Working title: A Review of Multimodal Hallucinations: Categorisation, Assessment, Theoretical Perspectives And Clinical Recommendations

Marcella Montagnese¹, Pantelis Leptourgos², Charles Fernyhough³, Flavie Waters⁴, Frank Larøi^{5,6,7}, Renaud Jardri^{8,9}, Simon McCarthy-Jones¹⁰, Neil Thomas^{11,12}, Rob Dudley^{13,14}, John-Paul Taylor¹⁵, Daniel Collerton¹⁶, Prabitha Urwyler^{16,17,18*}

Affiliations:

¹*Neuroimaging Department, Institute of Psychiatry, Psychology and Neuroscience, Kings College London, United Kingdom*

²*Department of Psychiatry, Connecticut Mental Health Center, Yale University, New Haven, CT, United States*

³*Department of Psychology, Durham University, Durham, United Kingdom*

⁴*School of Psychological Sciences, The University of Western Australia, Perth, Western Australia*

⁵*Department of Biological and Medical Psychology, Faculty of Psychology, University of Bergen, Bergen, Norway*

⁶*Psychology and Neuroscience of Cognition Research Unit, University of Liège, Liège, Belgium*

⁷*Norwegian Center of Excellence for Mental Disorders Research, University of Oslo, Oslo, Norway*

⁸*Univ. Lille, INSERM U1172, CHU Lille, Centre Lille Neuroscience & Cognition, F-59000 Lille, France*

⁹*Laboratoire de Neurosciences Cognitives et Computationnelles, ENS, INSERM U960, PSL Research University, F-75005, Paris, France*

¹⁰*Department of Psychiatry, Trinity College Dublin, Ireland*

¹¹*Centre for Mental Health, Swinburne University of Technology, Melbourne, Australia*

¹²*The Alfred Hospital, Melbourne, Australia*

¹³*Gateshead Early Intervention in Psychosis Service, Northumberland, Tyne and Wear NHS, UK*

¹⁴*School of Psychology, Newcastle University, Newcastle upon Tyne, UK*

¹⁵*Translational and Clinical Research Institute, Newcastle University, UK*

¹⁶*Institute of Neuroscience, Newcastle University, Campus for Ageing and Vitality, Newcastle upon Tyne, UK*

¹⁷*Gerontechnology and Rehabilitation, ARTORG Center for Biomedical engineering, University of Bern, Bern, Switzerland*

¹⁸*Department of Neurology, University Neurorehabilitation Unit, University Hospital Bern (Inselspital), University of Bern, Bern, Switzerland.*

***Corresponding Author**

PD Dr. Prabitha Urwyler

ARTORG Center for Biomedical Engineering Research, University of Bern, Murtenstrasse 50, 3008 Bern, Switzerland

E-mail: prabitha.urwyler@artorg.unibe.ch

Abstract

Hallucinations can occur in different sensory modalities within an individual, both simultaneously and serially in time. Historically, they have typically been studied in clinical populations as phenomena occurring in a single sensory modality. Yet, hallucinatory experiences that occur in two or more sensory systems - multimodal hallucinations (MMHs) - are more prevalent than previously thought, and may have greater adverse impact than unimodal ones, but they remain relatively under-researched. Why people experience multimodal hallucinations, what the implications for the person are, and how this could impact how such experiences are treated when distressing remain under-studied questions. Here, we review the available literature on MMHs and discuss some key concepts in the field, namely a) the definition and categorisation of both serial and simultaneous MMHs, b) which assessment tools are available and how they can be improved, and c) the explanatory power that current hallucination theories might have for MMHs. Overall, we suggest that current models need to be updated or developed in order to account for MMHs and to inform research into the underlying processes of such hallucinatory phenomena. We make recommendations for future research and clinical practice, highlighting the potential clinical impact of MMHs, the need for better assessment tools that can reliably measure MMHs and distinguish them from other related phenomena (such as delirium), as well as the need for service-user involvement in the validation of classification systems of MMHs.

Key Words (up to 5)

Multimodal hallucinations, multisensory, hallucinations, computational

1. Introduction

Various accounts exist to describe hallucinations, although there is a general consensus that a hallucination can be defined as a sensory experience that resembles veridical perception but that does not have a corresponding sensory stimulation from the external environment (David, 2004). Hallucinations can occur in all senses, including auditory, visual, olfactory, kinaesthetic and more (Chesterman & Boast, 1994). These experiences span nosological categories with little diagnostic specificity (Waters & Fernyhough, 2017), and are a clinical manifestation of many psychiatric disorders including schizophrenia (Fletcher & Frith, 2009) and bipolar disorder (Shinn et al., 2012), neurodegenerative disorders such as Dementia with Lewy Bodies (DLB, Waters et al., 2014) and Parkinson's Disease Psychosis (PDP, Fénelon et al., 2010), alongside sensory disorders such as hearing impairments or eye disease (ffytche, 2005; ffytche, 2009).

Traditionally, hallucinations are often assumed as occurring in one modality at a time (unimodal hallucinations). Hallucinatory experiences in specific modalities have also become diagnostic indicators in different disorders –with auditory hallucinations particularly associated with schizophrenia (Mellor, 1970) and visual hallucinations being a core symptom for the diagnosis of DLB (Aarsland, 2016).

Where hallucinations do occur in different modalities, the predominant understanding is that they occur at different times (i.e. they are not 'fused' or simultaneous, such as seeing and hearing a talking head; though see Goodwin et al., 1971 for a contrary report). Consequently, clinical interviews and questionnaires have had a focus on single modalities, thus biasing data collection towards unimodal hallucinations in potentially problematic ways. Nevertheless, growing recognition that hallucinations may occur in more than one modality has recently shifted the attention to a more systematic search for such multimodal phenomena (Waters et al., 2014; Waters and Fernyhough, 2017; Dudley et al., 2018; Dudley et al., 2019; McCarthy-Jones et al., 2017, Lim et al., 2016, Laloyaux et al., 2019).

Despite the lack of in-depth scrutiny in the scientific field, accounts of hallucinations across all senses can be traced through history (Freudenreich, Brown & Holt, 2016). Some historical examples include medieval descriptions of spiritual voice-hearing, such those by Margery Kempe (Margery and Bale, 2015) or by Julian of Norwich, who did not just hear the "voice of God" but also had visions and other sensory experiences (Fernyhough, 2016, pp. 135-136). In a more recent case, Jardri et al., (2009) describe the experience of Mr T.A., a patient with schizophrenia who saw and heard humanoid creatures that were associated with a foul smell and who went through his body, causing him an unpleasant coenesthetic sensation (i.e. a disorder of bodily perception – Rommel et al., 1999). Such examples challenge the notion that unimodal hallucinations are the most prevalent clinical manifestations of psychiatric and organic disorders (Toh et al., 2019; Dudley et al., 2018; Dudley et al., 2019; Lim et al., 2016; McCarthy-Jones et al., 2017), and point to the need for more accurate clinical assessment and management.

While hallucinations in multiple sensory modalities are of increasing research interest, there are many remaining questions about explanatory frameworks, assessment tools, impact, and classification implications. This novel review focuses on "multimodal hallucinations", i.e. hallucinations that co-occur in different modalities, either in a simultaneous or in a sequential (serial) manner, with the overall objective of providing an overview of the field, highlight areas that require further scrutiny and identify issues of potential clinical importance. Key questions include: (1) why people experience these multi-modal hallucinations (2) what implications they have for the experiencer, and (3) how this could impact how such phenomena are treated (if

distressing). Through a clearer and more in-depth understanding of the multimodality of hallucinations, we might gain a better insight into the underlying functional dimensions that characterise these trans-diagnostic experiences, which might in turn drive novel ways of categorising psychopathologies across diagnostic boundaries (NIMH Research Domain Criteria (RDoC) framework – Insel et al., 2010).

2. Multimodal hallucinations: definition and categorisation

Hallucinations that occur in more than one modality within an individual, either simultaneously or in a serial manner, are called multimodal hallucinations (MMHs) (Chesterman & Boast, 1994). Defining MMHs at the level of a person's range of experiences (e.g. someone has MMHs) vs at the level of a hallucinatory episode (e.g. someone's hallucinations include MMHs) is a major aspect of this definition. MMHs are also referenced in the literature by terms such as “polymodal hallucinations”, “polysensory hallucinations”, “fantastic hallucinations”, “intersensorial hallucinations” and so on (Blom, 2010), reflecting a lack of consensus on how to both name, categorise and understand such phenomena. This is coupled with the lack of consistent specification regarding the temporal relationships that such experiences might have with each other and the issue of whether they have to occur within a specific period to count as serial MMHs.

2.1. Implications of definition level

If conceptualised at the person level, MMHs do not require temporal relatedness, such that a person who hears voices in 2018 and has a vision in 2020 would still be classified as having MMHs. Conceptualising such experiences at the level of a single hallucinatory episode instead would be more stringent, but would require consideration of how closely together in time the hallucinations in different modalities would need to be in order to be considered part of the same hallucinatory episode. This could range from requiring them to occur simultaneously at some point, to being in the same hour or on the same day, to being within the same psychotic episode.

2.2. Categorisation

Given the lack of clarity in the literature, one of the aims of this review is to provide a framework for the categorisation of MMHs. See *Figure 1* for a visual chart of the suggested three dimensions/levels of categorisations (based on Lim et al., (2016), Dudley et al., (2018), and Dudley et al., (2019) and *Figure 2* for further examples of the different types of MMHs given the possible combination of features along these dimensions. The implications of such framework for clinical and research practice are discussed later in the paper.

Figure 1- Categorisation of multimodal hallucinations (level of a hallucinatory episode) across three dimensions: time, relatedness and congruence. The arrows show how the different categories/levels can be combined to give rise to different types of MMHs.

A first dimension regards whether the hallucinatory experiences are occurring on the same temporal scale across the two or more sensory modalities involved, in which case they will be categorised as “simultaneous MMHs”. If they are different hallucinatory experiences occurring in one sensory modality at a time (unimodal) in a sequential manner over time (ranging from minutes to days and more), they will be categorised as “serial MMHs”. Although this categorisation is presented as a dichotomy, when one conceptualises such experiences at the person level instead, dimensionality emerges: one would consider the proportion of hallucinatory experiences that are in multiple modalities simultaneously vs in the different modalities at different times.

The second dimension draws a distinction regarding the *relatedness* of these experiences to one another, i.e. whether they are experienced as the same entity or from the same source (Dudley et al., 2019, Lim et al., 2016). For example, Kumar et al., (2017) reports the case of a 50-year-old male with hallucinations of a person including both seeing them (visual) and hearing their voice (auditory). How to understand this concept of a common source remains partly underspecified in the literature: in the example above it is based on perceptions of the same source in different sensory modalities, but hallucinations might also be of distinct but semantically-related entities, such as having a religious vision and subsequently hearing the voice of God. Importantly, considering relatedness in a dimensional rather than dichotomous way thus suggests at least three important points along this dimension: first, cases of maximal relatedness in which multimodal hallucinations represent the same entity; second, cases of moderate relatedness in which multimodal hallucinations represent entities that are distinct but meaningfully related to each other; and third, cases in which hallucinations across different modalities represent completely unrelated entities.

Finally, the last level of categorisation is whether one can consider the combination of hallucinations across modalities as being coherent in reality, in which case the MMHs would be congruent; otherwise they would be incongruent. See examples in *Figure 2* below. One limitation here is that special combinations of the dimensions might give rise to definitional issues of MMHs. Would a (temporal) *sequence* of (conceptually) *unrelated* hallucinations occurring within a short time frame be considered multimodal?

Combinatorial features of MMHs					Example of MMH with such features
Serial	&	Unrelated		→	Seeing a dog today and hearing the voice of the devil a few days later
Simultaneous	&	Unrelated		→	Seeing a dog and hearing the voice of the devil
Simultaneous	&	Related	&	Congruent	→ Seeing a dog and hearing them bark
Simultaneous	&	Related	&	Incongruent	→ Seeing a dog and hearing them speak with the devil's voice
Serial	&	Related	&	Congruent	→ Seeing a dog today and associating an auditory hallucination of barking noise later in the day to the same entity (i.e. the dog)
Serial	&	Related	&	Incongruent	→ Seeing a dog today (visual hallucination only) and associating the voice of the devil heard later in the day (auditory hallucination only) to the same entity (i.e. the dog)

Figure 2- Examples of MMHs types based on the combinatorial features of MMHs along the three dimensions of time, relatedness and congruence.

Critically, it is important to point out that there is not a clear conceptual or theoretical basis for the classification system proposed here, as it is a face valid clinical heuristic that needs be further validated via empirical data: researchers and clinicians should ask service-users with MMHs and unimodal experiences whether this classification framework captures what is relevant and important to them about their experiences. Having a more rigorous classification and nomenclature of MMHs could make research in the field less ambiguous and more comparable across studies and patient groups, aiding in testing specific predictions of different theoretical models of hallucinations.

3. Prevalence

Overall, studies point to the fact that hallucinations in one modality incrementally increase the risk of hallucinations in one or more other modalities (David et al., 2011), a phenomenon that has its roots in the work of Storring in the 1900s. There also seems to be an inverse relationship between number of modalities and proportion of people reporting them (Lim et al., 2016, McCarthy-Jones et al., 2017), as well as specific patterns of frequencies of MMHs across disorders, which will be discussed in more details in the following sections.

3.1. Psychosis

Even though auditory hallucinations are a cardinal symptom of psychotic disorders, other modalities of hallucinations are typically overlooked. Recent studies have showed that the weighted mean prevalence of visual hallucinations is around 27% (Waters et al., 2014, based on 29 studies) compared to 79% for auditory hallucinations (Bauer et al., 2011). Prevalence estimates vary for olfactory hallucinations from 6% to 26%; gustatory hallucination 1% to 31%; somatic/tactile hallucinations 4%-19%, (Bauer et al., 2011; Jablensky et al., 1992; McCarthy Jones et al., 2017).

The overall lifetime prevalence of any hallucinations for this cohort is approximately 80%, with MMHs being twice as common as unimodal ones (53% vs 27%) (Lim et al, 2016; Llorca et al., 2016). Such higher prevalence of MMHs over unimodal hallucinations was found across studies of bipolar disorder patients as well (Waters and Fernyhough, 2017), suggesting continuity across psychotic illnesses. However, these studies did not specifically look at simultaneous MMHs, showing how a more careful categorisation and nomenclature as the one set out in this review could be of help in future research.

Studies show that visual hallucinations in psychosis almost always occur in combination with another hallucination modality (auditory, somatic or other) in 90% of cases (Clark et al, 2017; (Mueser, Bellack, & Brady, 1990), which stands in contrast to auditory hallucination which can occur independently of other modalities about half of the time (de Leede-Smith & Barkus, 2013). Another estimate showed that visual and auditory hallucinations co-occur in schizophrenia in approximately 32% of patients (Lim et al, 2016).

Finally, a study by Dudley et al. (2018) looked specifically at serial and multimodal MMHs in a group of 22 individuals with schizophrenia and found that 96% of them experienced serial MMHs vs. 86% experiencing simultaneous MMHs. MMHs were again more common than unimodal ones (See *Figure 3*). By contrast, other reports suggest that hallucinations in simultaneous multiple modalities (e.g. a talking head) are rare (Hoffman & Varanko, 2006). However, the sample in Dudley et al., (2018) had been recruited for presence of visual hallucinations, so it may not necessarily represent MMHs in psychosis in general.

Altogether, there is some preliminary evidence suggesting that when patients are specifically asked about them, the frequency of MMHs might be higher than that of unimodal ones, overturning and shedding light on some of the cardinal manifestations of psychosis in schizophrenia and bipolar disorder.

3.2. Eye Disease and Neurodegenerative Disorders

Dudley et al., (2019) compared hallucinations across different disorders using the NEVHI (North East Visual Hallucination Interview – Mosimann et al., 2008) and found that the frequencies of unimodal vs. multimodal ones varied across neurodegenerative disorders (See *Figure 3*, although no data is available for Alzheimer's Disease). Alongside visual hallucinations, which all participants in these studies experienced due to selection criteria, the subset of patients with Lewy Bodies Dementia (LBD) had the highest prevalence of MMHs, followed by Parkinson's Disease (PD) and then by those with eye disease. Unimodal hallucinations remained the most prevalent for all three groups, which is at odds with a study by Llorca et al., (2006), as they had found that in their sample of 200 PD patients a combination of hallucinations in 2 or 3 modalities was more common than experiencing unimodal ones, perhaps suggesting that bigger samples are needed in order to properly detect the prevalence of MMHs in neurodegenerative disorders.

In the Dudley et al., (2019) study, despite the higher frequency of unimodal hallucinations reported by participants, MMHs were found to be more irritating, distressing and frightening than their unimodal counterpart, alongside the fact that their visual hallucinations in the context of MMH were accompanied by a significantly stronger degree of conviction about their veracity, suggesting some important clinical implications that need further exploration.

Figure 3- Bar chart showing the prevalence (in n %) of hallucination modalities in combination with visual hallucinations (MMH) across four different disorders. Adapted from data in Table 2 in Dudley et al., (2019).

4. Phenomenology

It has previously been argued that phenomenological philosophy is an important tool to improve our understanding of the phenomenology of hallucinations (McCarthy-Jones et al., 2013). This approach can be applied to MMHs, where there is currently little systematic phenomenological evidence.

This would begin with in-depth questioning of people about their subjective experience of MMHs, with questions that suspend presuppositions about the phenomena under investigation. To do this requires us to first identify what presuppositions we have about hallucinations and MMHs in particular, such as expecting that hearing voices will be more common than hearing music, as is the case for unimodal hallucinations in schizophrenia (Baba & Amada, 1999). We

need to use these answers to begin a program of phenomenological research that begins with people's experiences of MMH, and not researchers' conceptions of what these experiences are like. Such research is badly needed and ought to involve those with lived experience of MMHs from the very start. This field of study should include both what has been termed a "*small-p*" phenomenological approach, which draws on people's subjective experience of MMHs, as well as a "*big-p*" phenomenological approach, which looks at how MMHs affect basic structures inherent in consciousness such as intentionality, self-awareness, temporality, embodiment, spatiality, agency, and intersubjectivity (McCarthy-Jones et al., 2013).

Several interesting questions remain unanswered regarding the phenomenology of MMH and it would be interesting to investigate the extent to which different modalities relate to social agents (see theories section for the aberrant social agent representation theory) and to what extent the relatedness dimension discussed earlier might correspond to this.

4.1. Cultural and social issues

There is a large body of literature on the influence of culture and social context on unimodal hallucinations (for example in schizophrenia - Bauer et al., 2011; Thomas et al., 2007, Luhrmann et al., 2015, and in the general population – Nuevo et al., 2012), but little systematic evidence looked at the influence of such factors on MMHs.

We have noted that MMH may be under-reported (Goodwin et al., 1971), perhaps as a result of them not featuring in standard psychiatric assessments (which may in turn be due to an over-emphasis on auditory verbal hallucinations in Western psychiatry; Fernyhough, 2014). When participants are given open-ended invitations to describe their experiences, other sensory and somatic experiences are frequently reported (Woods et al., 2015). It is probable that social and cultural forces will play a significant role in how likely respondents are to report non-auditory aspects of their experience, which will in turn affect their likelihood of reporting MMH. These forces are likely to configure differently across cultures and historical eras. For example, at times when religious beliefs meant that spiritual visions were highly valued (such as in the European Middle Ages), people experiencing hallucinations might have been more likely to report an experience in all its concomitant sensory modalities (Fernyhough, 2016). If you are going to have a vision of the Virgin Mary, and your prospects depend on your providing a convincing account of it, you are likely to report a hit on all your senses, rather than an experience limited to only one modality. Although impossible to prove empirically, this view makes sense of the apparently high incidence of MMH in accounts of medieval visionaries such as Margery Kempe and Julian of Norwich, but also points to the likelihood of significant cultural variation in the reporting of MMH in the present era.

Overall, it is not known what role culture may play in shaping the multimodality of hallucinations and research should look at transcultural data and compare MMHs across cultures, especially where there still is a strong element of spirituality. In fact, one's model of the world, with its priors and expectancy, can shape one's perception (see the theoretical section for a discussion of predictive coding and perception as a generative process) and it could be interesting to see if some subcultures or groups have stronger expectations that spiritual entities will manifest themselves in specific modalities over others, e.g. vision and auditory for "spiritual jaguars" in the Amazonian Wari' shamans (Vilaça, 2005), and vision, auditory, tactile and olfactory components in the experience of Jinns in Islamic cultures (Lim et al., 2015), and so on for all the other modalities. More research is clearly needed in this field and it would open interesting avenues for further discussion.

4.2. Developmental issues of MMHs

Hallucinations are frequently observed in children and adolescents even in non-clinical contexts (Maijer et al., 2019) and before 6 years of age (Pignon et al., 2018). A phenomenological analysis of the hallucinations reported in the NIMH childhood-onset schizophrenia cohort revealed that the number of sensory modalities involved may serve as an indicator of the neurodevelopmental weight of the disorder (David et al., 2011b), and notably that the presence of visual hallucinations was more often associated with intellectual disabilities. This neurodevelopmental hypothesis was later confirmed by an MRI study in which the gyrification index was compared between schizophrenia patients with pure auditory hallucinations and those with audio-visual experiences (Cachia et al., 2015), evidencing reduced sulcation for the more complex hallucinations. This idea of MMH as a proxy of developmental vulnerability was also confirmed in a recent case-series showing that the number of sensory modalities involved in early-onset hallucinations was related to the probability a given child ever experienced prior traumatic events (Medjkane et al., 2020).

5. Assessment of Multimodal hallucinations

In order to better understand the phenomenology and prevalence of MMHs, it is important to have appropriate, valid, and reliable assessment tools that go beyond the measurement of unimodal experiences in the most common sensory domains. To review the available measures fit for this purpose, published measures of MMHs across clinical and non-clinical populations were compared and summarised in Table 1. For a measure to be considered for review it needed to: 1) consider three or more modalities of hallucinations, 2) be published and used by researchers other than the developers, 3) have some evidence of its reliability and validity, 4) be accessible to researchers without extensive training, and finally, 5) be administrable in less than one hour.

Overall, although most of the scales examined can be used to detect serial MMHs, only four out of 16 have items that specifically assess simultaneous MMHs, and some of those that do still have a focus on one modality over others, such as the visual domain in the NEVHI. See the recommendations section at the end of the paper for a detailed discussion of improvements for future scales.

Table 1- Table showing the different scales for hallucinations alongside the sensory domains they assess and whether they capture if these hallucinations interact.

Target population	Scale	Intent of the scale	A U D	V I S	O L F	S O M	Other	Assess temporal features (simultaneity)	Items n.	Features	Scoring and Format	Format	Other
General population	LSHS (Extended and Modified versions) Launay-Slade Hallucination Scale	Hallucinations and related experiences							16	Presence	Items	Self-report	
	CAPS – Cardiff Anomalous Perception Scale	Perceptual changes and hallucinations							32	Frequency, distress, intrusiveness	Items	Self-report	
	MUSEQ - Multi-Modality Unusual Sensory Experiences Questionnaire	Continuum Perception-Hallucinations							43	Frequency (+ distress, intrusiveness, worry, impact)	Subscale	Self-report	
Children, adolescents, youths	MHASC – Multisensory Hallucination Scale for Children	Hallucinations							13/ modality	Frequency, intensity, conviction, insight, control, discomfort, emotional valence	Subscale	Both	App & online
	CAARMS – Comprehensive Assessment of At Risk Mental State	Diagnostic Interview							5	Frequency and duration	Items	Interview	
Psychotic Disorders	SAPS – Scale for the Assessment of Positive Symptoms	Broad symptoms profile							7	Frequency and severity	Subscale	Interview	
	DIP – Diagnostic Interview for Psychosis	Diagnostic interview and symptoms							9	Presence and frequency	Items	Interview	
	KGV – Krawiecka, Goldberg, Vaughn psychosis scale	Broad symptoms profile							6	Frequency, duration, subjective severity, level of control	Items	Interview	

Across disorders	QPE – Questionnaire for Psychotic Experiences	Hallucinations						11/50	Frequency, emotional content, distress, impact, content	Subscale	Interview	Online
	NEVHI – North East Visual Hallucination Interview	Hallucinations						21	Frequency, duration, severity, contents, emotional response, behavioural response	Items	Self + carer interview	Semi-structured
Parkinson's Disease and Alzheimer's Disease	UM-PDHQ – University of Miami Parkinson's Disease hallucinations Q	Broad symptoms profile (in Parkinson's)						20	Frequency, duration, emotional response, contents	Subscale	Self-report	
	MOUSEPAD – Manchester Oxford Universities Scale for the Psychopathological Assessment of Dementia	Broad symptoms profile (in dementia)						14	Severity, duration	Items	Interview with carers	
	Rush Inventory	Hallucinations (in Parkinson's)						53	Frequency, contents, emotional response, duration, time of day, context	Items	Self-report	
	TUHRAS – Tottori University Hallucinations Rating Scale	Hallucinations (in Parkinson's)						7	Frequency, severity, vividness	Items	Interview	
	BEHAVE-AD – Behavioural Symptoms in Alzheimer's Disease	Broad symptoms profile (in Parkinson's)						4	Clarity and behavioural response	Items	Interview	
	CUSPAD – Columbia University Scale for Psychopathology in AD	Broad symptoms profile (in Alzheimer's)						5	Presence, clarity	Items	Carer interview	

AUD= Auditory; VIS= Visual; OLF= Olfactory, SOM= Somatosensory; MMH= Multimodal hallucinations; AD= Alzheimer's Disease; PD=Parkinson's Disease.

6. Theoretical perspectives

Theories of hallucinations can largely be divided into those that consider these experiences to be attributable to modality-specific pathological processes, and those proposing modality-general processes that can affect, or are recruited by, different sensory modalities. An elegant discussion of theories from both of these fields and their link to the study of MMHs can be found in Fernyhough (2019). The present review builds on this work and aims to synthesise how these theories stand up to scrutiny given the available evidence on MMHs.

6.1. Modality-specific processes

The fact that some preliminary studies indicate a higher than previously assumed prevalence of MMHs in psychiatric and organic disorders, as well as in the general population - albeit without a rigorous distinction between the exact type of MMHs - raises the question of how to best conceptualise these hallucinatory experiences across diagnostic categories, and whether we should develop or update the theoretical approaches of unimodal hallucinations to account for such multimodality.

The presence of modality-specific processes of hallucinations is supported by evidence linking deficits in peripheral sensory systems to an increased likelihood of experiencing hallucinations. This is the case for visual hallucinations in eye diseases (ffytche, 2009), which is associated with abnormal activity of visual pathways. As well as in the auditory domain, where Linszen et al., (2019) found an association between hearing impairment and auditory hallucinations, the latter worsening as a function of hearing loss severity. For auditory hallucinations, the auditory cortex is an important region. Functional capture studies in schizophrenia show over-activation in speech-sensitive and auditory processing regions, involving both primary auditory cortex (Heschl's gyrus), and secondary auditory (association) cortex in the planum temporale (Allen et al., 2012; Zatorre, Chen and Penhune, 2007; Javitt & Sweet, 2015), even if meta-analyses only confirmed the involvement of associative speech-related areas in auditory hallucinations (Jardri et al., 2011). Finally, although not much research is available for the equivalent in other modalities, one study showed a similar relationship in case studies of Parkinson's Patients with impaired sense of smell and olfactory hallucinations (McAuley & Gregory, 2012).

Only few brain imaging studies explored the role of sensory complexity on the neural networks identified. A first fMRI capture study explored the functional patterns associated with occurrence of auditory, visual or audio-visual hallucinations in medication-free adolescents with a first-episode psychosis (Jardri et al., 2013), thus confirming the recruitment of physiological modality-specific pathways in these aberrant experiences. Beyond topography, specific functional and structural dysconnectivity patterns were later shown associated with audio-visual hallucinations compared with pure auditory experiences in schizophrenia (Amad et al., 2014) or even with schizophrenia patients without hallucinations (Rolland et al., 2015).

6.2. Modality-general processes

If both serial and simultaneous MMHs can be explained by the modality-specific processes discussed so far, one would expect to find specific sensory deficits in each and all of the sensory modalities in which a patient experiences hallucinations. To our knowledge, there is no empirical study that has yet shown such a pattern of results and the presence of MMHs across several disorders cannot be parsimoniously explained by considering modality-specific processes, thus possibly indicating the involvement of modality-general processes as well.

6.2.1. Misattribution biases

One candidate process that could explain hallucinations across modalities is a general bias to misattribute internally generated representations (of any modality) to an externally generated source. This concept stems from the inner speech misattribution theory of auditory hallucinations in schizophrenia (Frith, 1992), which posited that such experiences are the outcome of a misattribution of one's inner speech to an external entity. As Fernyhough (2019) suggested, the same mechanism could be translated to other modalities and there is evidence for its analogue in vision: Shine et al., (2015) found that PD patients with visual hallucinations also had strong visual imagery than those without hallucinations. Moreover, someone's tendency to be a visualiser or a verbaliser, or to be high on both of these dimensions relates to their proneness to MMH (McCarthy-Jones, Knowles & Rowse, 2012). However, there are two main issues with this model: a) in its current form it cannot explain why there are different rates of hallucinations across modalities, as it would predict all sensory systems to be equally affected, resulting in similar rates of hallucinatory experiences across them, and b) it is arguable whether one has internal smells, internal gustatory sensations etc. in the same way that one has internal speech.

6.2.2. Reality monitoring deficit

A second and related theoretical perspective of MMHs is that of deficits in reality monitoring. This refers to the ability to discern experiences that are internally generated from those externally generated. This is similar to the misattribution theories specified above, but differs from them in regard to the mechanism ascribed to such misattributions: here the mechanism specifically concerns monitoring the origin of information, while for general misattributions of percepts mechanisms other than reality monitoring might be in play (e.g. self-monitoring deficits - Frith, Blakemore & Wolpert, 2000).

Research suggests that reality monitoring might rely on the anterior paracingulate sulcus (PCS), a structure located in the medial prefrontal cortex (Garrison et al., 2015; Garrison et al., 2019). Evidence for a reality monitoring deficit in hallucinating patients can be found across different disorders (in schizophrenia and psychosis -Brébion et al., 2000, Aynsworth et al., 2017; and in Parkinson's Disease - Diederich, Goetz & Stebbins, 2004) and its relevance as an explanatory model of MMHs is linked to a study by Garrison et al., (2015). These researchers found that a reduced length of the PCS in a group of participants with diagnoses of schizophrenia was linked to an increased probability of them experiencing hallucinations (19.9% increased likelihood – but see Garrison et al., (2018) and Powers et al., (2020 - preprint) for work on PCS in non-clinical voice-hearers) and, even more importantly for the case of MMHs, this relationship was independent of the hallucinatory modality. This result, coupled with the evidence of reality monitoring deficits across psychiatric and neurodegenerative disorders, suggests that reality monitoring might be a good modality-general mechanism explaining the emergence of MMHs.

However, this theory still suffers from the same shortcoming of the previous theories, as in its current form it leaves unexplained why we see varying rates of MMHs across modalities and across disorders. Finally, there is also some evidence for additional separable and modality-specific reality monitoring systems (Moseley et al., 2014), which could be interacting with the modality-general ones. However, evidence for this comes from healthy individuals and to test this hypothesis one would need to replicate the results in clinical samples and see whether there are as many modality-specific systems as there are multi-modal hallucinatory experiences for these participants.

6.2.3. Social Agent Representations Theory

A third model-general theory of hallucinations that has the advantage of considering the often neglected social content of hallucinations is the “Aberrant Activation Of Social Agent Representations Theory” by Bell (2013). This theory posits that rather than specific sensory stimuli, such as voices or images, it is the general representation of another agent that is mistakenly activated, thus triggering the experience of that entity in all modalities. One prediction is that simultaneous and related MMHs should be more commonly experienced than other types. Despite its potential as an explanation of MMHs, there is currently not enough empirical evidence from MMHs to test such predictions and thus further research is needed to explore its potential.

6.3. Information theory frameworks: Predictive coding and circular inference

The next set of theories under discussion cannot be easily characterised as either modality-general or modality-specific but have elements that are compatible with both views. These two theories share the common concept that hallucinations arise from a dysfunction in the interaction between top-down expectations and bottom-up information. Where they diverge is in the specific way in which these sources of information are thought to interact. Each of them will be discussed with regards to their explanatory potential for MMHs.

The first of these theories is predictive coding (or predictive processing, PC; Fletcher and Frith, 2009; Clark, 2016). In a nutshell, it is a framework that considers the mind as a hierarchical structure engaged in message passing and where perception is a generative process (von Helmholtz, 1866). The levels of this hierarchy are thought to mirror the hierarchical structure of the world at different levels of abstraction and the message that is passed along is a prediction error (PE - Sokolov, 1960), i.e. the difference between what the higher level of the hierarchy predicted about the input from the lower level, and what the signal actually was (Lee & Mumford, 2003). Therefore, to have an optimal model of the world one should aim to minimize PEs (Rao & Ballard, 1999). If prediction errors are falsely generated or assigned too much precision, this would mistakenly signal that one’s model of the world must be updated, potentially leading to both altered perceptions (at the lower level, i.e. hallucinations) and altered beliefs (at the higher level, i.e. delusions). Research in schizophrenia and Parkinson’s Disease suggests that hallucinations might be linked to an issue of over-reliance on top-down influences on perception (Davies, Teufel & Fletcher, 2017; Corlett et al., 2019; Powers, Mathys & Corlett, 2017; O’Callaghan et al., 2017) thus possibly pointing towards a similar trans-diagnostic mechanism of hallucinatory experiences.

With regard to MMHs, given the generative nature of perception postulated by PC, one would predict that experiencing hallucinations in one modality might increase the prior expectation

(top-down mechanism) of experiencing a congruent hallucination in other modalities. This is in line with what shown by Dudley et al., (2018), who found that 88% of their early psychosis patients experienced congruent MMHs. However, in addition to the same shortcoming discussed for all the theories so far, there are additional issues with the explanatory power of PC for MMHs. Firstly, it does not explain the emergence of incongruent and/or unrelated serial or simultaneous MMHs, nor does it account for the fact that one can have experiences that are not consonant with one's general model of the world – as is the case with unimodal as well as serial unrelated MMHs in which one might experience disembodied voices (Dudley et al., 2018). A third problem, as argued by Fernyhough (2019), is the under-specification of whether PE and priors are modality-specific or modality-general or whether they can be a combination of the two. More details regarding this would allow one to test specific empirical hypotheses regarding MMHs within this PC framework and thus pave the way for further research in this field.

A second related theory that has been highly influential in hallucinations research involves the concept of circular inference as described by Jardri and Denève (2013). The core idea is that hallucinations and delusions can be understood in the framework of information theory, and specifically, of message-passing in the form of belief propagation in a hierarchical neural network. If not tightly controlled, the information propagated in both bottom-up and top-down directions can be amplified and reverberated through “loops” - generating reverberation errors. Bottom-up sensory evidence could be erroneously taken as top-down expectations, while top-down information could be fed back up and be mistaken for sensory information, leading to *‘expecting what we see’* or *‘seeing what we expect’* respectively (Jardri et al., 2017). This system is thought to be under the control of the excitatory (glutamatergic) and inhibitory (GABAergic) balance that becomes deranged leading to hallucinations and delusions (Jardri et al., 2016), with supporting evidence of such dysfunction from schizophrenia research (Benes et al., 2009).

Evidence linking circular inference as an explanation of MMHs comes from work done by Leptourgos, Denève and Jardri on synaesthesia, a perceptual phenomenon whereby the stimulation of one modality leads to experiences in another modality (Hochel & Milán, 2008) and that has been linked to disinhibited feedback from association cortex to sensory cortex (Grossenbacher & Lovelace, 2001). Ongoing research using simulations of drug-induced synaesthesia (Leptourgos, 2018) has shown that reverberation of information descending the cortical hierarchy (i.e. descending loops) could induce audio-visual experiences in the absence of clear sensory input (i.e. cross-modal hallucinations), but also a contamination of one modality by another in the presence of a unimodal stimulus (i.e. synaesthesia). These two features were retained as good candidates for modelling psychedelics-induced subjective experiences using probabilistic approaches. Ascending and descending loops as theorized in the CI framework can thus account for variations in the phenomenology of hallucinatory experiences observed in psychosis or that have been pharmacologically induced: auditory hallucinations with reduced illusions in the former and audio-visual hallucinations with synaesthesia in the latter.

6.4. Functional systems approach: a bridge between modality-specific and modality general processes?

Finally, it is important to consider how MMHs can be conceptualised through dysconnectivity between elements of a functional system (Fernyhough, 2019; Luria, 1965), a framework that

might allow one to understand how modality-general and modality-specific processes interact. Evidence of aberrant connectivity of neural networks has been found in relation to auditory hallucinations in schizophrenia (Alderson-Day et al., 2015) and to visual hallucinations in Parkinson's Disease (Dujardin et al., 2019; Shine et al., 2014). There is some work that looked at resting state and network connectivity in patients experiencing MMHs in schizophrenia, but no evidence is available for other disorders. One could speculate a hypothesis whereby the observed heterogeneity of unimodal and multimodal hallucinations within and across groups could be attributable to a common modality-general process that gives rise to different clinical phenomenological manifestations depending on what part of the network it affects, alongside potential, although perhaps not sufficient and necessary, pathology in modality-specific networks.

A related question is to what extent the processes underlying multimodal hallucinations are pathological. It could be that the pathology lies within one sensory system (visual in DLB or auditory in psychosis), but then the normal processes which ensure sensory consistency (given that information coming into perception is very limited) create an MMH from an initially unisensory experience. E.g. you start to see something, but that then primes hearing something or feeling something consistent with what is seen. This would be in line with an activation of modality-general representations, particularly of social agents - as discussed in the Social Agent Representation Theory. At present, we have very little idea about how MMH develop over time, both within a single episode, and over a period in an individual.

6.5. Interim summary

To conclude, when it comes to their explanatory power for MMHs, all these theories suffer from the general problems of not being able to explain a) why the rates of MMHs across modalities vary within an individual and across groups, b) why patients can show a combination of simultaneous MMHs, serial MMHs and unimodal hallucinations, c) and what might give rise to the relatedness and/or congruency of the content of both simultaneous and serial MMHs. We still need a theory to be developed or updated in order to account for these fundamental issues.

1. Clinical implications

The clinical understanding of hallucinations has primarily been focused on the auditory modality, with limited considerations of other modalities or of multimodal hallucinations. Yet, preliminary data indicate that MMHs are linked to higher levels of adverse mental health outcomes compared to unimodal hallucinations (Laloyaux et al., 2019; Dudley et al., 2018), being perceived as more distressing, frightening, and more veridical than unimodal ones. This highlights the importance of clinicians extending beyond the enquiry about the presence of the most likely hallucinatory experiences (e.g., hearing voices in psychotic disorders). As well as assessing a range of hallucinatory modalities, this indicates the importance of considering how different experiences relate to each other. Assessment strategies include asking whether an identified hallucination is experienced in other modalities (e.g., "Do you ever see [the voice]?") or whether other hallucinations occur at the same time (e.g., "Are there any physical sensations that happen when you [hear the voice]?").

Assessment can be extended by considering how consistently experiences in different modalities are connected temporally (e.g., "Do you usually see them when they are talking? Do you ever see them without hearing them?"). These are of relevance in formulating how they

may impact on distress. Hallucinations experienced simultaneously in multiple modalities are rated as seeming more real, and hence may make a hallucinated entity seem more threatening (Dudley et al., 2019). Likewise for serial MMHs, related phenomena can make hallucinations appear to have the power to affect the person in different ways, for example tactile sensations or visions that are meaningfully connected to a disembodied voice can contribute to beliefs that a voice has powers over the individual (Chadwick & Birchwood, 1994).

We need to evaluate if MMHs lead to poorer outcome in treatment trials as well as researching the effectiveness of antipsychotic medication for multi-modal hallucinations compared to unimodal ones. Whilst antipsychotic medications have a broad effect on psychotic symptoms, rather than any particular drugs having specificity for hallucinations (Sommer et al., 2012), it is not known whether medication may differentially affect multimodal vs unimodal hallucinatory experiences within subjects. This is an area for further research.

At present, most interventions are unimodal-related and predominantly for auditory hallucinations (e.g. Craig et al., 2018). In psychological interventions such as cognitive behavioural therapy for psychosis, clarifying the temporal sequencing of hallucinatory experiences in different modalities may also be informative about how hallucinatory episodes unfold over time. Considering what the person does in response to the first manifestations of a hallucinatory episode, and the potential role of expectancy for related experiences to occur, may indicate points of intervention with alternate coping strategies. Additionally, the beliefs that people hold about how different hallucinatory experiences are interconnected may be targets for cognitive therapy methods.

CBT for psychosis and auditory hallucinations is of modest effect (Jauhar et al., 2014), and there are no clinical trials of CBT for visions, with case studies showing mixed outcomes (Wilson et al., 2016). This raises the question of whether a poorer treatment outcome of visual hallucinations in psychosis is due to them being more often multimodal in nature, possibly having a compelling sense of reality that causes more disruption and distress and thus making them harder to treat (the lack of awareness that these are not real experiences could have an impact on to the development of pathological delusional thinking - Buchy et al., 2009). This is a clinical possibility that would need further investigation. Finally, it could be that the focus on the treatment of specific MMHs in clinical trials may also be unhelpful – unless one expects that the therapy “hits” an aetiological mechanism which is common to cross-modal hallucinations.

2. Unanswered Questions and Recommendations

At present, given the paucity of systematic evidence regarding MMHs, there are still several unanswered questions and avenues for further research. First, despite some preliminary data, it is still not clear exactly whether and how the base modality of hallucinations (i.e. the most prominent and frequent) changes the prevalence of experiencing hallucinations in other modalities. Secondly, it is not known if MMHs change over time and longitudinal studies would be needed to ascertain this. Thirdly, it is not known whether frequency of unusual experiences (e.g. someone only having a multimodal hallucination once a month but consistent unimodal ones daily) is important in understanding multimodality as well as the classification system outlined earlier on.

Thirdly, it remains debated how many senses one should take into account, as the established five sensory domains (auditory, visual, olfactory, gustatory, tactile) might not capture the whole range of hallucinatory experiences. Blom et al., (2013) describes 14 senses in which

hallucinations have been reported, thus widening the forest of sensory modalities involved. This also raises the question of whether hallucinations in less well-known sensory domains are equally understood by the experiencer themselves and whether they can be easily conveyed to others. It is arguable that there might be a general difficulty in having to convey non-verbal experiences to others in the first place, and this would be a very important limitation in the assessment of MMHs.

Finally, no current theory fully explains the different rates of MMHs within and across patient groups, nor the combination of congruent and incongruent serial and simultaneous MMHs.

To conclude, in line with what had been highlighted by the 2017 International Consortium on Hallucination Research (Jardri et al., 2019), this review shows the need to carry out a systematic investigation of MMHs. Overall, the evidence of the high prevalence and adverse prognostic outcomes of MMHs across disorders highlights the need to develop better assessment tools and theoretical models to systematically investigate these experiences and inform treatment strategies.

Box 1 - Clinical and research recommendations

- It is important to carry out a systematic study of multisensory experiences in non-clinical populations and across other clinical disorders in order to refine and further develop tools for assessing and recording MMHs across populations.
- To enable researchers and clinicians to reliably and validly detect both serial and simultaneous MMHs, scales need to include:
 - assessments of the dimensional categories discussed (temporal relationships, congruence and relatedness);
 - items that can assess and distinguish delirium, an acute state characterised by severe attentional impairments, cognitive dysfunction, and fluctuating awareness of the surroundings (Fong, Tulebaev, & Inouye, 2009). This can be common in those with neurodegenerative disorders (Vardy et al., 2015) and such patients could be describing experiences that might fit with MMHs but that are delirium episodes instead (Morandi et al., 2019).
 - Items that can assess if the person has sleep disorders (and incubus experiences in sleep paralysis for instance), as these can be linked to multisensory vivid experiences that might be confused as MMHs (especially in neurodegenerative disorders - Kulisevsky & Roldan, 2004)
 - items evaluating experiences beyond the common five sensory modalities. It is vital to have a systematic way of asking about the different sensory domains and then a systematic way of asking about their relationships
- Service-users who experience both MMHs and unimodal hallucinations should be consulted in order to validate the current classification framework and available measures to make sure that we are not imposing a classificatory system that limits their understanding of such experiences.
- We need to evaluate if MMHs lead to poorer outcome in treatment trials compared to unimodal ones.
- We may want to change our work from treating the appraisal of the experience (“it is a sign I am ill, or a sign I will be hurt”) to working with the content of the experiences, and incorporating sensory focussed treatment approaches that help people deal with the multimodal sensory experiences they have.

Funding

CF was supported by Wellcome Trust grants WT108720 and WT209513

Contributors

PU and DC were involved in the conception of this review. MM and PU drafted the first version of the manuscript. All authors provided critical feedback to initial draft and approved the final draft.

Declaration of interests

The authors declare no conflicts of interest.

Acknowledgements

Thank you to Dr. Daniel Williams for his help and comments on several drafts of this manuscript and to Dr. Dominic ffytche for the helpful and engaging discussions.

References

- Aarsland, D. (2016). Cognitive impairment in Parkinson's disease and dementia with Lewy bodies. *Parkinsonism & Related Disorders*, 22(Supplement 1), S144–S148.
<https://doi.org/10.1016/j.parkreldis.2015.09.034>
- Alderson-Day, B., McCarthy-Jones, S., & Fernyhough, C. (2015). Hearing voices in the resting brain: A review of intrinsic functional connectivity research on auditory verbal hallucinations. *Neuroscience & Biobehavioral Reviews*, 55, 78–87.
<https://doi.org/10.1016/j.neubiorev.2015.04.016>
- Allen, P., Modinos, G., Hubl, D., Shields, G., Cachia, A., Jardri, R., ... Hoffman, R. (2012). Neuroimaging Auditory Hallucinations in Schizophrenia: From Neuroanatomy to Neurochemistry and Beyond. *Schizophrenia Bulletin*, 38(4), 695–703.
<https://doi.org/10.1093/schbul/sbs066>
- Amad, A., Cachia, A., Gorwood, P., Pins, D., Delmaire, C., Rolland, B., ... Jardri, R. (2014). The multimodal connectivity of the hippocampal complex in auditory and visual hallucinations. *Molecular Psychiatry*, 19(2), 184–191.
<https://doi.org/10.1038/mp.2012.181>
- Aynsworth, C., Nemat, N., Collerton, D., Smailes, D., & Dudley, R. (2017). Reality monitoring performance and the role of visual imagery in visual hallucinations. *Behaviour Research and Therapy*, 97, 115–122.
<https://doi.org/10.1016/j.brat.2017.07.012>
- Baba, A., & Hamada, H. (1999). Musical Hallucinations in Schizophrenia. *Psychopathology*, 32(5), 242–251. <https://doi.org/10.1159/000029096>

- Bauer, S. M., Schanda, H., Karakula, H., Olajosy-Hilkesberger, L., Rudaleviciene, P., Okribelashvili, N., ... Stompe, T. (2011). Culture and the prevalence of hallucinations in schizophrenia. *Comprehensive Psychiatry*, 52(3), 319–325.
<https://doi.org/10.1016/j.comppsy.2010.06.008>
- Bell, V. (2013). A Community of One: Social Cognition and Auditory Verbal Hallucinations. *PLoS Biology*, 11(12), e1001723.
<https://doi.org/10.1371/journal.pbio.1001723>
- Benes, F. M. (2009). Neural Circuitry Models of Schizophrenia: Is it Dopamine, GABA, Glutamate, or Something Else? *Biological Psychiatry*, 65(12), 1003–1005.
<https://doi.org/10.1016/j.biopsych.2009.04.006>
- Blom, J. D. (2010). *A Dictionary of hallucinations*. Springer.
- Brébion, G., Amador, X., David, A., Malaspina, D., Sharif, Z., & Gorman, J. M. (2000). Positive symptomatology and source-monitoring failure in schizophrenia — an analysis of symptom-specific effects. *Psychiatry Research*, 95(2), 119–131.
[https://doi.org/10.1016/s0165-1781\(00\)00174-8](https://doi.org/10.1016/s0165-1781(00)00174-8)
- Buchy, L., Malla, A., Joober, R., & Lepage, M. (2009). Delusions are associated with low self-reflectiveness in first-episode psychosis. *Schizophrenia Research*, 112(1–3), 187–191. <https://doi.org/10.1016/j.schres.2009.03.019>
- Cachia, A., Amad, A., Brunelin, J., Krebs, M.-O., Plaze, M., Thomas, P., & Jardri, R. (2015). Deviations in cortex sulcation associated with visual hallucinations in schizophrenia. *Molecular Psychiatry*, 20(9), 1101–1107.
<https://doi.org/10.1038/mp.2014.140>
- Chadwick, P., & Birchwood, M. (1994). The Omnipotence of Voices. *British Journal of Psychiatry*, 164(2), 190–201. <https://doi.org/10.1192/bjp.164.2.190>
- Chesterman, L., & Boast, N. (1994). Multi-modal Hallucinations. *Psychopathology*, 27(6), 273–280. <https://doi.org/10.1159/000284883>
- Clark, A. (2016). *Surfing uncertainty : prediction, action, and the embodied mind*. Oxford ; New York: Oxford University Press.
- Clark, M. L., Waters, F., Vatskalis, T. M., & Jablensky, A. (2017). On the interconnectedness and prognostic value of visual and auditory hallucinations in first-episode psychosis. *European Psychiatry*, 41, 122–128.
<https://doi.org/10.1016/j.eurpsy.2016.10.011>
- Corlett, P. R., Horga, G., Fletcher, P. C., Alderson-Day, B., Schmack, K., & Powers, A. R. (2019). Hallucinations and Strong Priors. *Trends in Cognitive Sciences*, 23(2), 114–127. <https://doi.org/10.1016/j.tics.2018.12.001>
- Craig, T. K., Rus-Calafell, M., Ward, T., Leff, J. P., Huckvale, M., Howarth, E., ... Garety, P. A. (2018). AVATAR therapy for auditory verbal hallucinations in people with

- psychosis: a single-blind, randomised controlled trial. *The Lancet Psychiatry*, 5(1), 31–40. [https://doi.org/10.1016/s2215-0366\(17\)30427-3](https://doi.org/10.1016/s2215-0366(17)30427-3)
- David, A. (2004). The cognitive neuropsychiatry of auditory verbal hallucinations: An overview. *Cognitive Neuropsychiatry*, 9(1–2), 107–123. <https://doi.org/10.1080/13546800344000183>
- David, C. N., Greenstein, D., Clasen, L., Gochman, P., Miller, R., Tossell, J. W., ... Rapoport, J. L. (2011a). Childhood Onset Schizophrenia: High Rate of Visual Hallucinations. *Journal of the American Academy of Child & Adolescent Psychiatry*, 50(7), 681–686.e3. <https://doi.org/10.1016/j.jaac.2011.03.020>
- David, C. N., Greenstein, D., Clasen, L., Gochman, P., Miller, R., Tossell, J. W., ... Rapoport, J. L. (2011b). Childhood Onset Schizophrenia: High Rate of Visual Hallucinations. *Journal of the American Academy of Child & Adolescent Psychiatry*, 50(7), 681–686.e3. <https://doi.org/10.1016/j.jaac.2011.03.020>
- Davies, D. J., Teufel, C., & Fletcher, P. C. (2017). Anomalous Perceptions and Beliefs Are Associated With Shifts Toward Different Types of Prior Knowledge in Perceptual Inference. *Schizophrenia Bulletin*, 44(6), 1245–1253. <https://doi.org/10.1093/schbul/sbx177>
- de Leede-Smith, S., & Barkus, E. (2013). A comprehensive review of auditory verbal hallucinations: lifetime prevalence, correlates and mechanisms in healthy and clinical individuals. *Frontiers in Human Neuroscience*, 7. <https://doi.org/10.3389/fnhum.2013.00367>
- Diederich, N. J., Goetz, C. G., & Stebbins, G. T. (2004). Repeated visual hallucinations in Parkinson's disease as disturbed external/internal perceptions: Focused review and a new integrative model. *Movement Disorders*, 20(2), 130–140. <https://doi.org/10.1002/mds.20308>
- Dudley, R., Aynsworth, C., Mosimann, U., Taylor, J.-P., Smailes, D., Collerton, D., ... Urwyler, P. (2019). A comparison of visual hallucinations across disorders. *Psychiatry Research*, 272, 86–92. <https://doi.org/10.1016/j.psychres.2018.12.052>
- Dudley, Robert, Aynsworth, C., Cheetham, R., McCarthy-Jones, S., & Collerton, D. (2018). Prevalence and characteristics of multi-modal hallucinations in people with psychosis who experience visual hallucinations. *Psychiatry Research*, 269, 25–30. <https://doi.org/10.1016/j.psychres.2018.08.032>
- Dujardin, K., Roman, D., Baille, G., Pins, D., Lefebvre, S., Delmaire, C., ... Jardri, R. (2019). What can we learn from fMRI capture of visual hallucinations in Parkinson's disease? *Brain Imaging and Behavior*. <https://doi.org/10.1007/s11682-019-00185-6>
- Fénelon, G., Soulas, T., Zenasni, F., & de Langavant, L. C. (2010). The changing face of Parkinson's disease-associated psychosis: A cross-sectional study based on the new NINDS-NIMH criteria. *Movement Disorders*, 25(6), 763–766. <https://doi.org/10.1002/mds.22839>

- Fernyhough, C. (2014). Hearing the voice. *The Lancet*, 384(9948), 1090–1091. [https://doi.org/10.1016/s0140-6736\(14\)61665-2](https://doi.org/10.1016/s0140-6736(14)61665-2)
- Fernyhough, C. (2016). *Voices within - the history and science of how we talk to ourselves*. (pp. 135–136). Profile Books Ltd.
- Fernyhough, C. (2019). Modality-general and modality-specific processes in hallucinations. *Psychological Medicine*, 49(16), 2639–2645. <https://doi.org/10.1017/s0033291719002496>
- Ffytche, D. H. (2005). Visual hallucinations and the charles bonnet syndrome. *Current Psychiatry Reports*, 7(3), 168–179. <https://doi.org/10.1007/s11920-005-0050-3>
- ffytche, D. H. (2009). Visual hallucinations in eye disease. *Current Opinion in Neurology*, 22(1), 28–35. <https://doi.org/10.1097/wco.0b013e32831f1b3f>
- Fletcher, P. C., & Frith, C. D. (2009). Perceiving is believing: a Bayesian approach to explaining the positive symptoms of schizophrenia. *Nature Reviews Neuroscience*, 10(1), 48–58. <https://doi.org/10.1038/nrn2536>
- Fong, T. G., Tulebaev, S. R., & Inouye, S. K. (2009). Delirium in elderly adults: diagnosis, prevention and treatment. *Nature Reviews Neurology*, 5(4), 210–220. <https://doi.org/10.1038/nrneurol.2009.24>
- Frith, C. (1992). Essays in cognitive psychology. The cognitive neuropsychology of schizophrenia. In *Lawrence Erlbaum Associates, Inc.* Lawrence Erlbaum Associates, Inc.
- Frith, C. D., Blakemore, S.-J., & Wolpert, D. M. (2000). Abnormalities in the awareness and control of action. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, 355(1404), 1771–1788. <https://doi.org/10.1098/rstb.2000.0734>
- Garrison, J. R., Fernyhough, C., McCarthy-Jones, S., Haggard, M., & Simons, J. S. (2015). Paracingulate sulcus morphology is associated with hallucinations in the human brain. *Nature Communications*, 6(1). <https://doi.org/10.1038/ncomms9956>
- Garrison, J. R., Fernyhough, C., McCarthy-Jones, S., Simons, J. S., & Sommer, I. E. C. (2018). Paracingulate Sulcus Morphology and Hallucinations in Clinical and Nonclinical Groups. *Schizophrenia Bulletin*, 45(4), 733–741. <https://doi.org/10.1093/schbul/sby157>
- Garrison, J. R., Fernyhough, C., McCarthy-Jones, S., Simons, J. S., & Sommer, I. E. C. (2019). Paracingulate Sulcus Morphology and Hallucinations in Clinical and Nonclinical Groups. *Schizophrenia Bulletin*, 45(4), 733–741. <https://doi.org/10.1093/schbul/sby157>

- Goodwin, D. W. (1971). Clinical Significance of Hallucinations in Psychiatric Disorders. *Archives of General Psychiatry*, 24(1), 76. <https://doi.org/10.1001/archpsyc.1971.01750070078011>
- Grossenbacher, P. G., & Lovelace, C. T. (2001). Mechanisms of synesthesia: cognitive and physiological constraints. *Trends in Cognitive Sciences*, 5(1), 36–41. [https://doi.org/10.1016/s1364-6613\(00\)01571-0](https://doi.org/10.1016/s1364-6613(00)01571-0)
- Hochel, M., & Milán, E. G. (2008). Synaesthesia: The existing state of affairs. *Cognitive Neuropsychology*, 25(1), 93–117. <https://doi.org/10.1080/02643290701822815>
- Hoffman, R. E., & Varanko, M. (2006). “Seeing voices”: fused visual/auditory verbal hallucinations reported by three persons with schizophrenia-spectrum disorder. *Acta Psychiatrica Scandinavica*, 114(4), 290–292. <https://doi.org/10.1111/j.1600-0447.2006.00791.x>
- Insel, T., Cuthbert, B., Garvey, M., Heinssen, R., Pine, D. S., Quinn, K., ... Wang, P. (2010). Research Domain Criteria (RDoC): Toward a New Classification Framework for Research on Mental Disorders. *American Journal of Psychiatry*, 167(7), 748–751. <https://doi.org/10.1176/appi.ajp.2010.09091379>
- Jablensky, A., Sartorius, N., Ernberg, G., Anker, M., Korten, A., Cooper, J. E., ... Bertelsen, A. (1992). Schizophrenia: manifestations, incidence and course in different cultures A World Health Organization Ten-Country Study. *Psychological Medicine. Monograph Supplement*, 20, 1. <https://doi.org/10.1017/s0264180100000904>
- Jardri, R., & Denève, S. (2013). Circular inferences in schizophrenia. *Brain*, 136(11), 3227–3241. <https://doi.org/10.1093/brain/awt257>
- Jardri, R., Duverne, S., Litvinova, A. S., & Denève, S. (2017). Experimental evidence for circular inference in schizophrenia. *Nature Communications*, 8(1). <https://doi.org/10.1038/ncomms14218>
- Jardri, R., Hugdahl, K., Hughes, M., Brunelin, J., Waters, F., Alderson-Day, B., ... Denève, S. (2016). Are Hallucinations Due to an Imbalance Between Excitatory and Inhibitory Influences on the Brain? *Schizophrenia Bulletin*, 42(5), 1124–1134. <https://doi.org/10.1093/schbul/sbw075>
- Jardri, R., Larøi, F., Waters, F., Waters, F., Woodward, T., Aleman, A., ... Sommer, I. (2019). Hallucination Research: Into the Future, and Beyond. *Schizophrenia Bulletin*, 45(Supplement_1), S1–S4. <https://doi.org/10.1093/schbul/sby170>
- Jardri, R., Pins, D., Bubrovsky, M., Lucas, B., Lethuc, V., Delmaire, C., ... Thomas, P. (2009). Neural functional organization of hallucinations in schizophrenia: Multisensory dissolution of pathological emergence in consciousness. *Consciousness and Cognition*, 18(2), 449–457. <https://doi.org/10.1016/j.concog.2008.12.009>
- Jardri, R., Pouchet, A., Pins, D., & Thomas, P. (2011). Cortical Activations During Auditory Verbal Hallucinations in Schizophrenia: A Coordinate-Based Meta-

- Analysis. *American Journal of Psychiatry*, 168(1), 73–81.
<https://doi.org/10.1176/appi.ajp.2010.09101522>
- Jardri, R., Thomas, P., Delmaire, C., Delion, P., & Pins, D. (2013). The Neurodynamic Organization of Modality-Dependent Hallucinations. *Cerebral Cortex*, 23(5), 1108–1117. <https://doi.org/10.1093/cercor/bhs082>
- Jauhar, S., McKenna, P. J., Radua, J., Fung, E., Salvador, R., & Laws, K. R. (2014). Cognitive-behavioural therapy for the symptoms of schizophrenia: systematic review and meta-analysis with examination of potential bias. *British Journal of Psychiatry*, 204(1), 20–29. <https://doi.org/10.1192/bjp.bp.112.116285>
- Javitt, D. C., & Sweet, R. A. (2015). Auditory dysfunction in schizophrenia: integrating clinical and basic features. *Nature Reviews Neuroscience*, 16(9), 535–550.
<https://doi.org/10.1038/nrn4002>
- Kulisevsky, J., & Roldan, E. (2004). Hallucinations and sleep disturbances in Parkinson's disease. *Neurology*, 63(Issue 8, Supplement 3), S28–S30.
https://doi.org/10.1212/wnl.63.8_suppl_3.s28
- Kumar, V., Bagewadi, V., Sagar, D., & Varambally, S. (2017). Multimodal hallucinations in schizophrenia and its management. *Indian Journal of Psychological Medicine*, 39(1), 86. <https://doi.org/10.4103/0253-7176.198955>
- Laloyaux, J., Bless, J. J., Hugdahl, K., Kråkvik, B., Vedula-Kjelsås, E., Kalhovde, A. M., & Larøi, F. (2019). Multimodal hallucinations are associated with poor mental health and negatively impact auditory hallucinations in the general population: Results from an epidemiological study. *Schizophrenia Research*, 210, 319–322.
<https://doi.org/10.1016/j.schres.2019.06.005>
- Lee, T. S., & Mumford, D. (2003). Hierarchical Bayesian inference in the visual cortex. *Journal of the Optical Society of America A*, 20(7), 1434.
<https://doi.org/10.1364/josaa.20.001434>
- Leptourgos, P. (2018). *Dynamical circular inference in the general population and the psychosis spectrum : insights from perceptual decision making*.
- Lim, A., Hoek, H. W., & Blom, J. D. (2015). The attribution of psychotic symptoms to jinn in Islamic patients. *Transcultural Psychiatry*, 52(1), 18–32.
<https://doi.org/10.1177/1363461514543146>
- Lim, A., Hoek, H. W., Deen, M. L., Blom, J. D., Bruggeman, R., Cahn, W., ... Wiersma, D. (2016). Prevalence and classification of hallucinations in multiple sensory modalities in schizophrenia spectrum disorders. *Schizophrenia Research*, 176(2–3), 493–499.
<https://doi.org/10.1016/j.schres.2016.06.010>
- Linszen, M. M. J., van Zanten, G. A., Teunisse, R. J., Brouwer, R. M., Scheltens, P., & Sommer, I. E. (2018). Auditory hallucinations in adults with hearing impairment: a large prevalence study. *Psychological Medicine*, 49(1), 132–139.
<https://doi.org/10.1017/s0033291718000594>

- Llorca, P. M., Pereira, B., Jardri, R., Chereau-Boudet, I., Brousse, G., Misdrahi, D., ... de Chazeron, I. (2016). Hallucinations in schizophrenia and Parkinson's disease: an analysis of sensory modalities involved and the repercussion on patients. *Scientific Reports*, 6(1). <https://doi.org/10.1038/srep38152>
- Luhrmann, T. M., Padmavati, R., Tharoor, H., & Osei, A. (2015). Differences in voice-hearing experiences of people with psychosis in the USA, India and Ghana: Interview-based study. *British Journal of Psychiatry*, 206(1), 41–44. <https://doi.org/10.1192/bjp.bp.113.139048>
- Luria, A. R. (1965). L.S. Vygotsky and the problem of localization of functions. *Neuropsychologia*, 3(4), 387–392. [https://doi.org/10.1016/0028-3932\(65\)90012-6](https://doi.org/10.1016/0028-3932(65)90012-6)
- Maijer, K., Hayward, M., Fernyhough, C., Calkins, M. E., Debbané, M., Jardri, R., ... Bartels-Velthuis, A. A. (2019). Hallucinations in Children and Adolescents: An Updated Review and Practical Recommendations for Clinicians. *Schizophrenia Bulletin*, 45(Supplement_1), S5–S23. <https://doi.org/10.1093/schbul/sby119>
- Margery, K., & Bale, A. (2015). *The Book of Margery Kempe*. Oxford Oxford University Press.
- Massachusetts General Hospital, Freudenreich, Brown, & Holt. (2016). *Psychosis and Schizophrenia* (Stern, Fava, Wilens, & Rosenbaum, Eds.). Elsevier.
- McAuley, J. H., & Gregory, S. (2012). Prevalence and Clinical Course of Olfactory Hallucinations in Idiopathic Parkinson's Disease. *Journal of Parkinson's Disease*, 2(3), 199–205. <https://doi.org/10.3233/jpd-2012-012086>
- McCarthy-Jones, S., Knowles, R., & Rowse, G. (2012). More than words? Hypomanic personality traits, visual imagery and verbal thought in young adults. *Consciousness and Cognition*, 21(3), 1375–1381. <https://doi.org/10.1016/j.concog.2012.07.004>
- McCarthy-Jones, S., Krueger, J., Larøi, F., Broome, M., & Fernyhough, C. (2013). Stop, look, listen: the need for philosophical phenomenological perspectives on auditory verbal hallucinations. *Frontiers in Human Neuroscience*, 7. <https://doi.org/10.3389/fnhum.2013.00127>
- McCarthy-Jones, S., Smailes, D., Corvin, A., Gill, M., Morris, D. W., Dinan, T. G., ... Dudley, R. (2017). Occurrence and co-occurrence of hallucinations by modality in schizophrenia-spectrum disorders. *Psychiatry Research*, 252, 154–160. <https://doi.org/10.1016/j.psychres.2017.01.102>
- Medjkane, F., Notredame, C.-E., Sharkey, L., D'Hondt, F., Vaiva, G., & Jardri, R. (2020). Association between childhood trauma and multimodal early-onset hallucinations. *The British Journal of Psychiatry*, 1–3. <https://doi.org/10.1192/bjp.2019.266>

- Mellor, C. S. (1970). First Rank Symptoms of Schizophrenia: I. the Frequency in Schizophrenics on Admission to Hospital II. Differences between Individual First Rank Symptoms. *British Journal of Psychiatry*, 117(536), 15–23. <https://doi.org/10.1192/s0007125000192116>
- Morandi, A., Davis, D., Bellelli, G., Arora, R. C., Caplan, G. A., Kamholz, B., ... Rudolph, J. L. (2017). The Diagnosis of Delirium Superimposed on Dementia: An Emerging Challenge. *Journal of the American Medical Directors Association*, 18(1), 12–18. <https://doi.org/10.1016/j.jamda.2016.07.014>
- Moseley, P., Fernyhough, C., & Ellison, A. (2014). The role of the superior temporal lobe in auditory false perceptions: A transcranial direct current stimulation study. *Neuropsychologia*, 62, 202–208. <https://doi.org/10.1016/j.neuropsychologia.2014.07.032>
- Mosimann, U. P., Collerton, D., Dudley, R., Meyer, T. D., Graham, G., Dean, J. L., ... McKeith, I. G. (2008). A semi-structured interview to assess visual hallucinations in older people. *International Journal of Geriatric Psychiatry*, 23(7), 712–718. <https://doi.org/10.1002/gps.1965>
- Mueser, K. T., Bellack, A. S., & Brady, E. U. (1990). Hallucinations in schizophrenia. *Acta Psychiatrica Scandinavica*, 82(1), 26–29. <https://doi.org/10.1111/j.1600-0447.1990.tb01350.x>
- Nuevo, R., Chatterji, S., Verdes, E., Naidoo, N., Arango, C., & Ayuso-Mateos, J. L. (2012). The Continuum of Psychotic Symptoms in the General Population: A Cross-national Study. *Schizophrenia Bulletin*, 38(3), 475–485. <https://doi.org/10.1093/schbul/sbq099>
- O’Callaghan, C., Hall, J. M., Tomassini, A., Muller, A. J., Walpola, I. C., Moustafa, A. A., ... Lewis, S. J. G. (2017). Visual Hallucinations Are Characterized by Impaired Sensory Evidence Accumulation: Insights From Hierarchical Drift Diffusion Modeling in Parkinson’s Disease. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, 2(8), 680–688. <https://doi.org/10.1016/j.bpsc.2017.04.007>
- Pignon, B., Geoffroy, P. A., Gharib, A., Thomas, P., Moutot, D., Brabant, W., ... Jardri, R. (2018). Very early hallucinatory experiences: a school-based study. *Journal of Child Psychology and Psychiatry*, 59(1), 68–75. <https://doi.org/10.1111/jcpp.12780>
- Powers, A. R., Mathys, C., & Corlett, P. R. (2017). Pavlovian conditioning–induced hallucinations result from overweighting of perceptual priors. *Science*, 357(6351), 596–600. <https://doi.org/10.1126/science.aan3458>
- Powers, A., van Dyck, L., Garrison, J. R., & Corlett, P. (2020). Paracingulate sulcus length is shorter in voice-hearers regardless of need for care. *MedRxiv*. <https://doi.org/10.1101/2020.01.13.19015891>
- Rao, R. P. N., & Ballard, D. H. (1999). Predictive coding in the visual cortex: a functional interpretation of some extra-classical receptive-field effects. *Nature Neuroscience*, 2(1), 79–87. <https://doi.org/10.1038/4580>

- Rolland, B., Amad, A., Poulet, E., Bordet, R., Vignaud, A., Bation, R., ... Jardri, R. (2015). Resting-State Functional Connectivity of the Nucleus Accumbens in Auditory and Visual Hallucinations in Schizophrenia. *Schizophrenia Bulletin*, 41(1), 291–299. <https://doi.org/10.1093/schbul/sbu097>
- Rollins, C. P. E., Garrison, J. R., Simons, J. S., Rowe, J. B., O’Callaghan, C., Murray, G. K., & Suckling, J. (2019). Meta-analytic Evidence for the Plurality of Mechanisms in Transdiagnostic Structural MRI Studies of Hallucination Status. *EClinicalMedicine*, 8, 57–71. <https://doi.org/10.1016/j.eclinm.2019.01.012>
- Rommel, O., Bokeloh, M., Malin, J. P., Braunig, P., Strumpf, M., & Zenz, M. (1999). Coenesthesia - An important differential diagnosis in chronic pain syndromes. *Der Schmerz*, 13(3), 201–204. <https://doi.org/10.1007/s004829900021>
- Shine, J. M., Keogh, R., O’Callaghan, C., Muller, A. J., Lewis, S. J. G., & Pearson, J. (2015). Imagine that: elevated sensory strength of mental imagery in individuals with Parkinson’s disease and visual hallucinations. *Proceedings of the Royal Society B: Biological Sciences*, 282(1798), 20142047. <https://doi.org/10.1098/rspb.2014.2047>
- Shine, J. M., O’Callaghan, C., Halliday, G. M., & Lewis, S. J. G. (2014). Tricks of the mind: Visual hallucinations as disorders of attention. *Progress in Neurobiology*, 116, 58–65. <https://doi.org/10.1016/j.pneurobio.2014.01.004>
- Shinn, A. K., Pfaff, D., Young, S., Lewandowski, K. E., Cohen, B. M., & Öngür, D. (2012). Auditory hallucinations in a cross-diagnostic sample of psychotic disorder patients: a descriptive, cross-sectional study. *Comprehensive Psychiatry*, 53(6), 718–726. <https://doi.org/10.1016/j.comppsy.2011.11.003>
- Sokolov, E. N. (1960). Neuronal models and the orienting reflex. In M. Brazier (Ed.), *The central nervous system and behaviour* (pp. 187–276). Josiah Macy Jr.
- Sommer, I. E., Begemann, M. J. H., Temmerman, A., & Leucht, S. (2012). Pharmacological Augmentation Strategies for Schizophrenia Patients With Insufficient Response to Clozapine: A Quantitative Literature Review. *Schizophrenia Bulletin*, 38(5), 1003–1011. <https://doi.org/10.1093/schbul/sbr004>
- Storring. (1900). Vorlesungen über Psychopathologie in Ihrer Bedeutung für die Normale Psychologie mit Einschluss der Psychologischen Grundlagen der Erkenntnistheorie. *Leipzig: Verlag von Wilhelm Engelmann*.
- Thomas, P., Mathur, P., Gottesman, I. I., Nagpal, R., Nimgaonkar, V. L., & Deshpande, S. N. (2007). Correlates of hallucinations in schizophrenia: A cross-cultural evaluation. *Schizophrenia Research*, 92(1–3), 41–49. <https://doi.org/10.1016/j.schres.2007.01.017>
- Toh, W. L., McCarthy-Jones, S., Copolov, D., & Rossell, S. L. (2019). Have we overlooked the significance of multinodal hallucinations in schizophrenia? *Psychiatry Research*, 279, 358–360. <https://doi.org/10.1016/j.psychres.2019.06.018>

- Vardy, E. R. L. C., Teodorczuk, A., & Yarnall, A. J. (2015). Review of delirium in patients with Parkinson's disease. *Journal of Neurology*, 262(11), 2401–2410. <https://doi.org/10.1007/s00415-015-7760-1>
- Vilaca, A. (2005). Chronically Unstable Bodies: Reflections on Amazonian Corporalities. *Journal of the Royal Anthropological Institute*, 11(3), 445–464. <https://doi.org/10.1111/j.1467-9655.2005.00245.x>
- von Helmholtz. (1866). *Handbuch der Physiologischen Optik*. Voss, Leipzig.
- Waters, F., Collerton, D., ffytche, D. H., Jardri, R., Pins, D., Dudley, R., ... Larøi, F. (2014). Visual Hallucinations in the Psychosis Spectrum and Comparative Information From Neurodegenerative Disorders and Eye Disease. *Schizophrenia Bulletin*, 40(Suppl_4), S233–S245. <https://doi.org/10.1093/schbul/sbu036>
- Waters, F., & Fernyhough, C. (2017). Hallucinations: A Systematic Review of Points of Similarity and Difference Across Diagnostic Classes. *Schizophrenia Bulletin*, 43(1), 32–43. <https://doi.org/10.1093/schbul/sbw132>
- Wilson, R., Collerton, D., Freeston, M., Christodoulides, T., & Dudley, R. (2016). Is Seeing Believing? The Process of Change During Cognitive-behavioural Therapy for Distressing Visual Hallucinations. *Clinical Psychology & Psychotherapy*, 23(4), 285–297. <https://doi.org/10.1002/cpp.1962>
- Woods, A., Jones, N., Alderson-Day, B., Callard, F., & Fernyhough, C. (2015). Experiences of hearing voices: analysis of a novel phenomenological survey. *The Lancet Psychiatry*, 2(4), 323–331. [https://doi.org/10.1016/s2215-0366\(15\)00006-1](https://doi.org/10.1016/s2215-0366(15)00006-1)
- Zatorre, R. J., Chen, J. L., & Penhune, V. B. (2007). When the brain plays music: auditory–motor interactions in music perception and production. *Nature Reviews Neuroscience*, 8(7), 547–558. <https://doi.org/10.1038/nrn2152>