaquebeke, Lincoln, Köther & Andreou, 2013; that is, "Did you ever have the hallucination of seeing white mice or other small animals?" "Did you ever have a disruption in your perception of time and had the feeling that you are another person?"). At TP1 and TP2, six and three validity items were included, respectively. The number was lower at TP2 due to the lower total number of items. We excluded participants who answered three or more validity check items incorrectly at TP1 or who answered two or three items incorrectly at TP2, as some items were relatively subjective and/or related to possible, albeit highly rare phenomena (see also Laloyaux, Collazoni, Hirnstein, Kusztrits & Larøi, submitted).

Demographic questions and other measures. To examine factors that could be associated with PLEs, participants provided basic demographic and clinical information, including age, sex, education, employment status, family history of mental disorders, psychiatric and neurological diagnoses, medication, alcohol and drug consumption. The level of education was grouped into three categories: primary ("Grunnskole"), secondary (including "Framhaldsskole," "Folkehøyskole," "Realskole," "Middelskole," "Yrkeskole," "Videregående Skole," "Artium," "økonomisk gymnasium" and "allmennfaglig studieretning") and higher education (university degree). In addition, the online survey contained questions about trauma and auditory verbal hallucinations as well as the revised Beliefs About Voices Questionnaire (BAVQ-R; Chadwick, Lees & Birchwood, 2000), the Self-Compassion Scale (SCS;

Neff, 2003), and the Resilience Scale for Adults (RSA; Hjemdal, Friborg, Stiles, Rosenvinge & Martinussen, 2006). These questionnaires were collected to address other research questions (e.g., Laloyaux *et al*., 2020) and are therefore not described in more detail in this paper.

Procedure

The online survey was administered with the online tool SurveyXact (http://www.surveyxact.no). It was advertised via posters, flyers, email, publications on homepages and social media channels; on Facebook, there were advertisements targeting people who live in Norway and speak Norwegian, are over 18 years old, but without restrictions to sex, or geography. The online survey was accessible from August 2017 until the end of June 2018.

At TP1, participants first completed demographic questions, the QPE screening questionnaire, the PDI, and CAPS. Then, they completed questions regarding their clinical background, followed by questions related to auditory verbal hallucinations and trauma, as well as the BAVQ-R, SCS, and RSA. At the end, they were asked to voluntarily provide their email address for future research and had the opportunity to comment on the online survey. The total time to complete the online survey was between 20 and 40 min, depending on whether participants had experienced auditory hallucinations or not. Only participants who gave their informed consent to participate in future research were invited to TP2. Two invitations were sent out via email, seven and nine days after TP1 was completed. At TP2, participants only completed the QPE screening questionnaire, the PDI, and the CAPS.

The study was approved by the regional ethics committee (REK 2017/69) and informed consent was obtained beforehand from all participants at both time points.

Data analysis

The characteristics of the general sample are presented in Table 1. *Retest reliability* of the QPE screening questionnaire was determined with a test/retest-design and is expressed as the percentage of concordant and discordant answers across TP1 and TP2. (Dis-)concordance rates could thus only be calculated for participants who completed the QPE screening questionnaire at TP1 and TP2. A response was considered concordant when the same "yes" or "no" answer was given at TP1 and TP2. Discordance could arise for two reasons: first, it could reflect truly inconsistent responses, termed here "true discordance." That is, somebody who indicated "yes" at TP1 when asked about, for instance, lifetime auditory hallucinations but indicated "no" lifetime auditory hallucinations at TP2. There is, however, the possibility that somebody correctly indicated at TP1 that he/she had never experienced auditory hallucinations in their lifetime (= "no" answer) but experienced auditory hallucinations in the period between TP1 and TP2, leading to a "yes" answer at TP2. We termed this pattern "ambiguous discordance" and treated it as a separate category. For *convergent validity*, inter-scale concordance rates were calculated between the QPE screening questionnaire and corresponding items of the PDI and CAPS. We chose the items from the QPE, PDI, and CAPS based on their matching content (see Table 6). Given that all three questionnaires have a "yes"/"no" response format, we also calculated concordance rates here. In addition, we provided the mean square contingency coefficient phi (φ). As effect size measures, we used the index suggested by Cohen, as it is recommended for contingency tables (Olivier & Bell, 2013). To determine the internal structure of the QPE screening questionnaire, we ran a principal component analysis (PCA) with all 13 items following the recommendations of Neill (2008). Eigenvalues greater than 1 and factor loadings of greater than 0.4 were retained and considered satisfactory (Mokkink *et al*., 2010).

To *map PLEs*, we first report the endorsement rates of lifetime, current, and childhood PLEs at TP1 descriptively, separately for individuals with and without a self-reported mental disorder that was diagnosed by a psychiatrist or psychologist. Subsequently, we ran a multiple linear regression (not distinguishing between individuals with and without a diagnosed mental disorder) with sex, age, employment status, level of education, parental mental disorder, as well as the consumption of drugs and alcohol as predictors for having PLEs. Unknown answers were treated as missing values and excluded from the analysis. The dependent variable was the total score of lifetime PLEs at TP1, which was calculated as the sum of all QPE items where participants indicated their presence. Finally, a binomial logistic regression model and a receiver operating characteristic curve (ROC) were computed to assess how well the items of the QPE screening version at TP1 discriminate between individuals with and without a self-reported mental disorder who experience PLEs. In addition, sensitivity, specificity, and positive and negative predictive values were calculated.

Table 1. *Participant characteristics*

Variables	TP 1	TP 2
n	1439	1115
Age (M ± SD)	39.1 (13 ± 37)	39.62 (13 ± 36)
Sex: female/ male [%]	1254:185 [87.1 %/ 12.9 %]	975:140 [87.4 %/ 12.6 %]
Education		
Primary	3.8%	3.5%
Secondary	27.4%	24.8%
Higher	68.9%	71.7%
Have parents with a psychiatric diagnosis	8.2% (Unsure: 9.8%)	8.6% (Unsure: 10.5%)
Neurological disorder	3.1%	3.3%
Mental disorder:	32.2%	34.4%
Depression	25%	27.5%
Anxiety	18.8%	20.2%
Schizophrenia	2.2%	2.3%
Bipolar Disorder	3.0%	3.3%
Personality Disorder	3.3%	3.5%
Other	1.7%	1.8%
Consulting a specialist for mental health problems:		
General practitioner	40.7%	43.3%
Psychiatrist	15.6%	16.7%
Psychologist	43.4%	46.3%
Neurologist	3.5%	4.0%
other	3.1%	3.3%

Note: Questions regarding mental disorder and consulting a specialist were enabled for multiple responses.

RESULTS

General sample description

The mean difference, in number of days, between TP1 and TP2 was 8.77 (SD = 3.4). Participants at both time points were mostly highly educated and female, with a mean age around 40 years. For more details about participant characteristics, see Table 1.

Psychometric Properties

Test-retest reliability. Concordance rates between answers at TP1 and TP2 show high consistency of ≥ 85 % in 12 out of 13 items. Only one item (paranoia) is below 78 %. Ambiguous discordance is relatively rare, ranging between 0.2% and 1.8% (see Table 2).

Convergent Validity. Concordance rates between QPE screening questions and related CAPS/PDI items were ≥ 50.4%, with corresponding weak to strong effects (ϕ between 0.199 and 0.789; see Table 3).

Table 2. *Concordance rates for lifetime presence of hallucinatory and delusional experiences at TP1 and TP2*

QPE-items	Concordant answers	Discordant answers	
		True	Ambiguous
(1) Auditory hallucinations	85.0%	13.2%	1.8%
(2) Visual hallucinations	88.1%	11.2%	0.7%
(3) Tactile hallucinations	85.9%	13.7%	0.4%
(4) Olfactory hallucinations	88.8%	9.9%	1.3%
(5) Paranoia	77.5%	22.1%	0.4%
(6) Delusions of reference	89.5%	10.2%	0.3%
(7) Delusions of guilt	87.5%	12.1%	0.4%
(8) Delusions of control	88.9%	10.6%	0.5%
(9) Delusion of religiosity	97.0%	2.7%	0.3%
(10) Delusion of grandeur	89.4%	9.6%	1.0%
(11) Somatic delusions	86.7%	12.8%	0.5%
(12) Delusions of nihilism	92.3%	7.3%	0.4%
(13) Delusions of misidentification	94.7%	5.1 %	0.2%

Note: True discordance includes participants reporting lifetime PLEs at TP1 but not at TP2, while ambiguous discordance includes participants who reported no lifetime PLEs at TP1 but at TP2, which is hypothetically possible if they only had PLEs in the period between TP1 and TP2.

Internal structure. The data screening showed that with 1439 participants for 13 items, we had a satisfactory participant-to-item ratio of approximately 111:1. Several indicators were checked to assess overall suitability for a factor analysis. First, the determinant derived from the correlation matrix was 0.217 and thus above the recommended value of 0.00001. Moreover, inter-correlations were well below $r = 0.80$, suggesting there was no multicollinearity. Second, eight out of 13 items correlated with at least one other item $r \geq 0.30$. Third, the Kaiser-Meyer-Olkin measure of sampling adequacy (0.83) was above 0.60, Bartlett's test of sphericity was significant [$\chi^2(78) = 2816.46$, $p \leq 0.001$], and 11 out of 13 items showed communalities above 0.30. Based on these indicators, the data including all 13 items was regarded suitable for factor analysis.

We carried out a PCA with promax rotation, since we expected that the underlying factors are correlated. Three factors had eigenvalues greater than 1, the first two explaining 24% and 11% of the variance, respectively, while the last factor explained 8% variance. A two-factor solution seemed most appropriate: first, the characteristic bend in the scree plot as reflected by the eigenvalues occurred after two factors. Second, we compared the observed eigenvalues to randomly generated eigenvalues based on

Table 3. *Concordance rates and effect sizes for QPE and related CAPS/PDI items*

QPE item	CAPS item	Concordance rate	Phi (ϕ)
1) People sometimes hear another person speak, while no one seems to be there. Also, music or other sounds can be heard, while it is unclear where this comes from. Have you ever heard such voices, music or other sounds?	6) Do you ever hear noises or sounds when there is nothing to explain them?	74.5 %	0.49
	11) Do you ever hear voices commenting on what you are thinking or doing?	62.5 %	0.27
	13) Do you ever hear voices saying words or sentences when there is no one around that might account for it?	75.3 %	0.54
	28) Have you ever heard two or more unexplained voices talking with each other?	59.6 %	0.24
	32) Do you ever hear sounds or music that people near you don't hear?	76.8 %	0.55
2) It sometimes occurs that people see a person, animal or object that others cannot see. For some people, this can be a shade or shadow. Have you seen any of those objects, persons or images?	4) Do you ever see shapes, lights or colours even though there is nothing really there?	77.7 %	0.53
	31) Do you ever see things that other people cannot?	81.5 %	0.62
3) People sometimes feel things that are not there. For example, feeling a hand on their shoulder, while no one is around. Another example is feeling a tickling or itching sensation, as if there are tiny creatures under the skin. Have you ever experienced this?	5) Do you ever experience unusual burning sensations or other strange feelings in or on your body?	65.9 %	0.34
	12) Do you ever feel that someone is touching you, but when you look, nobody is there?	72.1 %	0.52
4) People sometimes smell things that are not there. For example, the scent of smoke, while there is no fire. Another example is someone who smells flowers, while there are no flowers around. Have you ever had such an experience?	8) Do you ever detect smells which don't seem to come from your surroundings?	89.2 %	0.79
	29) Do you ever notice smells and odors that people next to you seem unaware of?	75.7 %	0.52
QPE item	PDI item	Concordance rate	Phi (ϕ)
5) Were you ever convinced that other people were out to get you? Have you had the feeling that people were keeping an eye on you, or may even want to hurt you?	1) Do you ever feel as if people seem to drop hints about you or say things with a double meaning?	65.1 %	0.36
	4) Do you ever feel as if you are being persecuted in some way?	52.2 %	0.21
	5) Do you ever feel as if there is a conspiracy against you?	50.4 %	0.22
		86.5 %	0.48

(continued)

Table 3. (continued)

QPE item	CAPS item	Concordance rate	Phi (ϕ)
6) Were you ever convinced that things in your environment might have a special meaning just for you? For example, certain messages on TV or in the newspaper?	2) Do you ever feel as if things in magazines or on TV were written especially for you?		
7) Were you ever convinced that you were guilty of some bad things that have happened? While others did not feel you were responsible?	14) Do you ever feel that you have sinned more than the average person?	77.5 %	0.30
8) Were you ever convinced that a thought or action was not quite your own? As if you were being controlled by someone else?	10) Do you ever feel as if electrical devices such as computers can influence the way you think?	83.6 %	0.22
9) Were you ever convinced you were specifically chosen by a god for a special purpose in life? Have you ever thought you were a god, devil, angel or a saint?	6) Do you ever feel as if you are, or destined to be someone very important?	88.5 %	0.30
	8) Do you ever feel that you are especially close to god?	89.2 %	0.34
	11) Do you ever feel as if you have been chosen by God in some way?	93.6 %	0.40
10) Were you ever convinced you had extraordinary talents or powers that no one else has?	7) Do you ever feel that you are a very special or unusual person?	75.3 %	0.32
11) Were you ever convinced that there was something strange with your body, while others said that this was not the case?	15) Do you ever feel that people look at you oddly because of your appearance?	64.6 %	0.20
12) Were you ever convinced that you somehow no longer existed? Have you ever had the feeling that you might be dead?	No similar item in CAPS		
13) Were you ever convinced that someone close to you might not be who they say they are? Or have you ever had the thought that this person had been replaced by an imposter?	No similar item in PDI 3) Do you ever feel as if some people are not what they seem to be?	66.5 %	0.22

Table 4. *Mean scores of psychotic experiences and factor loadings of the QPE screening questions*

QPE-Item	Mean	Factor 1 delusional experiences	Factor 2 Hallucinatory experiences
(1) Auditory hallucinations	0.45		0.71
(2) Visual hallucinations	0.40		0.74
(3) Tactile hallucinations	0.51		0.63
(4) Olfactory hallucinations	0.47		0.68
(5) Paranoia	0.57	0.56	
(6) Delusions of reference	0.18	0.60	
(7) Delusions of guilt	0.24	0.65	
(8) Delusions of control	0.16	0.56	
(9) Delusions of religiosity	0.06	0.42	
(10) Delusions of grandeur	0.18	0.43	
(11) Somatic delusions	0.34	0.46	
(12) Delusions of nihilism	0.11	0.52	
(13) Delusions of misidentification	0.08	0.49	

13 variables, 1,439 participants, and 100 replications with the tool "Monte Carlo PCA for parallel analysis" (Watkins, 2000). Only the eigenvalues of the first two observed factors (3.1 and 1.4) were above the randomly generated eigenvalues (1.2 and 1.1), while subsequent observed eigenvalues were level with or below the randomly generated ones.

We then re-ran the PCA with the two-factor solution preselected, explaining a total variance of 35%. Factor loadings higher than 0.40 are presented in Table 4. As can be seen, Factor 1 represents items about delusions, while Factor 2 only contained items about hallucinations. We therefore called the two factors *delusional experiences* and *hallucinatory experiences*, respectively. In a last step, we analyzed the internal consistency for the two factors. Cronbach's alpha for *delusional experiences* and *hallucinatory experiences* were 0.671 and 0.645, respectively, suggesting relatively moderate, internal consistency.

Mapping PLEs

Endorsement rates of PLEs. In general, hallucinatory experiences were more often reported than delusional experiences (Table 5). Individuals with a mental disorder experienced more *lifetime* PLEs than those without a mental disorder. Looking at *current experiences*, a similar pattern arises, clustering around roughly ten percent. In general, just a few people reported having experienced PLEs only during *childhood.*

Factors predicting the frequency of PLEs. Using the enter method, the multiple regression model significantly predicted PLEs, $F(7, 1431) = 28.36$, $p < 0.001$, adj. $R^2 = 0.12$ (see Table 6). Age, education, parental mental disorder, drug and alcohol consumption were significant predictors of PLEs.

Discriminating Individuals with and without Mental Disorders based on QPE Screening Questions. The logistic regression model was statistically significant, $\chi^2(13) = 134.76$, $p \leq 0.001$. The model explained 12.6% (Nagelkerke R^2) of the variance of discriminating participants with and without a diagnosis and correctly classified 71.4% of cases. Sensitivity was 24.2%, specificity was 92.5%, positive predictive value was 58.8% and negative predictive value was 41.2%. Of the 13 predictor

Table 5. *Frequency of PLEs in the study sample*

	Lifetime		Current		Child	
	With	Without	With	Without	With	Without
Hallucinatory experiences						
Auditory	50.10%	42.70%	10.40%	5.60%	2.80%	4.10%
Visual	47.50%	36.80%	9.30%	5.00%	5.80%	4.50%
Tactile	58.30%	47.40%	18.40%	11.80%	2.40%	2.80%
Olfactory	55.70%	43.30%	14.00%	10.60%	0.90%	0.90%
Delusional experiences						
Paranoia	71.30%	50.60%	21.00%	10.00%	2.20%	2.80%
Reference	23.10%	16.30%	6.90%	5.00%	1.30%	0.50%
Guilt	39.50%	16.20%	8.40%	2.90%	4.80%	1.90%
Control	20.70%	13.10%	3.90%	2.00%	1.30%	1.20%
Religiosity	9.50%	4.00%	1.50%	1.60%	1.30%	0.70%
Grandeur	21.40%	16.40%	4.50%	5.60%	5.20%	3.90%
Somatic	43.60%	29.10%	13.40%	6.70%	1.70%	1.10%
Nihilism	17.50%	8.30%	2.20%	1.10%	1.70%	1.20%
Misidentification	10.60%	6.80%	0.40%	0.90%	3.50%	2.50%

Note: Percentage of individuals with and without a mental disorder diagnosed by a mental health professional, with separate rates for lifetime, current and childhood experiences.

Table 6. *Predictors of experiencing PLEs*

			CI_B 95%		
Variables	B	SE_B	Lower	Upper	β
Intercept	7.36	0.44	6.51	8.22	
Age	−0.02	0.01	−0.03	−0.01	−0.08*
Sex	−0.35	0.20	−0.74	0.05	−0.04
Employment status	0.01	0.01	−0.01	0.02	0.04
Education	−0.84	0.12	−1.08	−0.59	−0.17**
Parental mental disorder	0.01	0.01	0.01	0.02	0.16**
Illegal drugs	1.11	0.39	0.34	1.88	0.07*
Alcohol	−0.32	0.05	−0.43	−0.22	−0.16**

Notes: *$p \leq 0.005$, **$p < 0.001$; B = unstandardized regression coefficient; SE_B = standard error of coefficient; CI_B = confidence intervals of coefficient; β = standardized coefficient. Variable coding: age (in years), sex (male/female: 1/0), employment status (employed/unemployed: 1/0), education (primary/secondary/higher: 1/2/3), parental mental disorder (yes/no: 1/0), illegal drugs (yes/no: 1/0), alcohol (six-point-scale from "never" to "5 times per week: 0–5).

variables, five were statistically significant (in order of descending level of significance): guilt, paranoia, visual hallucinatory experiences, and delusional experiences of religiosity and nihilism (Table 7). The area under the ROC curve was 0.686 with a 95% CI between 0.656 and 0.716. According to Hosmer, Lemeshow and Sturdivant (2013), this represents a poor level of the whole model classifying individuals into the two groups.

DISCUSSION

Psychometric Properties

Our first aim was to examine the psychometric properties of the QPE screening questionnaire. Measures for retest reliability showed high concordance rates between the answers at the two time points, indicating that the QPE screening questionnaire is a stable measure. Only the item about paranoia had a medium concordance rate. In general, the screening questions are phrased rather broadly. This reduces stigma and lowers the threshold of reporting PLEs, but might also lead to higher fluctuations in participants' answers over time and, thus, more frequent (truly) discordant answers, even in non-clinical populations (Garety & Freeman, 2013). *Ambiguous discordance* is more difficult to interpret. It is possible that participants indeed had never experienced PLEs in their life before but experienced them in the week between TP1 and TP2. However, it is also possible that this reflects priming effects where individuals were more aware of their everyday experiences after participating in our survey (Weingarten, Chen, McAdams, Yi, Hepler & Albarracín, 2016). Nevertheless, the *ambiguous discordance* rates were rather rare and therefore not a concern.

Concordance rates between the selected items of the PDI/CAPS and the QPE screening questionnaire showed considerable variation. QPE items were designed to capture a lot of information about PLEs by merging questions of different existing instruments. At the same time, the wording of the QPE items was modified such that they represent one common theme. As a result, there is varying overlap between the phrasing of QPE items and items from other instruments (Rossell *et al*., 2019). For example, for the QPE screening item that asks about visual hallucinations ("It sometimes occurs that people see a person, animal or object that others cannot see. For some people, this can be a shade or shadow. Have you seen any of those objects, persons or images?"), there are two corresponding items in the CAPS ("Do you ever see shapes, lights or colours even though there is nothing really there?," "Do you ever see things that other people cannot?"). These modifications might be an explanation for the high variation in effect sizes and the difference in the psychometric properties to the full QPE interview. There were no corresponding items in the PDI or CAPS for delusions of nihilism and misidentification, as these delusions are typically not

Table 7. *Logistic regression predicting likelihood of having a diagnosed mental disorder based on the occurrence of psychotic experiences*

						95% CI for odds ratio	
QPE item	B	SE	Wald	df	odds ratio	lower	upper
(1) Auditory hallucinations	−0.13	0.14	0.92	1	0.34	0.67	1.15
(2) Visual hallucinations	0.32	0.14	5.74*	1	1.38	1.06	1.79
(3) Tactile hallucinations	0.10	0.14	0.53	1	1.10	0.85	1.44
(4) Olfactory hallucinations	0.23	0.13	2.88	1	1.25	0.97	1.63
(5) Paranoia	0.54	0.14	15.88**	1	1.72	1.32	2.24
(6) Delusions of reference	−0.20	0.17	1.38	1	0.82	0.59	1.14
(7) Delusions of guilt	0.89	0.14	38.65**	1	2.43	1.84	3.22
(8) Delusions of control	−0.05	0.18	0.07	1	0.96	0.68	1.35
(9) Delusion of religiosity	0.57	0.25	5.13*	1	1.77	1.08	2.91
(10) Delusion of grandeur	−0.10	0.16	0.40	1	0.90	0.66	1.24
(11) Somatic delusions	0.19	0.13	2.03	1	1.21	0.93	1.57
(12) Delusions of nihilism	0.38	1.88	4.11*	1	1.46	1.01	2.11
(13) Delusions of misidentification	0.02	0.22	0.01	1	1.02	0.66	1.57
Constant	−1.71	0.13	179.56**	1	0.18		

*p = 0.05, **p = 0.01

employed in psychiatric assessments due to their neurological character and the fact that they are very rare (Rossell *et al*., 2019).

The internal structure revealed two components: *hallucinatory experiences* and *delusional experiences*. While a solution with two components is highly intuitive, given that there were items about hallucinatory and delusional experiences, Rossell *et al*. (2019) found a three-factor solution in the full QPE interview. That is, one factor for auditory and visual hallucinations each, as well as a unidimensional solution for delusions. Tactile and olfactory hallucinations were not included in the analysis, as there were no other validation instruments available in a semi-structured interview format. In comparison to our study, however, the authors analyzed the follow-up questions of the interview and not the screening questions (Rossell *et al*., 2019). Cronbach's alpha for the two factors in the present study were moderate. This is not surprising given that it reflects the heterogeneity of hallucinatory and delusional experiences in the clinical reality: For example, while having hallucinatory experiences in one modality increases the odds of having hallucinatory experiences in other modalities, many individuals experience only auditory, or visual, or tactile, or olfactory hallucinatory experiences or various combinations thereof (Larøi, Bless, Laloyaux et *al*., 2019). This is also true for delusions. Taken together, the QPE screening questionnaire has satisfactory reliability and validity and can be used as a complementary tool for epidemiological studies: it provides less information than the full QPE interview but can be carried out much faster and does not require trained interviewers.

One should also bear in mind that while the low-threshold wording of the screening items invites participants to be more open about their experiences, the phrasing is also likely going to yield rather high endorsement rates of PLEs.

Mapping endorsement rates of PLEs

The second aim of the study was to map PLEs in our sample. The proportion of individuals with a diagnosed mental disorder was rather high (30%), as compared to an estimated 11% of individuals suffering from any mental health disorder worldwide, according to the World Health Organization (Ritchie & Roser, 2018). Therefore, we mapped PLEs for participants with and without a diagnosed mental disorder separately.

Both lifetime and current PLEs were consistently reported more often by individuals with a mental disorder. This was to be expected, as PLEs are associated with a wide range of mental disorders (Linscott & van Os, 2013). The frequency of delusional experiences with religious, grandiose and misidentification content were similar in both groups.

There were some differences between individuals with and without a diagnosed mental disorder with respect to childhood PLEs. While for all modalities of hallucinatory experiences participants without a mental disorder had higher endorsement rates than those with a mental disorder, delusional experiences did not show this pattern, as prevalence of delusional ideas were rather low in both groups. In general, however, childhood PLEs were rather rare, suggesting that when adults report lifetime PLEs they usually do not reflect childhood experiences. Kelleher and colleagues (2012) suggested that PLEs are part of normal childhood experiences that decrease over time. While the authors directly tested children and adolescents, we investigated PLEs in adults. This approach might give room for a memory bias that is connected to reporting retrospective life events (Lalande & Bonanno, 2011; Van den Bergh & Walentynowicz, 2016). Another potential issue is that we did not further define "childhood" when we asked participants about their experiences. We worded our question as "Did you experience this only when you were a child?." Thus, the definition of "when you were a child" may have varied between the participants, which might have made it difficult for participants to classify their childhood PLEs as such.

Regardless of individuals with and without a mental disorder, in general, frequencies in all lifetime PLEs were rather high. Between 4.0% and 71.3% of participants in our sample reported experiencing PLEs in their life. In comparison, Bourgin and colleages (2019) reported more than 26% with at least one

lifetime PLE, while prevalence rates of lifetime PLEs in Linscott and van Os (2013) ranged between 1.2% and 25.5%. In the present study, hallucinatory experiences in both individuals with and without a mental disorder were reported typically by 40% and more (lifetime perspective). For hallucinatory experiences in the auditory modality, for example, a meta-analysis reported a prevalence rate of below 10% (Maijer *et al*., 2018). In the present study the rate was 50% and 43% for participants with and without a mental disorder, respectively. For delusional experiences, there was a large variation, with highest endorsement rates for paranoia. The large variation is in accordance with the results of a recent review article, however, that reported rates between 3% and 91% for different delusional experiences (Heilskov *et al*., 2019). The high PLEs rates in the present study are likely due to the fact that the online survey was advertised as a project to assess PLEs, which probably attracted individuals who have had such experiences. As outlined above, another reason could be the open phrasing of the QPE screening questions. This possibility aligns with the similar high prevalence of endorsement in studies using the full QPE interview (Begemann *et al*., 2019; de Boer *et al*., 2019).

Predictive factors of PLEs

Irrespective of whether participants had a diagnosed mental disorder or not, young age, lower education, parental mental disorder, and the use of illegal drugs and alcohol were significantly associated with higher frequency of PLEs. Thus, despite a possible selection bias in our convenience sample, these findings replicate previous studies regarding age, parental mental disorder, and drug consumption effects on PLEs (Bourgin *et al*., 2019; Linscott & van Os, 2013b). The results are more inconsistent regarding education: Both Bourgin *et al*. (2019) and Pignon et al. (2018b) found a higher prevalence for "at least one PLE" in individuals with a secondary education level and higher, but Linscott and van Os (2013) did not find an association between education and PLEs. This discrepancy might arise from the fact that Linscott and van Os (2013) conducted a meta-analysis based on several samples, while Bourgin *et al*. (2019) and Pignon *et al*. (2018b) had only one sample in their analysis. Counterintuitively, we found that the consumption of more alcohol is associated with fewer PLEs. Possibly, alcohol consumption reflects the social behavior of participants in our sample, meaning that individuals go out more often and therefore consume alcohol more often per week. The resulting social network might function as a protective factor against the onset and recurrence of mental disorders (Avison, 1996). In general, however, the standardized coefficients did not exceed beta = 0.17, suggesting that the correlations we found in the present study were weak and their significance are rather the result of the large sample.

Discriminating individuals with and without mental disorders

Finally, we investigated whether PLEs, as assessed with the QPE screening questionnaire, can discriminate between people with and without a mental disorder. Five QPE questions were found to be significantly discriminating. These included items assessing (the highest are presented first): delusional experiences of guilt and paranoia, visual hallucinatory experiences, and delusional experiences of religiosity and nihilism. The significance levels of both delusional experiences of guilt and paranoia were much higher than those of the other significant items. This is in line with another study that reported delusional experiences of guilt and paranoia to be discriminators between psychotic and non-psychotic patients (Verdoux, Maurice-Tison, Gay, Van Os, Salamon & Bourgeois, 1998). However, the highest odds ratio in the present study was 2.4, implying that participants indicating "yes" on the item about delusional experiences of guilt have 2.4 times the odds of having a diagnosed mental disorder. Moreover, the logistic regression model showed a poor level of discrimination between the two groups. Both, the positive and negative predictive value congregate around 50%, which can also be based on chance. The fact that the presence (or absence) of PLEs appears to be fairly similar in both groups, although the frequency of PLEs is generally higher in individuals with a diagnosed mental disorder, supports the phenomenological aspect of the continuum hypothesis of PLEs (Linscott & van Os, 2013). These data show that the mere experience of a PLE does not provide much information about mental health status, as such experiences are ubiquitous. In the full QPE interview, additional questions are asked regarding the underlying phenomenology of PLEs. This information is necessary to differentiate between groups with and without mental health issues.

Limitations and conclusion

The results of our study should be interpreted in the light of some limitations. First, while our online survey was completed by a high number of participants, thus providing good statistical power and the possibility to compare subgroups, it attracted mostly female and highly educated participants, implying this is not a representative sample of the general population and makes it difficult to generalize our findings. This is a typical issue with convenience samples in epidemiological research on PLEs and in online surveys in general (see, e.g., Armando, Nelson, Yung *et al*., 2010, whose sample consisted of 75% college students). As pointed out above, the sample selection, together with the open phrasing of the QPE items, could account for the relatively high PLEs rates. The self-reporting nature of the QPE screening questionnaire could have further contributed to the high frequency. Linscott and van Os (2013) demonstrated a higher prevalence rate of PLEs in studies where researchers only used self-report measures in comparison to interview measures. However, there is also evidence that self-report instruments rather underestimate subthreshold PLEs which speaks for a social desirability bias (DeVylder & Hilimire, 2015). Moreover, while our strategy to use Facebook as a tool to recruit a lot of participants has already been used before and proved to be a viable approach (Kosinski, Matz, Gosling, Popov & Stillwell, 2015), the downside of this recruitment strategy is that a high number of clicks does not automatically translate into high quality data (Crosier, Brian & Ben-Zeev, 2016). This made it necessary to include survey validity items and have a rigid data cleaning procedure. In addition, we did not assess ethnicity, migration status, and the context in which PLEs were occurring, such as in sleep or while intoxicated, which are all relevant factors (Tortelli,

Nakamura, Suprani *et al*., 2018; Waters & Fernyhough, 2017). Finally, clinical diagnoses were self-reported and we had to trust participants, as we had no possibility to validate the diagnoses externally.

Despite the issues with representativeness, the present study allows us to draw a couple of conclusions with relevance to the ongoing debate about PLEs in the general population. First, we showed that the QPE screening questions have satisfactory psychometric properties. Researchers need to be aware that because of the open phrasing it is likely going to lead to higher frequencies of PLEs. Still, the open phrasing reduces the risk that participants refrain from reporting PLEs due to social desirability. We also showed that a range of PLEs, especially hallucinatory experiences, are ubiquitous in both individuals with and without a diagnosed mental disorder. Corroborating previous research, PLEs were predicted by young age, use of illegal drugs and parental mental disorder. Finally, the finding that the presence of PLEs discriminates rather poorly between individuals with and without a diagnosed mental disorder further supports the continuum hypothesis, implying a spectrum from subthreshold experiences in healthy people to severe symptoms of psychosis in those with mental disorders.

FUNDING

The work was supported by a grant from the Bergen Research Foundation (grant number BFS2016REK03).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon request.

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Received 21 February 2020, accepted 17 August 2020

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1981	Myhrer, Trond, Dr. philos.	Behavioral Studies after selective disruption of hippocampal inputs in albino rats.
1982	Svebak, Sven, Dr. philos.	The significance of motivation for task-induced tonic physiological changes.
1983	Myhre, Grete, Dr. philos.	The Biopsychology of behavior in captive Willow ptarmigan.
	Eide, Rolf, Dr. philos.	PSYCHOSOCIAL FACTORS AND INDICES OF HEALTH RISKS. The relationship of psychosocial conditions to subjective complaints, arterial blood pressure, serum cholesterol, serum triglycerides and urinary catecholamines in middle aged populations in Western Norway.
	Værnes, Ragnar J., Dr. philos.	Neuropsychological effects of diving.
1984	Kolstad, Arnulf, Dr. philos.	Til diskusjonen om sammenhengen mellom sosiale forhold og psykiske strukturer. En epidemiologisk undersøkelse blant barn og unge.
	Løberg, Tor, Dr. philos.	Neuropsychological assessment in alcohol dependence.
1985	Hellesnes, Tore, Dr. philos.	Læring og problemløsning. En studie av den perseptuelle analysens betydning for verbal læring.
	Håland, Wenche, Dr. philos.	Psykoterapi: relasjon, utviklingsprosess og effekt.
1986	Hagtvet, Knut A., Dr. philos.	The construct of test anxiety: Conceptual and methodological issues.
	Jellestad, Finn K., Dr. philos.	Effects of neuron specific amygdala lesions on fear-motivated behavior in rats.
1987	Aarø, Leif E., Dr. philos.	Health behaviour and sosioeconomic Status. A survey among the adult population in Norway.
	Underlid, Kjell, Dr. philos.	Arbeidsløyse i psykososialt perspektiv.
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	Vollmer, Fred, Dr. philos.	Essays on explanation in psychology.
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1988	Kaufmann, Astrid, Dr. philos.	Antisosial atferd hos ungdom. En studie av psykologiske determinanter.

	Mykletun, Reidar J., Dr. philos.	Teacher stress: personality, work-load and health.
	Havik, Odd E., Dr. philos.	After the myocardial infarction: A medical and psychological study with special emphasis on perceived illness.
1989	Bråten, Stein, Dr. philos.	Menneskedyaden. En teoretisk tese om sinnets dialogiske natur med informasjons- og utviklingspsykologiske implikasjoner sammenholdt med utvalgte spedbarnsstudier.
	Wold, Bente, Dr. psychol.	Lifestyles and physical activity. A theoretical and empirical analysis of socialization among children and adolescents.
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1991	Alsaker, Françoise D., Dr. philos.	Global negative self-evaluations in early adolescence.
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	Bø, Inge B., Dr. philos.	Ungdoms sosiale økologi. En undersøkelse av 14-16 åringers sosiale nettverk.
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	Johnsen, Bjørn Helge, Dr. psychol.	Brain assymetry and facial emotional expressions: Conditioning experiments.
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2004 H	Thomsen, Tormod, Dr. psychol.	Localization of attention in the brain.
	Løberg, Else-Marie, Dr. psychol.	Functional laterality and attention modulation in schizophrenia: Effects of clinical variables.
	Kyrkjebø, Jane Mikkelsen, Dr. philos.	Learning to improve: Integrating continuous quality improvement learning into nursing education.
	Laumann, Karin, Dr. psychol.	Restorative and stress-reducing effects of natural environments: Experiencal, behavioural and cardiovascular indices.
	Holgersen, Helge, PhD	Mellom oss - Essay i relasjonell psykoanalyse.
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	Iversen, Anette Christine, Dr. philos.	Social differences in health behaviour: the motivational role of perceived control and coping.
2005 H	Mathisen, Gro Ellen, PhD	Climates for creativity and innovation: Definitions, measurement, predictors and consequences.
	Sævi, Tone, Dr. philos.	Seeing disability pedagogically – The lived experience of disability in the pedagogical encounter.
	Wiium, Nora, PhD	Intrapersonal factors, family and school norms: combined and interactive influence on adolescent smoking behaviour.
	Kanagaratnam, Pushpa, PhD	Subjective and objective correlates of Posttraumatic Stress in immigrants/refugees exposed to political violence.
	Larsen, Torill M. B. , PhD	Evaluating principals` and teachers` implementation of Second Step. A case study of four Norwegian primary schools.
	Bancila, Delia, PhD	Psychosocial stress and distress among Romanian adolescents and adults.
2006 V	Hillestad, Torgeir Martin, Dr. philos.	Normalitet og avvik. Forutsetninger for et objektivt psykopatologisk avviksbegrep. En psykologisk, sosial, erkjennelsesteoretisk og teorihistorisk framstilling.

	Nordanger, Dag Øystein, Dr. psychol.	Psychosocial discourses and responses to political violence in post-war Tigray, Ethiopia.
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	Glasø, Lars, PhD	Affects and emotional regulation in leader-subordinate relationships.
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	Matthiesen, Stig Berge, PhD	Bullying at work. Antecedents and outcomes.
2006 H	Gramstad, Arne, PhD	Neuropsychological assessment of cognitive and emotional functioning in patients with epilepsy.
	Bendixen, Mons, PhD	Antisocial behaviour in early adolescence: Methodological and substantive issues.
	Mrumbi, Khalifa Maulid, PhD	Parental illness and loss to HIV/AIDS as experienced by AIDS orphans aged between 12-17 years from Temeke District, Dar es Salaam, Tanzania: A study of the children's psychosocial health and coping responses.
	Hetland, Jørn, Dr. psychol.	The nature of subjective health complaints in adolescence: Dimensionality, stability, and psychosocial predictors
	Kakoko, Deodatus Conatus Vitalis, PhD	Voluntary HIV counselling and testing service uptake among primary school teachers in Mwanza, Tanzania: assessment of socio-demographic, psychosocial and socio-cognitive aspects
	Mykletun, Arnstein, Dr. psychol.	Mortality and work-related disability as long-term consequences of anxiety and depression: Historical cohort designs based on the HUNT-2 study
	Sivertsen, Børge, PhD	Insomnia in older adults. Consequences, assessment and treatment.
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	Janvin, Carmen Ani Cristea, PhD	Cognitive impairment in patients with Parkinson's disease: profiles and implications for prognosis
	Braarud, Hanne Cecilie, Dr.psychol.	Infant regulation of distress: A longitudinal study of transactions between mothers and infants
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	Thuen, Elin Marie, Dr.philos.	Learning environment, students' coping styles and emotional and behavioural problems. A study of Norwegian secondary school students.
	Solberg, Ole Asbjørn, PhD	Peacekeeping warriors – A longitudinal study of Norwegian peacekeepers in Kosovo
2007 H	Søreide, Gunn Elisabeth, Dr.philos.	Narrative construction of teacher identity
	Svensen, Erling, PhD	WORK & HEALTH. Cognitive Activation Theory of Stress applied in an organisational setting.
	Øverland, Simon Nygaard, PhD	Mental health and impairment in disability benefits. Studies applying linkages between health surveys and administrative registries.
	Eichele, Tom, PhD	Electrophysiological and Hemodynamic Correlates of Expectancy in Target Processing
	Børhaug, Kjetil, Dr.philos.	Oppseding til demokrati. Ein studie av politisk oppseding i norsk skule.
	Eikeland, Thorleif, Dr.philos.	Om å vokse opp på barnehjem og på sykehus. En undersøkelse av barnehjemsbarns opplevelser på barnehjem sammenholdt med sanatoriebarns beskrivelse av langvarige sykehusopphold – og et forsøk på forklaring.
	Wadel, Carl Cato, Dr.philos.	Medarbeidersamhandling og medarbeiderledelse i en lagbasert organisasjon
	Vinje, Hege Forbech, PhD	Thriving despite adversity: Job engagement and self-care among community nurses
	Noort, Maurits van den, PhD	Working memory capacity and foreign language acquisition
2008 V	Breivik, Kyrre, Dr.psychol.	The Adjustment of Children and Adolescents in Different Post-Divorce Family Structures. A Norwegian Study of Risks and Mechanisms.
	Johnsen, Grethe E., PhD	Memory impairment in patients with posttraumatic stress disorder
	Sætrevik, Bjørn, PhD	Cognitive Control in Auditory Processing
	Carvalhosa, Susana Fonseca, PhD	Prevention of bullying in schools: an ecological model
2008 H	Brønnick, Kolbjørn Selvåg	Attentional dysfunction in dementia associated with Parkinson's disease.
	Posserud, Maj-Britt Rocio	Epidemiology of autism spectrum disorders
	Haug, Ellen	Multilevel correlates of physical activity in the school setting
	Skjerve, Arvid	Assessing mild dementia – a study of brief cognitive tests.

	Kjønniksen, Lise	The association between adolescent experiences in physical activity and leisure time physical activity in adulthood: a ten year longitudinal study
	Gundersen, Hilde	The effects of alcohol and expectancy on brain function
	Omvik, Siri	Insomnia – a night and day problem
2009 V	Molde, Helge	Pathological gambling: prevalence, mechanisms and treatment outcome.
	Foss, Else	Den omsorgsfulle væremåte. En studie av voksnes væremåte i forhold til barn i barnehagen.
	Westrheim, Kariane	Education in a Political Context: A study of Konwledge Processes and Learning Sites in the PKK.
	Wehling, Eike	Cognitive and olfactory changes in aging
	Wangberg, Silje C.	Internet based interventions to support health behaviours: The role of self-efficacy.
	Nielsen, Morten B.	Methodological issues in research on workplace bullying. Operationalisations, measurements and samples.
	Sandu, Anca Larisa	MRI measures of brain volume and cortical complexity in clinical groups and during development.
	Guribye, Eugene	Refugees and mental health interventions
	Sørensen, Lin	Emotional problems in inattentive children – effects on cognitive control functions.
	Tjomsland, Hege E.	Health promotion with teachers. Evaluation of the Norwegian Network of Health Promoting Schools: Quantitative and qualitative analyses of predisposing, reinforcing and enabling conditions related to teacher participation and program sustainability.
	Helleve, Ingrid	Productive interactions in ICT supported communities of learners
2009 H	Skorpen, Aina Øye, Christine	Dagliglivet i en psykiatrisk institusjon: En analyse av miljøterapeutiske praksiser
	Andreassen, Cecilie Schou	WORKAHOLISM – Antecedents and Outcomes
	Stang, Ingun	Being in the same boat: An empowerment intervention in breast cancer self-help groups
	Sequeira, Sarah Dorothee Dos Santos	The effects of background noise on asymmetrical speech perception
	Kleiven, Jo, dr.philos.	The Lillehammer scales: Measuring common motives for vacation and leisure behavior
	Jónsdóttir, Guðrún	Dubito ergo sum? Ni jenter møter naturfaglig kunnskap.
	Hove, Oddbjørn	Mental health disorders in adults with intellectual disabilities - Methods of assessment and prevalence of mental health disorders and problem behaviour
	Wageningen, Heidi Karin van	The role of glutamate on brain function

	Bjørkvik, Jofrid	God nok? Selvaktelse og interpersonlig fungering hos pasienter innen psykisk helsevern: Forholdet til diagnoser, symptomer og behandlingsutbytte
	Andersson, Martin	A study of attention control in children and elderly using a forced-attention dichotic listening paradigm
	Almås, Aslaug Grov	Teachers in the Digital Network Society: Visions and Realities. A study of teachers' experiences with the use of ICT in teaching and learning.
	Ulvik, Marit	Lærerutdanning som danning? Tre stemmer i diskusjonen
2010 V	Skår, Randi	Læringsprosesser i sykepleieres profesjonsutøvelse. En studie av sykepleieres læringserfaringer.
	Roald, Knut	Kvalitetsvurdering som organisasjonslæring mellom skole og skoleeigar
	Lunde, Linn-Heidi	Chronic pain in older adults. Consequences, assessment and treatment.
	Danielsen, Anne Grete	Perceived psychosocial support, students' self-reported academic initiative and perceived life satisfaction
	Hysing, Mari	Mental health in children with chronic illness
	Olsen, Olav Kjellevold	Are good leaders moral leaders? The relationship between effective military operational leadership and morals
	Riese, Hanne	Friendship and learning. Entrepreneurship education through mini-enterprises.
	Holthe, Asle	Evaluating the implementation of the Norwegian guidelines for healthy school meals: A case study involving three secondary schools
H	Hauge, Lars Johan	Environmental antecedents of workplace bullying: A multi-design approach
	Bjørkelo, Brita	Whistleblowing at work: Antecedents and consequences
	Reme, Silje Endresen	Common Complaints – Common Cure? Psychiatric comorbidity and predictors of treatment outcome in low back pain and irritable bowel syndrome
	Helland, Wenche Andersen	Communication difficulties in children identified with psychiatric problems
	Beneventi, Harald	Neuronal correlates of working memory in dyslexia
	Thygesen, Elin	Subjective health and coping in care-dependent old persons living at home
	Aanes, Mette Marthinussen	Poor social relationships as a threat to belongingness needs. Interpersonal stress and subjective health complaints: Mediating and moderating factors.
	Anker, Morten Gustav	Client directed outcome informed couple therapy

	Bull, Torill	Combining employment and child care: The subjective well-being of single women in Scandinavia and in Southern Europe
	Viig, Nina Grieg	Tilrettelegging for læreres deltakelse i helsefremmende arbeid. En kvalitativ og kvantitativ analyse av sammenhengen mellom organisatoriske forhold og læreres deltakelse i utvikling og implementering av Europeisk Nettverk av Helsefremmende Skoler i Norge
	Wolff, Katharina	To know or not to know? Attitudes towards receiving genetic information among patients and the general public.
	Ogden, Terje, dr.philos.	Familiebasert behandling av alvorlige atferdsproblemer blant barn og ungdom. Evaluering og implementering av evidensbaserte behandlingsprogrammer i Norge.
	Solberg, Mona Elin	Self-reported bullying and victimisation at school: Prevalence, overlap and psychosocial adjustment.
2011 V	Bye, Hege Høivik	Self-presentation in job interviews. Individual and cultural differences in applicant self-presentation during job interviews and hiring managers' evaluation
	Notelaers, Guy	Workplace bullying. A risk control perspective.
	Moltu, Christian	Being a therapist in difficult therapeutic impasses. A hermeneutic phenomenological analysis of skilled psychotherapists' experiences, needs, and strategies in difficult therapies ending well.
	Myrseth, Helga	Pathological Gambling - Treatment and Personality Factors
	Schanche, Elisabeth	From self-criticism to self-compassion. An empirical investigation of hypothesized change prosesses in the Affect Phobia Treatment Model of short-term dynamic psychotherapy for patients with Cluster C personality disorders.
	Våpenstad, Eystein Victor, dr.philos.	Det tempererte nærvær. En teoretisk undersøkelse av psykoterapautens subjektivitet i psykoanalyse og psykoanalytisk psykoterapi.
	Haukebø, Kristin	Cognitive, behavioral and neural correlates of dental and intra-oral injection phobia. Results from one treatment and one fMRI study of randomized, controlled design.
	Harris, Anette	Adaptation and health in extreme and isolated environments. From 78°N to 75°S.
	Bjørknes, Ragnhild	Parent Management Training-Oregon Model: intervention effects on maternal practice and child behavior in ethnic minority families
	Mamen, Asgeir	Aspects of using physical training in patients with substance dependence and additional mental distress
	Espevik, Roar	Expert teams: Do shared mental models of team members make a difference
	Haara, Frode Olav	Unveiling teachers' reasons for choosing practical activities in mathematics teaching

2011 H	Hauge, Hans Abraham	How can employee empowerment be made conducive to both employee health and organisation performance? An empirical investigation of a tailor-made approach to organisation learning in a municipal public service organisation.
	Melkevik, Ole Rogstad	Screen-based sedentary behaviours: pastimes for the poor, inactive and overweight? A cross-national survey of children and adolescents in 39 countries.
	Vøllestad, Jon	Mindfulness-based treatment for anxiety disorders. A quantitative review of the evidence, results from a randomized controlled trial, and a qualitative exploration of patient experiences.
	Tolo, Astrid	Hvordan blir lærerkompetanse konstruert? En kvalitativ studie av PPU-studenters kunnskapsutvikling.
	Saus, Evelyn-Rose	Training effectiveness: Situation awareness training in simulators
	Nordgreen, Tine	Internet-based self-help for social anxiety disorder and panic disorder. Factors associated with effect and use of self-help.
	Munkvold, Linda Helen	Oppositional Defiant Disorder: Informant discrepancies, gender differences, co-occuring mental health problems and neurocognitive function.
	Christiansen, Øivin	Når barn plasseres utenfor hjemmet: beslutninger, forløp og relasjoner. Under barnevernets (ved)tak.
	Brunborg, Geir Scott	Conditionability and Reinforcement Sensitivity in Gambling Behaviour
	Hystad, Sigurd William	Measuring Psychological Resiliency: Validation of an Adapted Norwegian Hardiness Scale
2012 V	Roness, Dag	Hvorfor bli lærer? Motivasjon for utdanning og utøving.
	Fjermestad, Krister Westlye	The therapeutic alliance in cognitive behavioural therapy for youth anxiety disorders
	Jenssen, Eirik Sørnes	Tilpasset opplæring i norsk skole: politikeres, skolelederes og læreres handlingsvalg
	Saksvik-Lehouillier, Ingvild	Shift work tolerance and adaptation to shift work among offshore workers and nurses
	Johansen, Venke Frederike	Når det intime blir offentlig. Om kvinners åpenhet om brystkreft og om markedsføring av brystkreftsaken.
	Herheim, Rune	Pupils collaborating in pairs at a computer in mathematics learning: investigating verbal communication patterns and qualities
	Vie, Tina Løkke	Cognitive appraisal, emotions and subjective health complaints among victims of workplace bullying: A stress-theoretical approach
	Jones, Lise Øen	Effects of reading skills, spelling skills and accompanying efficacy beliefs on participation in education. A study in Norwegian prisons.

2012 H	Danielsen, Yngvild Sørebø	Childhood obesity – characteristics and treatment. Psychological perspectives.
	Horverak, Jøri Gytre	Sense or sensibility in hiring processes. Interviewee and interviewer characteristics as antecedents of immigrant applicants' employment probabilities. An experimental approach.
	Jøsendal, Ola	Development and evaluation of BE smokeFREE, a school-based smoking prevention program
	Osnes, Berge	Temporal and Posterior Frontal Involvement in Auditory Speech Perception
	Drageset, Sigrunn	Psychological distress, coping and social support in the diagnostic and preoperative phase of breast cancer
	Aasland, Merethe Schanke	Destructive leadership: Conceptualization, measurement, prevalence and outcomes
	Bakibinga, Pauline	The experience of job engagement and self-care among Ugandan nurses and midwives
	Skogen, Jens Christoffer	Foetal and early origins of old age health. Linkage between birth records and the old age cohort of the Hordaland Health Study (HUSK)
	Leversen, Ingrid	Adolescents' leisure activity participation and their life satisfaction: The role of demographic characteristics and psychological processes
	Hanss, Daniel	Explaining sustainable consumption: Findings from cross-sectional and intervention approaches
	Rød, Per Arne	Barn i klem mellom foreldrekonflikter og samfunnsmessig beskyttelse
2013 V	Mentzoni, Rune Aune	Structural Characteristics in Gambling
	Knudsen, Ann Kristin	Long-term sickness absence and disability pension award as consequences of common mental disorders. Epidemiological studies using a population-based health survey and official ill health benefit registries.
	Strand, Mari	Emotional information processing in recurrent MDD
	Veseth, Marius	Recovery in bipolar disorder. A reflexive-collaborative exploration of the lived experiences of healing and growth when battling a severe mental illness
	Mæland, Silje	Sick leave for patients with severe subjective health complaints. Challenges in general practice.
	Mjaaland, Thera	At the frontiers of change? Women and girls' pursuit of education in north-western Tigray, Ethiopia
	Odéen, Magnus	Coping at work. The role of knowledge and coping expectancies in health and sick leave.
	Hynninen, Kia Minna Johanna	Anxiety, depression and sleep disturbance in chronic obstructive pulmonary disease (COPD). Associations, prevalence and effect of psychological treatment.

	Flo, Elisabeth	Sleep and health in shift working nurses
	Aasen, Elin Margrethe	From paternalism to patient participation? The older patients undergoing hemodialysis, their next of kin and the nurses: a discursive perspective on perception of patient participation in dialysis units
	Ekornås, Belinda	Emotional and Behavioural Problems in Children: Self-perception, peer relationships, and motor abilities
	Corbin, J. Hope	North-South Partnerships for Health: Key Factors for Partnership Success from the Perspective of the KIWAKKUKI
	Birkeland, Marianne Skogbrott	Development of global self-esteem: The transition from adolescence to adulthood
2013 H	Gianella-Malca, Camila	Challenges in Implementing the Colombian Constitutional Court's Health-Care System Ruling of 2008
	Hovland, Anders	Panic disorder – Treatment outcomes and psychophysiological concomitants
	Mortensen, Øystein	The transition to parenthood – Couple relationships put to the test
	Årdal, Guro	Major Depressive Disorder – a Ten Year Follow-up Study. Inhibition, Information Processing and Health Related Quality of Life
	Johansen, Rino Bandlitz	The impact of military identity on performance in the Norwegian armed forces
	Bøe, Tormod	Socioeconomic Status and Mental Health in Children and Adolescents
2014 V	Nordmo, Ivar	Gjennom nåløyet – studenters læringserfaringer i psykologutdanningen
	Dovran, Anders	Childhood Trauma and Mental Health Problems in Adult Life
	Hegelstad, Wenche ten Velden	Early Detection and Intervention in Psychosis: A Long-Term Perspective
	Urheim, Ragnar	Forståelse av pasientaggresjon og forklaringer på nedgang i voldsrate ved Regional sikkerhetsavdeling, Sandviken sykehus
	Kinn, Liv Grethe	Round-Trips to Work. Qualitative studies of how persons with severe mental illness experience work integration.
	Rød, Anne Marie Kinn	Consequences of social defeat stress for behaviour and sleep. Short-term and long-term assessments in rats.
	Nygård, Merethe	Schizophrenia – Cognitive Function, Brain Abnormalities, and Cannabis Use
	Tjora, Tore	Smoking from adolescence through adulthood: the role of family, friends, depression and socioeconomic status. Predictors of smoking from age 13 to 30 in the "The Norwegian Longitudinal Health Behaviour Study" (NLHB)
	Vangsnes, Vigdis	The Dramaturgy and Didactics of Computer Gaming. A Study of a Medium in the Educational Context of Kindergartens.

	Nordahl, Kristin Berg	Early Father-Child Interaction in a Father-Friendly Context: Gender Differences, Child Outcomes, and Protective Factors related to Fathers' Parenting Behaviors with One-year-olds
2014 H	Sandvik, Asle Makoto	Psychopathy – the heterogenety of the construct
	Skotheim, Siv	Maternal emotional distress and early mother-infant interaction: Psychological, social and nutritional contributions
	Halleland, Helene Barone	Executive Functioning in adult Attention Deficit Hyperactivity Disorder (ADHD). From basic mechanisms to functional outcome.
	Halvorsen, Kirsti Vindal	Partnerskap i lærerutdanning, sett fra et økologisk perspektiv
	Solbue, Vibeke	Dialogen som visker ut kategorier. En studie av hvilke erfaringer innvandrerungdommer og norskfødte med innvandrerforeldre har med videregående skole. Hva forteller ungdommenes erfaringer om videregående skoles håndtering av etniske ulikheter?
	Kvalevaag, Anne Lise	Fathers' mental health and child development. The predictive value of fathers' psychological distress during pregnancy for the social, emotional and behavioural development of their children
	Sandal, Ann Karin	Ungdom og utdanningsval. Om elevar sine opplevingar av val og overgangsprosessar.
	Haug, Thomas	Predictors and moderators of treatment outcome from high- and low-intensity cognitive behavioral therapy for anxiety disorders. Association between patient and process factors, and the outcome from guided self-help, stepped care, and face-to-face cognitive behavioral therapy.
	Sjølie, Hege	Experiences of Members of a Crisis Resolution Home Treatment Team. Personal history, professional role and emotional support in a CRHT team.
	Falkenberg, Liv Eggset	Neuronal underpinnings of healthy and dysfunctional cognitive control
	Mrdalj, Jelena	The early life condition. Importance for sleep, circadian rhythmicity, behaviour and response to later life challenges
	Hesjedal, Elisabeth	Tverrprofesjonelt samarbeid mellom skule og barnevern: Kva kan støtte utsette barn og unge?
2015 V	Hauken, May Aasebø	«*The cancer treatment was only half the work!»* A Mixed-Method Study of Rehabilitation among Young Adult Cancer Survivors
	Ryland, Hilde Katrin	Social functioning and mental health in children: the influence of chronic illness and intellectual function
	Rønsen, Anne Kristin	Vurdering som profesjonskompetanse. Refleksjonsbasert utvikling av læreres kompetanse i formativ vurdering

	Hoff, Helge Andreas	Thinking about Symptoms of Psychopathy in Norway: Content Validation of the Comprehensive Assessment of Psychopathic Personality (CAPP) Model in a Norwegian Setting
	Schmid, Marit Therese	Executive Functioning in recurrent- and first episode Major Depressive Disorder. Longitudinal studies
	Sand, Liv	Body Image Distortion and Eating Disturbances in Children and Adolescents
	Matanda, Dennis Juma	Child physical growth and care practices in Kenya: Evidence from Demographic and Health Surveys
	Amugsi, Dickson Abanimi	Child care practices, resources for care, and nutritional outcomes in Ghana: Findings from Demographic and Health Surveys
	Jakobsen, Hilde	The good beating: Social norms supporting men's partner violence in Tanzania
	Sagoe, Dominic	Nonmedical anabolic-androgenic steroid use: Prevalence, attitudes, and social perception
	Eide, Helene Marie Kjærgård	Narrating the relationship between leadership and learning outcomes. A study of public narratives in the Norwegian educational sector.
2015 H	Wubs, Annegreet Gera	Intimate partner violence among adolescents in South Africa and Tanzania
	Hjelmervik, Helene Susanne	Sex and sex-hormonal effects on brain organization of fronto-parietal networks
	Dahl, Berit Misund	The meaning of professional identity in public health nursing
	Røykenes, Kari	Testangst hos sykepleierstudenter: «Alternativ behandling»
	Bless, Josef Johann	The smartphone as a research tool in psychology. Assessment of language lateralization and training of auditory attention.
	Løvvik, Camilla Margrethe Sigvaldsen	Common mental disorders and work participation – the role of return-to-work expectations
	Lehmann, Stine	Mental Disorders in Foster Children: A Study of Prevalence, Comorbidity, and Risk Factors
	Knapstad, Marit	Psychological factors in long-term sickness absence: the role of shame and social support. Epidemiological studies based on the Health Assets Project.
2016 V	Kvestad, Ingrid	Biological risks and neurodevelopment in young North Indian children
	Sælør, Knut Tore	Hinderløyper, halmstrå og hengende snører. En kvalitativ studie av håp innenfor psykisk helse- og rusfeltet.
	Mellingen, Sonja	Alkoholbruk, partilfredshet og samlivsstatus. Før, inn i, og etter svangerskapet – korrelater eller konsekvenser?
	Thun, Eirunn	Shift work: negative consequences and protective factors

	Hilt, Line Torbjørnsen	The borderlands of educational inclusion. Analyses of inclusion and exclusion processes for minority language students
	Havnen, Audun	Treatment of obsessive-compulsive disorder and the importance of assessing clinical effectiveness
	Slåtten, Hilde	Gay-related name-calling among young adolescents. Exploring the importance of the context.
	Ree, Eline	Staying at work. The role of expectancies and beliefs in health and workplace interventions.
	Morken, Frøydis	Reading and writing processing in dyslexia
2016 H	Løvoll, Helga Synnevåg	Inside the outdoor experience. On the distinction between pleasant and interesting feelings and their implication in the motivational process.
	Hjeltnes, Aslak	Facing social fears: An investigation of mindfulness-based stress reduction for young adults with social anxiety disorder
	Øyeflaten, Irene Larsen	Long-term sick leave and work rehabilitation. Prognostic factors for return to work.
	Henriksen, Roger Ekeberg	Social relationships, stress and infection risk in mother and child
	Johnsen, Iren	«Only a friend» - The bereavement process of young adults who have lost a friend to a traumatic death. A mixed methods study.
	Helle, Siri	Cannabis use in non-affective psychoses: Relationship to age at onset, cognitive functioning and social cognition
	Glambek, Mats	Workplace bullying and expulsion in working life. A representative study addressing prospective associations and explanatory conditions.
	Oanes, Camilla Jensen	Tilbakemelding i terapi. På hvilke måter opplever terapeuter at tilbakemeldingsprosedyrer kan virke inn på terapeutiske praksiser?
	Reknes, Iselin	Exposure to workplace bullying among nurses: Health outcomes and individual coping
	Chimhutu, Victor	Results-Based Financing (RBF) in the health sector of a low-income country. From agenda setting to implementation: The case of Tanzania
	Ness, Ingunn Johanne	The Room of Opportunity. Understanding how knowledge and ideas are constructed in multidisciplinary groups working with developing innovative ideas.
	Hollekim, Ragnhild	Contemporary discourses on children and parenting in Norway. An empirical study based on two cases.
	Doran, Rouven	Eco-friendly travelling: The relevance of perceived norms and social comparison
2017 V	Katisi, Masego	The power of context in health partnerships: Exploring synergy and antagony between external and internal ideologies in implementing Safe Male Circumcision (SMC) for HIV prevention in Botswana

	Jamaludin, Nor Lelawati Binti	The “why” and “how” of International Students’ Ambassadorship Roles in International Education
	Berthelsen, Mona	Effects of shift work and psychological and social work factors on mental distress. Studies of onshore/offshore workers and nurses in Norway.
	Krane, Vibeke	Lærer-elev-relasjoner, elevers psykiske helse og frafall i videregående skole – en eksplorerende studie om samarbeid og den store betydningen av de små ting
	Søvik, Margaret Ljosnes	Evaluating the implementation of the Empowering Coaching™ program in Norway
	Tonheim, Milfrid	A troublesome transition: Social reintegration of girl soldiers returning ‘home’
	Senneseth, Mette	Improving social network support for partners facing spousal cancer while caring for minors. A randomized controlled trial.
	Urke, Helga Bjørnøy	Child health and child care of very young children in Bolivia, Colombia and Peru.
	Bakhturidze, George	Public Participation in Tobacco Control Policy-making in Georgia
	Fismen, Anne-Siri	Adolescent eating habits. Trends and socio-economic status.
2017 H	Hagatun, Susanne	Internet-based cognitive-behavioural therapy for insomnia. A randomised controlled trial in Norway.
	Eichele, Heike	Electrophysiological Correlates of Performance Monitoring in Children with Tourette Syndrome. A developmental perspective.
	Risan, Ulf Patrick	Accommodating trauma in police interviews. An exploration of rapport in investigative interviews of traumatized victims.
	Sandhåland, Hilde	Safety on board offshore vessels: A study of shipboard factors and situation awareness
	Blågestad, Tone Fidje	Less pain – better sleep and mood? Interrelatedness of pain, sleep and mood in total hip arthroplasty patients
	Kronstad, Morten	Frå skulebenk til deadlines. Korleis nettjournalistar og journaliststudentar lærer, og korleis dei utviklar journalistfagleg kunnskap
	Vedaa, Øystein	Shift work: The importance of sufficient time for rest between shifts.
	Steine, Iris Mulders	Predictors of symptoms outcomes among adult survivors of sexual abuse: The role of abuse characteristics, cumulative childhood maltreatment, genetic variants, and perceived social support.
	Høgheim, Sigve	Making math interesting: An experimental study of interventions to encourage interest in mathematics

2018 V	Brevik, Erlend Joramo	Adult Attention Deficit Hyperactivity Disorder. Beyond the Core Symptoms of the Diagnostic and Statistical Manual of Mental Disorders.
	Erevik, Eilin Kristine	User-generated alcohol-related content on social media: Determinants and relation to offline alcohol use
	Hagen, Egon	Cognitive and psychological functioning in patients with substance use disorder; from initial assessment to one-year recovery
	Adólfsdóttir, Steinunn	Subcomponents of executive functions: Effects of age and brain maturations
	Brattabø, Ingfrid Vaksdal	Detection of child maltreatment, the role of dental health personnel – A national cross-sectional study among public dental health personnel in Norway
	Fylkesnes, Marte Knag	Frykt, forhandlinger og deltakelse. Ungdommer og foreldre med etnisk minoritetsbakgrunn i møte med den norske barnevernstjenesten.
	Stiegler, Jan Reidar	Processing emotions in emotion-focused therapy. Exploring the impact of the two-chair dialogue intervention.
	Egelandsdal, Kjetil	Clickers and Formative Feedback at University Lectures. Exploring students and teachers' reception and use of feedback from clicker interventions.
	Torjussen, Lars Petter Storm	Foreningen av visdom og veltalenhet – utkast til en universitetsdidaktikk gjennom en kritikk og videreføring av Skjervheims pedagogiske filosofi på bakgrunn av Arendt og Foucault. *Eller hvorfor menneskelivet er mer som å spille fløyte enn å bygge et hus.*
	Selvik, Sabreen	A childhood at refuges. Children with multiple relocations at refuges for abused women.
2018 H	Leino, Tony Mathias	Structural game characteristics, game features, financial outcomes and gambling behaviour
	Raknes, Solfrid	Anxious Adolescents: Prevalence, Correlates, and Preventive Cogntive Behavioural Interventions
	Morken, Katharina Teresa Enehaug	Mentalization-based treatment of female patients with severe personality disorder and substance use disorder
	Braatveit, Kirsten Johanne	Intellectual disability among in-patients with substance use disorders
	Barua, Padmaja	Unequal Interdependencies: Exploring Power and Agency in Domestic Work Relations in Contemporary India
	Darkwah, Ernest	Caring for "parentless" children. An exploration of work-related experiences of caregivers in children's homes in Ghana.
	Valdersnes, Kjersti Bergheim	Safety Climate perceptions in High Reliability Organizations – the role of Psychological Capital

2019 V	Kongsgården, Petter	Vurderingspraksiser i teknologirike læringsmiljøer. En undersøkelse av læreres vurderingspraksiser i teknologirike læringsmiljøer og implikasjoner på elevenes medvirkning i egen læringsprosess.
	Vikene, Kjetil	Complexity in Rhythm and Parkinson's disease: Cognitive and Neuronal Correlates
	Heradstveit, Ove	Alcohol- and drug use among adolescents. School-related problems, childhood mental health problems, and psychiatric diagnoses.
	Riise, Eili Nygard	Concentrated exposure and response prevention for obsessive-compulsive disorder in adolescents: the Bergen 4-day treatment
	Vik, Alexandra	Imaging the Aging Brain: From Morphometry to Functional Connectivity
	Krossbakken, Elfrid	Personal and Contextual Factors Influencing Gaming Behaviour. Risk Factors and Prevention of Video Game Addiction.
	Solholm, Roar	Foreldrenes status og rolle i familie- og nærmiljøbaserte intervensjoner for barn med atferdsvansker
	Baldomir, Andrea Margarita	Children at Risk and Mothering Networks in Buenos Aires, Argentina: Analyses of Socialization and Law-Abiding Practices in Public Early Childhood Intervention.
	Samuelsson, Martin Per	Education for Deliberative Democracy. Theoretical assumptions and classroom practices.
	Visted, Endre	Emotion regulation difficulties. The role in onset, maintenance and recurrence of major depressive disorder.
2019 H	Nordmo, Morten	Sleep and naval performance. The impact of personality and leadership.
	Sveinsdottir, Vigdis	Supported Employment and preventing Early Disability (SEED)
	Dwyer, Gerard Eric	New approaches to the use of magnetic resonance spectroscopy for investigating the pathophysiology of auditory-verbal hallucinations
	Synnevåg, Ellen Strøm	Planning for Public Health. Balancing top-down and bottom-up approaches in Norwegian municipalities.
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Graphic design: Communication Division, UiB / Print: Skipnes Kommunikasjon AS

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ISBN: 9788230846834 (print)
9788230863718 (PDF)