Northumbria University
NEWCASTLE

University**Library**

RUNNING HEAD: HALLUCINATIONS IN SCHIZOPHRENIA

Occurrence and co-occurrence of hallucinations by modality in schizophrenia-spectrum disorders

Simon McCarthy-Jones[a*], David Smailes[b], Aiden Corvin[a], Michael Gill[a], Derek W. Morris[c], Timothy G. Dinan[d], Kieran C. Murphy[e], F. Anthony O'Neill[f], John L. Waddington[g], Australian Schizophrenia Research Bank[h], Gary Donohoe[c] & Robert Dudley[i,j]

a) Department of Psychiatry, Trinity College Dublin, Ireland.
b) Department of Psychology, Leeds Trinity University, Leeds, UK.
c) School of Psychology and Discipline of Biochemistry, National University of Ireland Galway, Ireland.
d) Department of Psychiatry, University College Cork, Ireland.
e) Department of Psychiatry, Royal College of Surgeons in Ireland, Dublin, Ireland.
f) Department of Psychiatry, Queen's University Belfast, Northern Ireland.
g) Molecular and Cellular Therapeutics, Royal College of Surgeons in Ireland, Dublin, Ireland.
h) Schizophrenia Research Institute, NSW, Australia
i) School of Psychology, Newcastle University, Newcastle, UK.
j) Northumberland Tyne and Wear NHS Foundation Trust, UK

* Corresponding author: Dr Robert Dudley, Doctorate of Clinical Psychology, Newcastle University, Ridley Building, Newcastle, NE1 7RU. Email: r.e.j.dudley@ncl.ac.uk. Tel: (+44) 191 222 7925. Fax (+44) 191 222 7520.

Abstract

It is not only unclear why hallucinations in schizophrenia occur with different prevalence by modality, but also to what extent they do. Reliable prevalence estimates of hallucinations by modality in schizophrenia are currently lacking, particularly for non-auditory hallucinations. Studies have also tended to report lifetime, not point prevalence by modality. This study assessed the prevalence and co-occurrence of hallucinations, for both lifetime and point prevalence, across the auditory, visual, olfactory, and tactile modalities, in people diagnosed with chronic schizophrenia-spectrum disorders in Ireland (N=693) and Australia (N=218). Lifetime prevalence was 64-80% auditory, 23-31% visual, 9-19% tactile, and 6-10% olfactory. Past month prevalence was 23-27% auditory, 5-8% visual, 4-7% tactile, and 2% olfactory. The majority of participants had only hallucinated in one modality, with this nearly always being the auditory. Approximately one-third had hallucinated in two modalities, most commonly the auditory and visual. Most currently hallucinating patients also hallucinated in a single modality, again, nearly always the auditory. Whereas 30-37% of patients with lifetime auditory hallucinations had experienced visual hallucinations, 83-97% of patients with experience of visual hallucinations had experienced auditory hallucinations. These findings help delineate the modality distribution of hallucinations in schizophrenia, and provide an explanatory target for theoretical models.

Keywords: Auditory; psychosis; olfactory; tactile; visual.

Occurrence and co-occurrence of hallucinations by modality in schizophrenia-spectrum disorders

1. Introduction

A major, and largely unaddressed, challenge for models of hallucinations in schizophrenia is to explain why hallucinations in different sensory modalities (e.g., the auditory, visual, olfactory, tactile) occur with differing prevalence. For example, models of hallucinations that propose source-monitoring deficits underpin the experience (e.g., Waters et al., 2012) do not predict that such deficits would preferentially attach to some modalities of perception rather than others. Hallucinations in the auditory modality are well-understood to be "by far the most common" (APA, 2013, p.300) and have been consistently found to exceed the prevalence of visual hallucinations (Jablensky, 1997; Bowman and Raymond, 1931; WHO, 1975; Thomas et al., 2007). The latter, in turn, have been found to occur with greater prevalence than hallucinations in the tactile and olfactory modalities (Thomas et al., 2007). Despite this apparent consensus over the hierarchy of hallucinations, there has been a lack of rigorous research into the prevalence of non-auditory hallucinations (Gauntlett-Gilbert and Kuipers, 2003; Langdon et al., 2011). For example, a recent review found a mean prevalence of visual hallucinations in schizophrenia of 27%, but noted significant variation between studies, with prevalence estimates varying from 4%-65% (Waters et al., 2014). This variation may have reflected cultural differences, a reliance on small sample sizes, and the use of both standardised and non-standardised assessment methods (Waters et al., 2014). Given this situation, the first aim of our study was to obtain a more reliable estimate of the lifetime prevalence of different modalities of hallucinations in schizophrenia. This was to be achieved by employing large samples, in two different countries, using standardised assessment measures.

Studies rarely report both lifetime and point prevalence of hallucination by modality, which has the potential to be misleading. For example, it has been suggested that visual hallucinations are often experienced infrequently (Gauntlett-Gilbert and Kuipers, 2003) meaning lifetime prevalence estimates may give a misleading, inflated impression of ubiquity. Furthermore, there is some suggestion that the hierarchy of hallucinations documented for lifetime prevalence of hallucinations in schizophrenia may not be mirrored for point prevalence. For example, Langdon et al. (2011) reported on the prevalence of hallucinations by modality in the past month (determined from interview-based assessments) in two large samples of people diagnosed with chronic schizophrenia-spectrum disorders. Auditory hallucinations were overwhelmingly the most prevalent modality of hallucination (50-57%). However, it was found that tactile hallucinations (28%), occurred at comparable levels to visual hallucinations (23-26%), with olfactory hallucinations (13-17%) occurring with lower prevalence. This finding of a comparable prevalence of current visual and tactile hallucinations was not without precedent (Baethge et al., 2005). Another study, which used an experience sampling methodology, found that current prevalence of visual hallucinations was higher than that of auditory hallucinations (Delespaul and van Os, 2002). Over the course of a week, 63% of patients reported visual hallucinations, but only 49% reported auditory hallucinations. However, this used a liberal criterion for the presence of hallucinations, and when more stringent criteria were employed by Oorschot et al. (2012) the more expected current rate of auditory hallucinations (34%) and visual hallucinations (26%) was found. In order to contribute further data pertaining to the nature of the hallucination-hierarchy in schizophrenia by point prevalence, the second aim of our study was to report point prevalence (past month) of hallucinations by modality.

In addition to lifetime and point prevalence by modality, it is not clear the extent to which different modalities of hallucinations co-occur (Oorschot et al., 2012), both over the

lifetime as well as in the past month. Preliminary evidence suggests that patients with visual hallucinations are highly likely to also have auditory hallucinations. The experience sampling study of Oorschot et al. found 79% of patients with visual hallucinations also had auditory hallucinations, and an interview-based study by Mueser et al. (1990) reported an equivalent figure of 84%. In contrast, those with auditory hallucinations are much less likely to have other forms of hallucinations. For example, Nayani and David (1996) found only 51% of people diagnosed with schizophrenia with auditory hallucinations reported visual hallucinations, and that these experiences of visual hallucinations were often rare and transitory. Oorschot et al.'s ESM study found that only 40% of patients with auditory hallucinations also reported visual hallucinations. Additional data concerning this question is required. People diagnosed with psychosis who experience visual hallucinations in the absence of auditory hallucinations may imply, at least in some people, separate and independent causation of their visual hallucinations. For example, visual hallucinations in neurodegenerative disorders (e.g., Lewy Body Dementia and Parkinson's disease) are not related to the presence of auditory hallucinations and are thought to arise from a combination of impaired visual perception and attentional deficits (Collerton et al., 2005). Thus, the third aim of our study was to examine how different modalities of hallucinations co-occur over the course of a lifetime, as well as contemporaneously.

Finally, given the aforementioned relative paucity of visual hallucinations research in samples of people diagnosed with schizophrenia (Gauntlett-Gilbert and Kuipers, 2003), we were also interested to record instances of the content of visual hallucinations experienced by such patients (Dudley et al., 2013), and to examine the relation between visual hallucinations and demographic factors. For example, in participants under 60 years of age, visual hallucinations presence has been found to be inversely related to age (Bauer et al., 2011). In terms of gender, women are more likely than men to experience hallucinations (Baethge et

al., 2005), but it is not clear if this is true for visual hallucinations specifically (Waters et al., 2014).

In summary, the present study aimed to document the prevalence and co-occurrence of hallucinations across the auditory, visual, olfactory, and tactile modalities, in terms of both lifetime and point prevalence, using a standardised assessment in two large, distinct samples of people (one drawn from Ireland, the other from Australia) who had formally been diagnosed with schizophrenia-spectrum disorders.

2. Methods

2.1 Participants

Ireland. Participants were 613 people with schizophrenia-spectrum diagnoses (schizophrenia, schizoaffective disorder, schizophreniform disorder), recruited from psychosis services across Ireland, for whom complete hallucination data was available. Clinical assessments were carried out by either a Psychiatric Research Fellow, or dedicated research nurses trained in the administration of the diagnostic interview test instruments, working under supervision. Demographic and clinical information is reported in Table 1. DSM-IV diagnosis was determined using the Structured Clinical Interview for DSM-IV Axis 1 Diagnoses (First et al., 2002). Exclusion criteria were that participants had a history of comorbid psychiatric disorder, substance abuse in the preceding 6 months, or prior head injury with loss of consciousness. While data have been reported previously on a subset of this sample (e.g., Corvin et al., 2008), all analyses reported here are novel.

Australia. Participants were 218 people with schizophrenia-spectrum diagnoses, recruited from psychosis services across Australia (Loughland et al., 2010), who had a complete response set for the hallucinations section of the Diagnostic Interview for Psychosis (DIP; Castle et al., 2006). Clinical assessments were performed by registered psychologists or

intern psychologists, trained in the administration of the diagnostic interview test instruments, working under supervision. DSM-IV (APA, 1994) diagnosis was determined using the DIP. Exclusion criteria included an inability to converse fluently in English, organic brain disorder, brain injury with post-traumatic amnesia >24 h, intellectual disability (IQ<70), current diagnosis of substance dependence, and electroconvulsive therapy received in the last 6 months. While data have been reported previously on subset of this sample (Loughland et al., 2010), the analyses reported here are novel.

2.2 Measures

Ireland. The presence of hallucinations was assessed using the Scale for the Assessment of Positive Symptoms (SAPS; Andreasen, 1984). All participants were assessed for current experience (present in the previous month) of hallucinations, and a subset (n=205) were also assessed for lifetime experiences of hallucinations. The SAPS inquires about hallucinations in the auditory, visual, tactile, and olfactory modalities (Auditory: "*Have you ever heard voices or other sounds when no one is around?*" Visual "*Have you had visions or seen things that other people cannot?"* Olfactory: "*Have you ever experienced any unusual smells or smells that others do not notice?"* Tactile: "*Have you ever had burning sensations or other strange feelings in your body? Did your body ever appear to change in shape or size?*"). All hallucination items are rated on a 0-5 scale (0 = absent; 1 = questionable; 2 = mild, occur only occasionally; 3 = moderate, have occurred at least weekly; 4 = marked, occur almost every day; 5 = severe, occur often every day). There is variability in what cut-off score researchers use to determine the presence of hallucinations. Studies have variously defined the presence of hallucinations as being indicated by a score of ≥1 (e.g., Ford et al., 2009), ≥2 (e.g., Andreasen and Flaum, 1991; David et al., 2011), ≥3 (e.g., Alba-Ferrara et al., 2007; Andreasen and Flaum, 1991), or ≥4 for "prominent hallucinations" (Andreasen and Flaum, 1991). Our approach was to report the full distribution of SAPS hallucination scores

in Supplemental Table 1, to allow the reader to make their own determinations, and to use a score of ≥3 as the criterion for the presence of hallucinations in the analyses presented here. This decision ensured that normative, fleeting hallucinatory experiences were not included in our data (e.g., Johns et al., 2004; Krakvik et al., 2015) and also maximised the comparability of the SAPS data with the measure of hallucinations employed in the Australian sample (see below).

Australia. All participants were assessed for both lifetime and current (experienced in the last month) experience of hallucinations in the auditory, visual, tactile, and olfactory modalities using the hallucinations section of the DIP. This enquires about the presence of each modality of hallucinations separately (Auditory: "*Have you ever heard noises or voices when there is nobody about and no ordinary explanation seems possible?*" Visual: "*Have you ever had visions or seen things that other people cannot?*" Olfactory: "*Have you ever noticed unusual smells you cannot account for? (rate experiences such as smell of 'death' or burning, which other people cannot smell*). Tactile: "*Have you ever experienced any strange sensations in your body, e.g. of touch, or temperature, or pain, or floating, or being weightless? Or a crawling sensation under the skin*?"). Participants who give affirmative responses to any of these items are then rated according to whether the hallucination had been a) "Present for less than 1 month or unspecified", or b) "Present for significant proportion of a 1-month period". Only those with hallucinations meeting criterion b) were defined as having hallucinations, as the broadness of criterion a) could potentially have led to the inclusion of false positives (potentially akin to the 'questionable' rating on the SAPS) or normative fleeting hallucinatory experiences (potentially akin to the 'mild' rating on the SAPS). Full frequency data for DIP hallucination scores by modality are presented in Supplemental Table 2.

2.3 Statistical analyses

Descriptive data on hallucination prevalence and co-occurrence by modality were to be presented, separately for the Irish and Australian samples, in the form of percentages. We did not perform between-country comparisons on hallucination prevalence owing to the different assessment tools used in these populations making direct comparisons problematic, as well as the large number of actual and potential differences between the two groups making it impossible to determine what may account for any differences. First, significant differences were found between the two groups on age, gender, duration of illness, and diagnoses. Second, differing exclusion criteria were employed for each sample. Third, there are greater levels of use of substances with potentially hallucinogenic sequalae in Australia compared to Ireland, including LSD (Entwistle et al., 2016) and alcohol (WHO, 2016). Finally, there was the potential for different diagnostic and prescribing practices for between these countries. We used binary logistic regression to test if gender and age predicted experience of hallucinations in each modality, entering both these variables in a single step. Chi squared tests were to be used to test for associations between the lifetime presence of auditory and visual hallucinations. All analyses were to be performed using two-tailed tests with $\alpha=.05$.

3. Results

Demographic and clinical information is reported in Table 1.

INSERT-TABLE-1-ABOUT-HERE

3.1 Lifetime prevalence

Ireland. Of the 693 people with schizophrenia-spectrum diagnoses, 69.3% had hallucinated in at least one of the modalities enquired about at some point in their lifetime (Table 2). Many hallucinations had religious themes. Patients' auditory hallucinations included hearing devils marching from hell over stones coming to get them, a choir of

demonic voices, the Devil telling them to burn down the house and go to the pub, and voices saying “the next time you see him he’ll be half dead”, “let her have her day in court”, “get up whore”, “keep going, keep going man”. Visual hallucinations included seeing people change into vampires, hell, flames, rats, people’s eyes gone black, wisps of smoke, ugly faces, Christ’s face, the Virgin Mary, and visions of Calvary. Tactile hallucinations included sensations in the mouth, energies around their body, being poked gently, and a multimodal experience of feeling ash in the throat whilst seeing hell. Olfactory hallucinations included smelling a brewery, burning rubber, sewage, roses, perfume, and themselves burning.

Patients were most likely to have lifetime experience of auditory hallucinations, with this type of hallucination being approximately three times as common as visual hallucinations, which were in turn around twice as common as tactile hallucinations, which in turn were approximately twice as prevalence as olfactory hallucinations (Table 2). Binary logistic regression found age and gender did not significantly predict lifetime experience of hallucinations in the auditory, $\chi^2(2)=1.53$, $p=.47$, visual, $\chi^2(2)=0.31$, $p=.86$, tactile, $\chi^2(2)=3.20$, $p=.20$, or olfactory, $\chi^2(2)=0.10$, $p=.95$, modalities.

INSERT-TABLE-2-ABOUT-HERE

Australia. Of the 218 people with schizophrenia-spectrum diagnoses, 81.7% had hallucinated in at least one of the modalities enquired about at some point in their lifetime (Table 2). Auditory hallucinations were more than twice as common as visual hallucinations, which were in turn three times as common as olfactory hallucinations and fifty percent more common than tactile hallucinations. This pattern broadly mirrored that from the Irish sample. Binary logistic regression found that age and gender did not predict lifetime experience of hallucination in any modality: auditory, $\chi^2(2)=5.22$, $p=.07$; visual, $\chi^2(2)=4.99$, $p=.08$, olfactory, $\chi^2(2)=2.02$, $p=.36$; tactile, $\chi^2(2)=1.93$, $p=.38$.

3.2 Point prevalence

Ireland. Although a quarter of patients had current hallucinations, these were predominantly in the auditory modality, with prevalence of current hallucinations in other modalities all being less than 5% (Table 2). Binary logistic regression found that age and gender did not predict current presence of auditory, $\chi^2(2)=1.98$, $p=.37$, visual, $\chi^2(2)=1.42$, $p=.49$, olfactory, $\chi^2(2)=1.46$, $p=.48$, or tactile hallucinations, $\chi^2(2)=1.65$, $p=.44$.

Australia. As with the Irish sample, approximately a quarter of patients had some current hallucinations (Table 2). Again, these were primarily in the auditory modality. Binary logistic regression found that age and gender did not significantly predict the presence of current hallucinations in any modality; auditory, $\chi^2(2)=2.97$, $p=.23$; visual, $\chi^2(2)=2.92$, $p=.23$; olfactory, $\chi^2(2)=1.76$, $p=.42$; tactile, $\chi^2(2)=1.22$, $p=.54$.

3.3 Ratio of lifetime to current hallucinations.

The proportion of patients with lifetime hallucinations who were currently hallucinating was broadly comparable for each modality, in both the Irish and Australian samples, being 34-36% in the auditory, 20-27% in the visual, 24-28% in the olfactory, and 36-40% in the tactile.

3.4 Co-occurrence of modalities

The majority of patients in both samples had only ever hallucinated in one modality, and this was most commonly the auditory (Table 3). Around a third of patients in both samples had experienced hallucinations in two modalities, with the most common combination being the auditory and visual (Table 3). Only a single digit percentage of patients had hallucinated in three modalities, with a similar result being found for four modalities (Table 3).

The majority of currently hallucinating patients were only hallucinating in one modality, nearly always the auditory (Table 4). The most common combination of

hallucinations in those who were currently experiencing hallucinations in two modalities was the auditory and visual (Table 4). Rates of current hallucinations in 3 or more modalities were very low (Table 4). The pattern of current hallucinations by modality for the Irish sample is presented in Figure 1.

INSERT-TABLES-3-AND-4-ABOUT-HERE

INSERT-FIGURE-1-ABOUT-HERE

In both samples there was an association between the lifetime presence of auditory and visual hallucinations (Table 5). It was more common to have experienced auditory hallucinations without ever having had visual hallucinations, than it was to have experienced visual hallucinations without ever having had auditory hallucinations. In the Irish and Australian samples, 30% and 37% and of patients with lifetime auditory hallucinations respectively had experienced visual hallucinations, whereas 83% and 97% of patients with lifetime visual hallucinations respectively had experienced auditory hallucinations (Table 5).

INSERT-TABLE-5-ABOUT-HERE

4. Discussion

This study aimed to document lifetime and point prevalence of hallucinations by modality, as well as the extent to which hallucinations in different modalities co-occurred, in people diagnosed with schizophrenia-spectrum disorders. In terms of lifetime prevalence, a broad pattern emerged of auditory hallucinations being 2-3-fold more common than visual hallucinations, which in turn were around twice as common as tactile hallucinations, which in turn were around twice as common as olfactory hallucinations. This was consistent with the cross-cultural findings of Thomas et al. (2007), except for our finding of an excess of tactile over olfactory hallucinations, two modalities which Thomas et al. found to occur with a comparable prevalence. Whereas research into the prevalence of hallucinations has often

focussed on lifetime prevalence, our study was able to offer insights into point prevalence. Hallucinations had been experienced in the past month by about a quarter of each sample, predominantly in the auditory modality. Prevalence of hallucinations in the past month in the visual, olfactory, and tactile modalities were much lower (<10%). Patients' reports also suggested visual hallucinations were often fleeting, transitory phenomena, compared to more chronic experiences of auditory hallucinations. This was consistent with Gauntlett-Gilbert and Kuipers' (2003) finding that 40% of their sample (a majority of whom had schizophrenia-spectrum diagnoses) had only experienced visions between one and three times, 45% had experiences of visions spanning a period of 2 weeks or less, and only 15% described their visions as constant. The clearly graded hallucination-hierarchy by modality found for lifetime prevalence (auditory > visual > tactile > olfactory) was less clearly discernable for present experiences, which emerged as more of a two-tier hierarchy (auditory and others).

In terms of associations between modalities, the majority of patients had only ever hallucinated in one modality, typically the auditory. Similarly, current hallucinatory experiences were uni-modal for the majority of patients, with 90% of these being in the auditory modality. When hallucinations in two different modalities co-occurred, auditory and visual hallucinations were the most common combination. When we further probed the relation between auditory and visual hallucinations, we found that only around a third of patients who had experienced auditory hallucinations had also experienced visual hallucinations, yet an overwhelming majority of patients who had experienced visual hallucinations had also experienced auditory hallucinations. This highlights the limited utility of a modality-independent hallucination mechanism (David, 2004), and reinforces the need to understand the reason for this pattern of co-occurrence.

The common co-occurrence of auditory and visual hallucinations suggests a different mechanism may be involved in visual hallucinations in schizophrenia than in neurodegenerative disorders (e.g., Lewy Body Dementia, Parkinson's Disease), as the latter are not typically related to the presence of auditory hallucinations (Inzelberg et al., 1998), whereas the former nearly always are. However, there have been reports of anticholinergic medications being effective for visual hallucinations in people diagnosed with schizophrenia who were refractory to antipsychotic treatment (Patel et al., 2010). This suggests there may be multiple mechanisms underpinning visual hallucinations in people diagnosed with schizophrenia, as has previously been argued to be the case for auditory hallucinations (McCarthy-Jones et al., 2014).

Lifetime rates of visual hallucinations, being 23% in the Irish sample and 31% in the Australian sample, were comparable with the mean visual hallucinations prevalence of 27% reported by Waters et al.'s (2014) recent review. Many of the visual hallucinations in the Irish sample were religious in nature, highlighting the potential effects of culture on the content of hallucinations (Larøi et al., 2014). We found no consistent association between visual hallucinations (or indeed, any modality of hallucination) and either age or gender. Previous studies have also reported mixed findings (Baethge et al., 2005; Bauer et al., 2011; Tien, 1991; Goodwin et al., 1971). Although visual hallucinations occurred at a lower prevalence than auditory hallucinations, and for many patients were a memory rather than a current phenomenon, they are often distressing (Dudley et al., 2012) and, at present, there is no evidence base supporting specific interventions for visual hallucinations in psychosis (Wilson et al., 2015). Further research examining the efficacy of novel treatments for visual hallucinations is required (Wilson et al., 2015).

Having provided further evidence of the nature of the distributions of hallucinations by modality, there is now a need to explain this. Whilst we are not able to provide clear

answers to this, we highlight how explanations could be proffered at multiple levels. Consider, for example, the excess of auditory over visual hallucinations. At the biological level, a cause may be sought in a greater degree of disruption to auditory (temporal) than visual (occipital) processing areas of the brain in those diagnosed with schizophrenia. There is some evidence of this. In terms of structural changes, a meta-analysis of over 18,000 patients, Haijma et al. (2013) found greater reductions in grey matter volumes in the temporal lobe (Cohen's d= 0.43) than the occipital lobe (d= 0.22). Similarly, studies of anti-psychotic naïve and first episode patients (Chan et al., 2011; Fusar-Poli et al., 2011), as well as studies of children at high risk of developing schizophrenia (Cullen et al., 2012) have found grey matter changes in temporal regions but not in other areas of sensory cortex. These structural changes are accompanied by functional changes. For example, grey matter reductions in the left superior temporal gyrus are associated with reductions in the auditory P300 event-related potential (McCarley et al., 1993). Similarly, functional changes detected by EEG studies of resting state activity have offered clearer evidence for abnormalities in the temporal lobe than in the occipital lobe (Mientus et al., 2002; Pascual-Marqui et al., 1999). Indeed, the characterisation of schizophrenia as predominantly a fronto-temporal disorder is consistent with phenomenological parallels with fronto-temporal dementia (Harciarek et al., 2013) and with Kraepelin's (1919) original conception of this disorder.

At the neurocognitive level, explanations could be sought within a predictive coding framework (Clark, 2013). For example, audition may be more amenable to the top-down effects of expectation than vision, or individuals may be more likely to find themselves without auditory input than visual input, potentially creating more fertile conditions for top-down influences on audition than vision. Another possibility is that hallucinations in schizophrenia are aberrant forms of social communications (Wilkinson and Bell, 2016), and given the primary role of language in social communication (Fedurek and Slocombe, 2011),

this may explain the excess of auditory over visual hallucinations. Similarly, models of schizophrenia that view it as a breakdown of the self (Sass and Parnas, 2003), could be taken to predict a primacy of auditory over visual hallucinations due to the greater role of speech/language than visual imagery in the construction of the self. Finally, whilst early trauma is associated with hallucinations in both the auditory (Bentall et al., 2012) and visual (Solesvik et al., 2016) modalities, intrusive visual experiences are more commonly recognised as a re-experiencing symptom of PTSD than intrusive auditory experiences (McCarthy-Jones and Longden, 2015). This could lead individuals with visual hallucinations to be more likely to be diagnosed with PTSD than schizophrenia, leaving an excess of auditory over visual hallucinations in people diagnosed with schizophrenia.

The hallucination-hierarchy in schizophrenia may be specific to this disorder. When standardised interviews (rather than self-report methods) assess the prevalence of hallucinations in the general population by modality, visual hallucinations are more commonly reported than auditory hallucinations (Tien, 1991; Sidgwick et al., 1894; Kessler et al., 2005). This highlights that hallucinations in schizophrenia do not represent a simple across the board inflation of prevalence of hallucinations in the general population, but rather a particular excess of auditory hallucinations. Future research should attempt to explain why there are such differing patterns in hallucination prevalence in these populations.

This study had a number of limitations. First, different hallucination assessment tools were employed in our two samples. Yet, whilst variation in prevalence between groups may be at least partly attributable to this (or many other factors, as noted above), our study focussed on within-group differences in hallucination prevalence by modality, which were comparable between the two samples. Second, it was not possible, for people who reported hallucinations in more than one modality (e.g., auditory and visual hallucinations), to determine if the person experienced a vision talking to them or if they saw visions and heard

voices independently from this. Thus, it was not possible to know the extent to which the co-occurrence of auditory and visual hallucinations represented a multimodal hallucinatory experience (Hoffman and Varanko, 2006) or their co-incidence. Third, we do not know under what conditions these experiences happened; past hallucinations could have occurred outside of the context of a psychotic illness, due to drug intoxication, sleep problems, or have been the type of hallucinatory experiences sometimes found in the general population (Blom and Sommer, 2012). Finally, interview-based prevalence assessments may create biases in responding. For example, the hallucination-hierarchy found here for current hallucinations, differed notably to that found by ESM studies (Delespaul and van Os, 2012; Oorschot et al., 2012). The reasons for this difference remain to be explained, but may be based in fleeting visual hallucinations being less readily recalled in interview-based studies.

In conclusion, although needing replication from studies with alternative methodologies, such as ESM, the findings reported here help clarify the distribution of hallucinations by modality, and provide an explanatory target for theoretical models of this experience.

Acknowledgements

We thank Prof. Colm McDonald for facilitating access to data, Kim Daley and Catherine Wen who undertook some preliminary work on this area for their Master's theses, and Prof. Eadbhard O'Callaghan (deceased) from the DETECT Early Intervention Service for Psychosis, Blackrock, Co. Dublin, Ireland, for his contribution.

Conflicts of interest

None

References

Alba-Ferrara, L., de Erausquin, G. A., Hirnstein, M., Weis, S., Hausmann, M. (2007). Emotional prosody modulates attention in schizophrenia patients with hallucinations. Front Hum Neurosci. 7, 59.

American Psychiatric Association. 2013. Diagnostic and Statistical Manual of Mental Disorders (DSM-5). American Psychiatric Publications, Washington, DC.

American Psychiatric Association. 1994. Diagnostic and Statistical Manual of Mental Disorders (DSM-IV). American Psychiatric Publications, Washington, DC.

Andreasen, N. C. 1984. Scale for the Assessment of Positive Symptoms. University of Iowa, Iowa City, IA.

Andreasen, N. C., Flaum, M. 1991. Schizophrenia: the characteristic symptoms. Schizophr Bull. 17(1), 27.

Ayuso-Mateos, J. L. (2014). Global Burden of Schizophrenia in the Year 2000-Version 1 Estimates. World Health Organization, Geneva.

Baethge, C., Baldessarini, R. J., Freudenthal, K., Streeruwitz, A., Bauer, M., Bschor, T. 2005. Hallucinations in bipolar disorder: characteristics and comparison to unipolar depression and schizophrenia. Bipolar Disord. 7(2), 136-45.

Bauer, S. M., Schanda, H., Karakula, H., Olajossy-Hilkesberger, L., Rudaleviciene, P., Okribelashvili, N., Chaudhry, H. R., Idemudia, S. E., Gscheider, S., Ritter, K., Stompe, T. 2011. Culture and the prevalence of hallucinations in schizophrenia. Compr Psychiat. 52(3), 319-25.

Bentall, R.P., Wickham, S., Shevlin, M., Varese, F. 2012. Do specific early-life adversities lead to specific symptoms of psychosis? A study from the 2007 the Adult Psychiatric Morbidity Survey. Schizophr Bull. 38(4), 734-740.

Blom, J. D., Sommer, I. E. (Eds.). 2011. Hallucinations: Research and Practice. Springer Science & Business Media.

Bowman, K. M., Raymond, A. F. 1931. A statistical study of hallucinations in the manic-depressive psychoses. Am J Psychiatry. 88(2), 299-309.

Castle, D. J., Jablensky, A., McGrath, J. J., Carr, V., Morgan, V., Waterreus, A., Valuri, G., Stain, H., McGuffin, P., Farmer, A. 2006. The diagnostic interview for psychoses (DIP): development, reliability and applications. Psychol Med. 36(01), 69-80.

Chan, R. C., Di, X., McAlonan, G. M., Gong, Q. Y. (2011). Brain anatomical abnormalities in high-risk individuals, first-episode, and chronic schizophrenia: an activation likelihood estimation meta-analysis of illness progression. *Schizophr Bull. 37*(1), 177-188.

Clark, A. 2013. Whatever next? Predictive brains, situated agents, and the future of cognitive science. Behav Brain Sci. 36(03), 181-204.

Collerton, D., Perry, E., McKeith, I. 2005. Why people see things that are not there: a novel perception and attention deficit model for recurrent complex visual hallucinations. Behav Brain Sci. 28(06), 737-57.

Corvin, A., Donohoe, G., Nangle, J. M., Schwaiger, S., Morris, D., Gill, M. 2008. A dysbindin risk haplotype associated with less severe manic-type symptoms in psychosis. Neurosci Lett. 431(2), 146-9.

Cullen, A. E., De Brito, S. A., Gregory, S. L., Murray, R. M., Williams, S. C., Hodgins, S., Laurens, K. R. 2012. Temporal lobe volume abnormalities precede the prodrome: a study of children presenting antecedents of schizophrenia. Schizophr Bull. 39(6), 1318–1327.

David, A. 2004. The cognitive neuropsychiatry of auditory verbal hallucinations: an overview. Cogn Neuropsychiatry. 9(1-2), 107-23.

David, C. N., Greenstein, D., Clasen, L., Gochman, P., Miller, R., Tossell, J. W., ... Rapoport, J. L. 2011. Childhood onset schizophrenia: high rate of visual hallucinations. *J Am Acad Child Adolesc Psychiatry 50*(7), 681-686.

Delespaul, P., van Os, J. 2002. Determinants of occurrence and recovery from hallucinations in daily life. Soc Psych Psych Epi. 37(3), 97-104.

Dudley, R., Collerton, D., Nicholson, M., Mosimann, U. 2013. Clinical characteristics of disclosed visual hallucinations in users of an Early Intervention in Psychosis Service. Psychosis. 5(2), 127-33.

Dudley, R., Wood, M., Spencer, H., Brabban, A., Mosimann, U. P., Collerton, D. 2012. Identifying specific interpretations and use of safety behaviours in people with distressing visual hallucinations: an exploratory study. Behav Cogn Psychoth.40(03), 367-75.

Entwistle, G., Sindicich, N., Burns, L. 2013. Rise in LSD use among regular psychostimulant users: why the increase and is it a cause for concern. Drugs Trends Bulletin.

Fedurek, P., Slocombe, K. E. 2011. Primate vocal communication: a useful tool for understanding human speech and language evolution? Hum Biol. 83(2), 153-73.

First, M. B., Spitzer, R. L., Gibbon, M., Williams, J. B. W. 2002. Structured Clinical Interview for DSM-IV-TR Axis I Disorders, Research Version, Patient Edition (SCID-I/P). New York, NY: Biometrics Research, New York State Psychiatric Institute.

Ford, J. M., Roach, B. J., Jorgensen, K. W., Turner, J. A., Brown, G. G., Notestine, R., ... Belger, A. 2009. Tuning in to the voices: a multisite FMRI study of auditory hallucinations. Schizophr Bull. 35(1), 58-66.

Fusar-Poli, P., Radua, J., McGuire, P., Borgwardt, S. (2011). Neuroanatomical maps of psychosis onset: voxel-wise meta-analysis of antipsychotic-naive VBM studies. Schizophr Bull. 38 (6), 1297-1307.

Gauntlett-Gilbert, J., Kuipers, E. 2003. Phenomenology of visual hallucinations in psychiatric conditions. J Nerv Ment Dis. 191(3), 203-5.

Goodwin, D. W., Rosenthal, R. 1971. Clinical significance of hallucinations in psychiatric disorders: a study of 116 hallucinatory patients. Arch Gen Psychiat. 24(1), 76-80.

Haijma, S. V., Van Haren, N., Cahn, W., Koolschijn, P. C., Pol, H. E., Kahn, R. S. 2013. Brain volumes in schizophrenia: a meta-analysis in over 18 000 subjects. Schizophr Bull. 39(5), 1129-38.

Hoffman, R. E., Varanko, M. 2006. 'Seeing voices': fused visual/auditory verbal hallucinations reported by three persons with schizophrenia-spectrum disorder. Acta Psychiatr Scand. 114(4), 290-2.

Harciarek, M., Malaspina, D., Sun, T., Goldberg, E. 2013. Schizophrenia and frontotemporal dementia: Shared causation? Int Rev Psychiatry 25(2), 168-177.

Inzelberg, R., Kipervasser, S., Korczyn, A. D. 1998. Auditory hallucinations in Parkinson's disease. J Neurol Psychiatry. 64(4), 533-5.

Jablensky, A. The 100-year epidemiology of schizophrenia. 1997. Schizophr Res. 28(2), 111-125.

Johns, L. C., Cannon, M., Singleton, N., Murray, R. M., Farrell, M., Brugha, T., ... Meltzer, H. 2004. Prevalence and correlates of self-reported psychotic symptoms in the British population. Br J Psychiatry 185(4), 298-305.

Kessler RC, Birnbaum H, Demler O, Falloon IR, Gagnon E, Guyer M, Howes MJ, Kendler KS, Shi L, Walters E, Wu EQ. 2005. The prevalence and correlates of nonaffective

psychosis in the National Comorbidity Survey Replication (NCS-R). Biol Psychiatry. 58(8), 668-76.

Kråkvik, B., Larøi, F., Kalhovde, A. M., Hugdahl, K., Kompus, K., Salvesen, Ø., ... Vedul-Kjelsås, E. 2015. Prevalence of auditory verbal hallucinations in a general population: A group comparison study. Scand J Psychol. 56(5), 508-515.

Kraepelin, E. 1919. Dementia Praecox and Paraphrenia. RM Barclay, transl. Huntington, NY: Robert E. Kreiger Publishing Co., Inc.

Langdon, R., McGuire, J., Stevenson, R., Catts, S. V. 2011. Clinical correlates of olfactory hallucinations in schizophrenia. Br J Clin Psychol. 50(2), 145-63.

Larøi, F., Luhrmann, T. M., Bell, V., Christian, W. A., Deshpande, S., Fernyhough, C., Jenkins, J., Woods, A. 2014. Culture and hallucinations: overview and future directions. Schizophr Bull. 40(Suppl 4), S213-20.

Loughland, C., Draganic, D., McCabe, K., Richards, J., Nasir, A., Allen, J., Catts, S., Jablensky, A., Henskens, F., Michie, P., Mowry, B. 2010. Australian Schizophrenia Research Bank: a database of comprehensive clinical, endophenotypic and genetic data for aetiological studies of schizophrenia. Aust NZ J Psychiatry. 44(11), 1029-35.

McCarley, R. W., Shenton, M. E., O'Donnell, B. F., Faux, S. F., Kikinis, R., Nestor, P. G., Jolesz, F. A. (1993). Auditory P300 abnormalities and left posterior superior temporal gyrus volume reduction in schizophrenia. Arch Gen Psychiat, 50(3), 190-197.

McCarthy-Jones, S., Longden, E. 2015. Auditory verbal hallucinations in schizophrenia and post-traumatic stress disorder: common phenomenology, common cause, common interventions? Frontiers in Psychology. 6.

McCarthy-Jones, S., Thomas, N., Strauss, C., Dodgson, G., Jones, N., Woods, A., Brewin, C. R., Hayward, M., Stephane, M., Barton, J., Kingdon, D. 2014. Better than mermaids

and stray dogs? Subtyping auditory verbal hallucinations and its implications for research and practice. Schizophr Bull. 40(Suppl 4), S275-84.

Mueser, K. T., Bellack, A. S., Brady, E. U. 1990. Hallucinations in schizophrenia. Acta Psychiat Scand. 82(1), 26-9.

Nayani, T. H., David, A. S. 1996. The auditory hallucination: a phenomenological survey. Psychol Med. 26(1), 177-89.

Oorschot, M., Lataster, T., Thewissen, V., Bentall, R., Delespaul, P., Myin-Germeys, I. 2012. Temporal dynamics of visual and auditory hallucinations in psychosis. Schizophr Res. 140(1), 77-82.

Pascual-Marqui, R. D., Lehmann, D., Koenig, T., Kochi, K., Merlo, M. C., Hell, D., Koukkou, M. 1999. Low resolution brain electromagnetic tomography (LORETA) functional imaging in acute, neuroleptic-naive, first-episode, productive schizophrenia. Psychiatry Res: Neuroimaging 90(3), 169-179.

Patel, S. S., Attard, A., Jacobsen, P., Shergill, S. 2010. Acetylcholinesterase Inhibitors (AChEI's) for the treatment of visual hallucinations in schizophrenia: a review of the literature. BMC Psychiatry. 10(1), 1.

Sass, L. A., Parnas, J. 2003. Schizophrenia, consciousness, and the self. Schizophr Bull. 29(3), 427-44.

Sidgwick, H., Johnson, A., Myers, F. W., Podmore, F., Sidgwick, E. M. 1984. Report on the Census of Hallucinations. Proc Soc Psychic Res. 10(26), 25-394.

Solesvik, M., Joa, I., Larsen, T. K., Langeveld, J., Johannessen, J. O., Bjørnestad, J., Anda, L. G., Gisselgård, J., ten Velden Hegelstad, W., Brønnick, K. 2016. Visual hallucinations in first-episode psychosis: association with childhood trauma. PloS one. 11(5), e0153458.

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. Schizophr Res. 92(1), 41-9.

Tien, A. Y. 1991. Distribution of hallucinations in the population. Soc Psych Psych Epi. 26(6), 287-92.

Waters, F., Collerton, D., Jardri, R., Pins, D., Dudley, R., Blom, J. D., Mosimann, U. P., Eperjesi, F., Ford, J., Larøi, F. 2014. Visual hallucinations in the psychosis spectrum and comparative information from neurodegenerative disorders and eye disease. Schizophr Bull. 40(Suppl 4), S233-45.

Waters, F., Allen, P., Aleman, A., Fernyhough, C., Woodward, T. S., Badcock, J. C., ... Vercammen, A. (2012). Auditory hallucinations in schizophrenia and nonschizophrenia populations: a review and integrated model of cognitive mechanisms. Schizophrenia Bulletin, 38(4), 683-693.

Wilkinson, S., Bell, V. 2016. The representation of agents in auditory verbal hallucinations. Mind Lang. 31(1), 104-26.

Wilson, R., Collerton, D., Freeston, M., Christodoulides, T., Dudley, R. 2015. Is seeing believing? The process of change during cognitive–behavioural therapy for distressing visual hallucinations. Clin Psychol Psychother.

World Health Organisation. 2016. World Health Statistics 2016: Monitoring health for the SDGs. World Health Organisation, Geneva.

World Health Organization. 1975. Schizophrenia: A Multinational Study. World Health Organization, Geneva.

Table 1

Demographic and clinical characteristics of samples

Variable (mean, SD)	Ireland (N=693)	Australia (N=218)	Comparison
Age (years)	44.09 (13.49)	38.72 (11.00)	$t(909)=5.35$, $p<0.001$
Gender (% male)	70.3%	65.0%	$\chi(1)=3.74$, $p=0.05$
Illness duration (years)	20.40 (13.51) [a]	15.70 (10.46)	$t(852)=4.68$, $p<0.001$
Diagnoses			
Schizophrenia	82.5%	74.3%	
Schizoaffective	16.9%	25.2%	$\chi(2)=7.55$, $p=0.02$
Schizophreniform	0.6%	0.5%	

a = Due to missing data, n=636.

Table 2

Prevalence of hallucinations by modality

	Lifetime		Current (past month)	
Modality	Ireland (n=205)	Australia (n=218)	Ireland (n=693)	Australia (n=218)
Any hallucination	69.3%	81.7%	26.1% [b]	28.9%
Auditory	63.9%	79.8%	23.2% [c]	27.1%
Visual	22.9%	30.7%	4.6% [d]	8.3%
Olfactory	5.8% [a]	9.6%	1.6% [e]	2.3%
Tactile	9.3%	19.3%	3.7% [d]	6.9%

[a] n = 206, [b] n=674; [c] n=682; [d] n=679; [e] n=676.

Table 3

Co-occurrence of lifetime experiences of hallucinations by modality

	Number of lifetime hallucination modalities									
	0		1		2		3		4	
	Ire	Aus	Ire	Aus	Ire	Aus	Ire	Aus	Ire	Aus
Number of patients	63	40	88	92	39	59	9	14	3	13
% of all hallucinating patients	-	-	63.3%	51.7%	28.1%	33.1%	6.5%	7.9%	2.2%	7.3%
Modalities of hallucinations										
Auditory	-	-	89.8%	95.6%	-	-	-	-	-	-
Visual	-	-	6.8%	2.2%	-	-	-	-	-	-
Tactile	-	-	2.3%	2.2%	-	-	-	-	-	-
Olfactory	-	-	1.1%	0.0%	-	-	-	-	-	-
Auditory + visual	-	-	-	-	66.7%	66.1%	-	-	-	-
Auditory + tactile	-	-	-	-	17.9%	22.0%	-	-	-	-
Auditory + olfactory	-	-	-	-	10.3%	45.8%	-	-	-	-
Visual + tactile	-	-	-	-	2.6%	0.0%	-	-	-	-
Visual + olfactory	-	-	-	-	2.6%	0.0%	-	-	-	-
Auditory + visual + tactile	-	-	-	-	-	-	66.7%	92.9%	-	-
Auditory + visual + olfactory	-	-	-	-	-	-	33.3%	0.0%	-	-
Auditory + olfactory + tactile	-	-	-	-	-	-	0.0%	7.1%	-	-

Note. Ire = Irish sample. Aus = Australian sample. Due to missing data, N(Irish sample) = 202.

Table 4

Co-occurrence of current hallucinations (past month) by modality

	Number of current hallucination modalities									
	0		1		2		3		4	
	Ire	Aus	Ire	Aus	Ire	Aus	Ire	Aus	Ire	Aus
Number of patients	498	155	133	37	29	21	9	2	0	3
% of all hallucinating patients	-	-	77.8%	58.7%	17.0%	33.3%	5.3%	3.2%	0.0%	4.8%
Modalities of hallucinations										
Auditory	-	-	90.2%	89.2%	-	-	-	-	-	-
Visual	-	-	3.8%	2.7%	-	-	-	-	-	-
Tactile	-	-	5.3%	8.1%	-	-	-	-	-	-
Olfactory	-	-	0.7%	0.0%	-	-	-	-	-	-
Auditory + visual	-	-	-	-	41.4%	57.1%	-	-	-	-
Auditory + tactile	-	-	-	-	24.1%	33.3%	-	-	-	-
Auditory + olfactory	-	-	-	-	20.7%	9.5%	-	-	-	-
Visual + tactile	-	-	-	-	10.3%	0.0%	-	-	-	-
Visual + olfactory	-	-	-	-	3.4%	0.0%	-	-	-	-
Auditory + visual + tactile	-	-	-	-	-	-	66.7%	100.0%	-	-
Auditory + visual + olfactory	-	-	-	-	-	-	11.1%	0.0%	-	-
Auditory + olfactory + tactile	-	-	-	-	-	-	11.1%	0.0%	-	-
Visual + tactile + olfactory	-	-	-	-	-	-	11.1%	0.0%	-	-

Note. Due to missing data, N(Irish sample) = 669, of which 171 experienced hallucinations.

Table 5

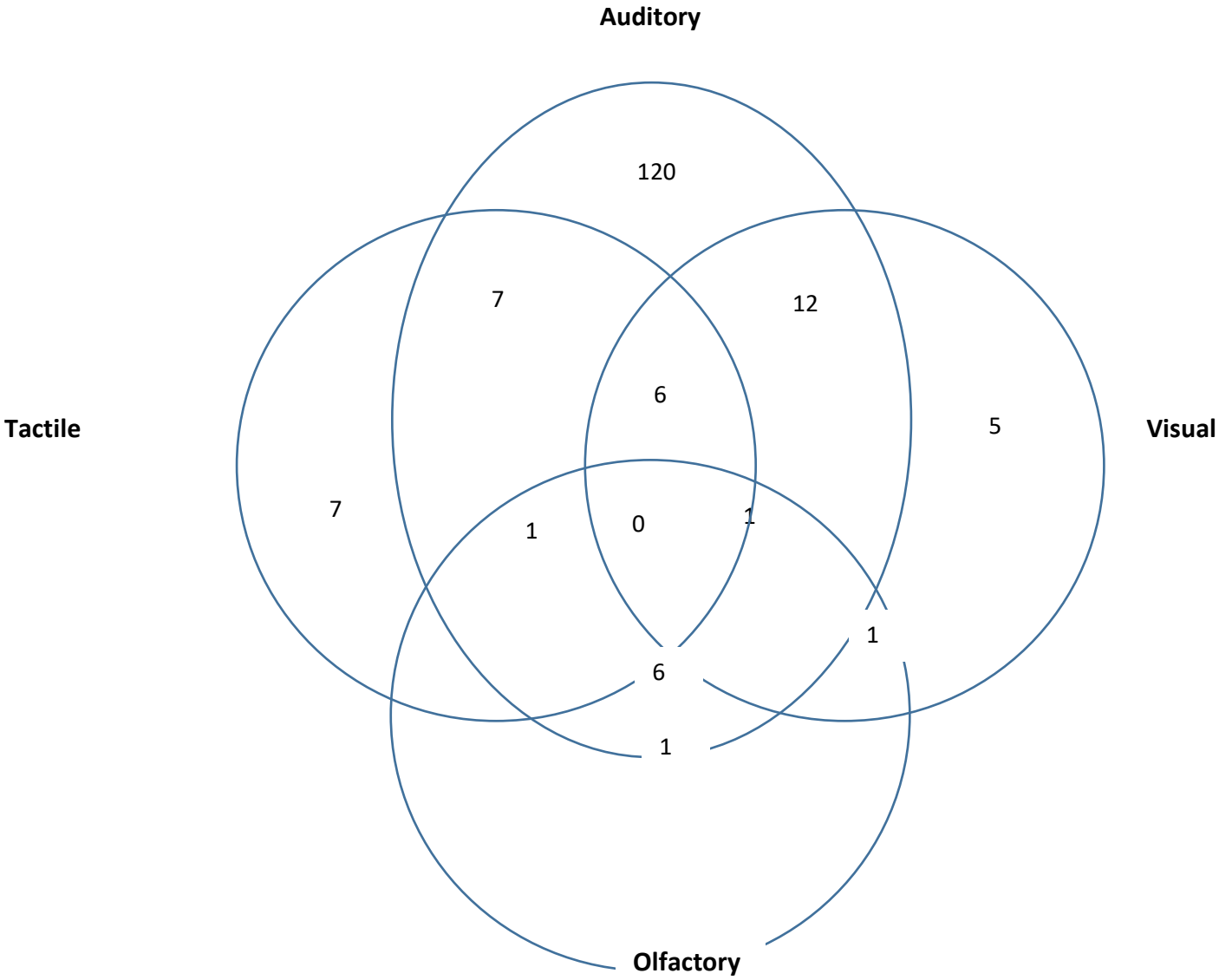
Associations between lifetime presence of auditory and visual hallucinations.

	Never had visual hallucinations	Lifetime visual hallucinations	Association
Ireland			
Never had auditory hallucinations	66	8	$\chi(1)=9.97$, $p=0.002$
Lifetime auditory hallucinations	90	39	
Australia			
Never had auditory hallucinations	42	2	$\chi(1)=17.76$, $p<0.001$
Lifetime auditory hallucinations	109	65	

Note. Due to missing data, N(Irish sample) = 203.

Figure 1

Co-occurrence of current hallucinations by modality in Irish sample



Note. Not able to be shown on the diagram are: Visual + tactile, n=3; Visual + tactile + olfactory, n=1.