



# EVIDENCE SEARCH RESULTS

<b>Question/subject of request:</b>	Our service currently are exploring if there is a link with Sensory integration and hearing voices (auditory hallucinations)
<b>Date requested:</b>	3/8/2024
<b>Date completed:</b>	23/8/2024
<b>Compiled by:</b>	Roxanne Hart

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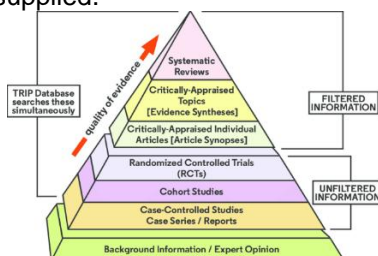
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**Contents** (click to jump to each section):

[Aldhafeeri 2024](#) Current results suggest that AVH may induce functional reorganization in emotion-related brain regions.

[Benrimoh et al 2024](#) We replicate the finding that increased Conditioned Hallucinations rates and recent hallucinations correlate with increased prior weighting using a linguistic version of the Conditioned Hallucinations task. Results support a role for reduced sensory precision in the interplay between prior weighting and hallucination-proneness.

[Bose et al 2024](#) This is the first study to demonstrate a lack of meaningful modulation of Mismatch Negativity with left fronto-temporo-parietal tDCS therapy in Schizophrenia-Auditory Verbal Hallucinations patients despite significant clinical response in a sham-controlled and open-label study designs

[Duggirala et al 2024](#) The current study highlights an association between increased Hallucination Proneness and systematic changes in the emotional quality and certainty in sensory feedback processing (N1) and attentional control (N2) in self-voice production in a nonclinical population. Considering that voice hearers also display these changes, these findings support the continuum hypothesis

[Li et al 2024](#) Our findings point to altered interactions between auditory perceptual processing and higher-level processes related to self-reference and executive functioning. This is the first study to show alterations in auditory cortical connectivity in trauma-related VH.

[Mariano et al 2024](#) Does altered Sensory Attenuation reflects a sufficient mechanism to explain positive symptoms such as auditory hallucinations. A systematic association of reduced auditory Sensory Attenuation.

[Orepic et al 2024](#) By demonstrating an experimental procedure (robotically induced AVH) able to induce AVH-like sensations in non-hallucinating individuals, we shed new light on AVH phenomenology, thereby integrating self-monitoring and strong-priors accounts

[Pinheiro et al 2021](#) Erratic prediction of sensory consequences in voice production could be linked to impaired cerebellar function, which initiates AVH and affects higher-level cognitive functions

[Niemantsverdriet et al 2019](#) The impaired sensory gating in patients with borderline personality disorder who experience AVH implies that P50 sensory gating deficiencies may underlie psychotic vulnerability in this specific patient group

[Thoma et al 2017](#) These findings link onset of AVH with a failure of an empirically-defined auditory inhibition system, auditory sensory gating, and pave the way for a sensory gating model of AVH.

[Pinheiro et al 2020](#) These findings suggest that selective changes in sensory feedback to voice are core to AVH.

[Toh et al 2021](#) The current study aimed to characterize the auditory hallucination and delusion profiles in patients with auditory hallucinations only versus those with multisensory hallucinations.

[He et al 2022](#) It is suggested that patients with AVHs may have multisensory processing dysfunctions and internal timing deficits.





[Yang et al 2023](#) These results suggest that 'broken' CD plus 'noisy' EC causes erroneous monitoring on the imprecise generation of internal auditory representation and yields auditory hallucinations.

### **Summary of search results:**

**Aldhafeeri, F. M. (2024). Altered brain responses to emotional auditory stimuli in AVH subjects: An fMRI study. *International Journal of Neuroscience*, 134(4). For a copy of the full text please email [library@somersetft.nhs.uk](mailto:library@somersetft.nhs.uk)**

The aim of this study was to investigate the neural basis of emotional disturbance in auditory hallucinating subjects who do not suffer from any psychological or neurological disorder. Materials and Methods: Fourteen subjects suffering from auditory hallucinations and 15 age- and sex-matched healthy controls were recruited in this study. All participants underwent fMRI in two experimental sessions. In the first experimental session, all participants from both groups listened to pleasant auditory stimuli. In the second session, both groups listened to unpleasant auditory stimuli. The auditory stimuli were obtained from the International Affective Digitized Sounds (IADS). Results: Compared with the healthy control group, AVH subjects exhibited significantly increased activation in limbic, auditory, and frontal regions. Conclusion: Current results suggest that AVH may induce functional reorganization in emotion-related brain regions.

**Benrimoh, D., Fisher, V. L., Seabury, R., Sibarium, E., Mourgues, C., Chen, D., & Powers, A. (2024). [Evidence for reduced sensory precision and increased reliance on priors in hallucination-prone individuals in a general population sample](#). *Schizophrenia Bulletin*, 50(2), 349–362.**

**BACKGROUND:** There is increasing evidence that people with hallucinations overweight perceptual beliefs relative to incoming sensory evidence. Past work demonstrating prior overweighting has used simple, nonlinguistic stimuli. However, auditory hallucinations in psychosis are often complex and linguistic. There may be an interaction between the type of auditory information being processed and its perceived quality in engendering hallucinations. **CONCLUSIONS:** We replicate the finding that increased Conditioned Hallucinations rates and recent hallucinations correlate with increased prior weighting using a linguistic version of the Conditioned Hallucinations task. Results support a role for reduced sensory precision in the interplay between prior weighting and hallucination-proneness.

**Bose, A., Agarwal, S. M., Nawani, H., Shivakumar, V., Shenoy, S., Sreeraj, V. S., . . . Venkatasubramanian, G. (2024). Effect of add-on tDCS therapy for auditory hallucinations on frequency and duration deviant mismatch negativity in schizophrenia. *Schizophrenia Research*, 269. For a copy of the full text please email [library@somersetft.nhs.uk](mailto:library@somersetft.nhs.uk)**

This study examines the effects of add-on transcranial direct current stimulation (tDCS) therapy for auditory hallucinations on frequency and duration deviant mismatch negativity in schizophrenia. Abnormalities in encoding predictive signals like mismatch negativity (MMN) contribute to abnormal percepts like auditory verbal hallucinations (AVH). To examine the effects of tDCS on frequency (MMNf) and duration (MMNd) deviant MMN, twenty-three SZ patients with persistent AVH (SZ-AVH) underwent ten-sessions of add-on left fronto-temporo-parietal tDCS (2 mA, twice-daily, 20-min-session, 5 consecutive days) in either (i) a double-blind, randomized, sham-controlled design (n = 16) or (ii) an open-label design. In the sham protocol, 2 mA current was administered initially for 40 s, producing a brief sensation akin to active stimulation. Following this, a low-intensity pulse of 110  $\mu$ A, lasting 15 ms with a peak current of 3 ms, was delivered every 550 ms. We expected (1) Verum tDCS groups to have lower AVH scores than the sham tDCS group following tDCS therapy and (2) multi-session tDCS therapy will increase MMN amplitudes and lower MMN latencies in Verum tDCS groups compared to sham tDCS group. This is the first study to demonstrate a lack of meaningful modulation of





Mismatch Negativity with left fronto-temporo-parietal tDCS therapy in Schizophrenia-Auditory Verbal Hallucinations patients despite significant clinical response in a sham-controlled and open-label study designs.

**Duggirala, S. X., Schwartz, M., Goller, L. K., Linden, D. E. J., Pinheiro, A. P., & Kotz, S. A. (2024).** [Hallucination proneness alters sensory feedback processing in self-voice production.](#) *Schizophrenia Bulletin*,

**BACKGROUND:** Sensory suppression occurs when hearing one's self-generated voice, as opposed to passively listening to one's own voice. Quality changes in sensory feedback to the self-generated voice can increase attentional control. These changes affect the self-other voice distinction and might lead to hearing voices in the absence of an external source (ie, auditory verbal hallucinations). However, it is unclear how changes in sensory feedback processing and attention allocation interact and how this interaction might relate to hallucination proneness (HP). **STUDY DESIGN:** Participants varying in HP self-generated (via a button-press) and passively listened to their voice that varied in emotional quality and certainty of recognition-100% neutral, 60%-40% neutral-angry, 50%-50% neutral-angry, 40%-60% neutral-angry, 100% angry, during electroencephalography (EEG) recordings. **STUDY RESULTS:** The N1 auditory evoked potential was more suppressed for self-generated than externally generated voices. Increased HP was associated with (1) an increased N1 response to the self-compared with externally generated voices, (2) a reduced N1 response for angry compared with neutral voices, and (3) a reduced N2 response to unexpected voice quality in sensory feedback (60%-40% neutral-angry) compared with neutral voices. **CONCLUSIONS:** The current study highlights an association between increased Hallucination Proneness and systematic changes in the emotional quality and certainty in sensory feedback processing (N1) and attentional control (N2) in self-voice production in a nonclinical population. Considering that voice hearers also display these changes, these findings support the continuum hypothesis.

**Li, M., Lebois, L. A. M., Ridgewell, C., Palermo, C. A., Winternitz, S., Liu, H., . . . Shinn, A. K. (2024).** [Functional connectivity of the auditory cortex in women with trauma-related disorders who hear voices.](#) *Biological Psychiatry : Cognitive Neuroscience and Neuroimaging*,

**BACKGROUND:** 'Voice-hearing' (VH) is a transdiagnostic experience that is common in trauma-related disorders (trauma-D). However, the neural substrates underlying trauma-related VH remain largely unexplored. While auditory perceptual dysfunction is among the abnormalities implicated in schizophrenia VH, whether VH in trauma-D also involves auditory perceptual alterations is unknown. **RESULTS:** We found that Voice Hearing severity positively correlated with left ISTG-frontoparietal network FC, while it negatively correlated with FC between left ISTG and both cerebral and cerebellar representations of the default mode network. VH severity was not predicted by FC of left HG or right AC subregions. **CONCLUSIONS:** Our findings point to altered interactions between auditory perceptual processing and higher-level processes related to self-reference and executive functioning. This is the first study to show alterations in auditory cortical connectivity in trauma-related VH. While VH in trauma-D appears to be mediated by brain networks that are also implicated in schizophrenia VH, the results suggest a unique mechanism that could distinguish VH in trauma-D.

**Mariano, M., Rossetti, I., Maravita, A., Paulesu, E., & Zapparoli, L. (2024).** [Sensory attenuation deficit and auditory hallucinations in schizophrenia: A causal mechanism or a risk factor? evidence from meta-analyses on the N1 event-related potential component.](#) *Biological Psychiatry*, *96*(3), 207–221.

Background: Sensory attenuation (SA), the dampened perception of self-generated sensory information, is typically associated with reduced event-related potential signals, such as for the N1 component of auditory event-related potentials. SA, together with efficient monitoring of intentions and actions, should facilitate the distinction between self-generated and externally generated sensory events, thereby optimizing interaction with the world. According to many, Sensory Attenuation is deficient in schizophrenia. The question arises whether altered Sensory Attenuation reflects a sufficient mechanism to explain positive symptoms such as auditory hallucinations. A systematic association of reduced auditory Sensory Attenuation in hallucinating patients would support this hypothesis.





Orepic, P., Bernasconi, F., Faggella, M., Faivre, N., & Blanke, O. (2024). [Robotically-induced auditory-verbal hallucinations: Combining self-monitoring and strong perceptual priors](#). *Psychological Medicine*, 54(3), 569–581.

**BACKGROUND:** Inducing hallucinations under controlled experimental conditions in non-hallucinating individuals represents a novel research avenue oriented toward understanding complex hallucinatory phenomena, avoiding confounds observed in patients. Auditory-verbal hallucinations (AVH) are one of the most common and distressing psychotic symptoms, whose etiology remains largely unknown. Two prominent accounts portray AVH either as a deficit in auditory-verbal self-monitoring, or as a result of overly strong perceptual priors. **METHODS:** In order to test both theoretical models and evaluate their potential integration, we developed a robotic procedure able to induce self-monitoring perturbations (consisting of sensorimotor conflicts between poking movements and corresponding tactile feedback) and a perceptual prior associated with otherness sensations (i.e. feeling the presence of a non-existing another person). **RESULTS:** Here, in two independent studies, we show that this robotic procedure led to AVH-like phenomena in healthy individuals, quantified as an increase in false alarm rate in a voice detection task. Robotically-induced AVH-like sensations were further associated with delusional ideation and to both AVH accounts. Specifically, a condition with stronger sensorimotor conflicts induced more AVH-like sensations (self-monitoring), while, in the otherness-related experimental condition, there were more AVH-like sensations when participants were detecting other-voice stimuli, compared to detecting self-voice stimuli (strong-priors). **CONCLUSIONS:** By demonstrating an experimental procedure able to induce AVH-like sensations in non-hallucinating individuals, we shed new light on AVH phenomenology, thereby integrating self-monitoring and strong-priors accounts.

Yang, F., Zhu, H., Cao, X., Li, H., Fang, X., Yu, L., . . . Tian, X. (2023). [Impaired motor-to-sensory transformation mediates auditory hallucinations](#). *bioRxiv*, (pagination), Date of Publication: 12 Jun 2023.

Distinguishing reality from hallucinations requires efficient monitoring of agency. It has been hypothesized that a copy of motor signals, termed efference copy (EC) or corollary discharge (CD), suppresses sensory responses to yield the sense of agency; impairment of the inhibitory function leads to hallucinations. However, how can the sole absence of inhibition yield positive symptoms of hallucinations? We hypothesize that selective impairments in functionally distinct signals of CD and EC during motor-to-sensory transformation cause the positive symptoms of hallucinations. In an electroencephalography (EEG) experiment with a delayed articulation paradigm in schizophrenic patients with (AVHs) and without auditory verbal hallucinations (non-AVHs), we found that preparing to speak without knowing the contents (general preparation) did not suppress auditory responses in both patient groups, suggesting the absent of inhibitory function of CD. Whereas, preparing to speak a syllable (specific preparation) enhanced the auditory responses to the prepared syllable in non-AVHs, whereas AVHs showed enhancement in responses to unprepared syllables, opposite to the observations in the normal population, suggesting that the enhancement function of EC is not precise in AVHs. A computational model with a virtual lesion of an inhibitory inter-neuron and disproportional sensitization of auditory cortices fitted the empirical data and further quantified the distinct impairments in motor-to-sensory transformation in AVHs. These results suggest that 'broken' CD plus 'noisy' EC causes erroneous monitoring on the imprecise generation of internal auditory representation and yields auditory hallucinations. Specific impairments in functional granularity of motor-to-sensory transformation mediate positivity symptoms of agency abnormality in mental disorders.

He, J., Ren, H., Li, J., Dong, M., Dai, L., Li, Z., . . . Tang, J. (2022). [Deficits in sense of body ownership, sensory processing, and temporal perception in schizophrenia patients with/without auditory verbal hallucinations](#). *Frontiers in Neuroscience*, 16, 831714.

It has been claimed that individuals with schizophrenia have difficulty in self-recognition and, consequently, are unable to identify the sources of their sensory perceptions or thoughts, resulting in delusions, hallucinations, and unusual experiences of body ownership. The deficits also contribute to the enhanced rubber hand illusion (RHI; a body perception illusion, induced by synchronous visual and tactile stimulation). Evidence based on RHI paradigms is emerging that auditory information can make an impact on the sense of body ownership, which





relies on the process of multisensory inputs and integration. Hence, we assumed that auditory verbal hallucinations (AVHs), as an abnormal auditory perception, could be linked with body ownership, and the RHI paradigm could be conducted in patients with AVHs to explore the underlying mechanisms. In this study, we investigated the performance of patients with/without AVHs in the RHI. We administered the RHI paradigm to 80 patients with schizophrenia (47 with AVHs and 33 without AVHs) and 36 healthy controls. We conducted the experiment under two conditions (synchronous and asynchronous) and evaluated the RHI effects by both objective and subjective measures. Both patient groups experienced the RHI more quickly and strongly than HCs. The RHI effects of patients with AVHs were significantly smaller than those of patients without AVHs. Another important finding was that patients with AVHs did not show a reduction in RHI under asynchronous conditions. These results emphasize the disturbances of the sense of body ownership in schizophrenia patients with/without AVHs and the associations with AVHs. Furthermore, it is suggested that patients with AVHs may have multisensory processing dysfunctions and internal timing deficits.

**Pinheiro, A. (2021). [Sensory feedback processing in auditory verbal hallucinations](#). *International Journal of Psychophysiology, Conference: Proceedings of the 20th World Congress of Psychophysiology (IOP 2021) of the International Organization of Psychophysiology (IOP)*, Date of Publication: October 2021.**

Why do some people hear voices in the absence of actual acoustic input? Auditory verbal hallucinations (AVH) are a cardinal symptom of psychosis but are also present in 6-13% of the general population. Alterations in sensory feedback processing are a likely cause of AVH, indicative of changes in the forward model of motor control. However, it is unknown whether such alterations are related to anomalies in forming an efference copy during action preparation, selective for voices, and similar along the psychosis continuum. Controls with low AVH proneness, NCVH, and first-episode psychotic patients with AVH engaged in a task with two types of stimuli: self-initiated and externally generated voices (Experiment 1) or tones (Experiment 2). Data from two experiments were recorded during a single EEG session, with the presentation order counterbalanced across participants. A button-press task was chosen as a more controlled way to study sensory feedback and comprised three conditions: auditory-motor (AMC), auditory-only (AOC), and motor-only (MOC). In the AMC, a button-press instantaneously elicited a tone or the prerecorded voice of the participant. In the AOC, participants were instructed to passively listen and attend to the tones or to their prerecorded self-voice. AVH proneness altered sensory suppression for the self-voice but not for simple tones. Specifically, higher AVH proneness in nonclinical participants was associated with N1 enhancement to self-voice feedback compared to externally presented voices. The N1 response to self- vs. externally generated voices did not differ in psychotic patients. Furthermore, the P2 suppression for voices was enhanced in NCVH, whereas in patients the P2 was similar for self-initiated and externally generated voices. AVH proneness also affected the preparatory motor activity reflected in the Readiness Potential (RP): a smaller RP was observed in patients compared to healthy controls (both early and late phases) and NCVH (late phase only), irrespective of condition. A smaller RP in voice hearers was associated with reduced N1 suppression. These findings indicate that altered neural responses to voice feedback may be a core feature of AVH. Alterations of sensory feedback processing in both psychotic and NCVH are related to changes in preparatory motor activity prior to voluntary actions and their sensory consequences. Erratic prediction of sensory consequences in voice production could be linked to impaired cerebellar function, which initiates AVH and affects higher-level cognitive functions. We propose new research directions linking the forward model to voice feedback processing.

**Toh, W. L., Thomas, N., & Rossell, S. L. (2021). [Comparing primary voice-hearers with and without hallucinations in other sensory modalities](#). *Psychopathology*, 54(4), 214–220.**

There has been burgeoning interest in studying hallucinations in psychosis occurring across multiple sensory modalities. The current study aimed to characterize the auditory hallucination and delusion profiles in patients with auditory hallucinations only versus those with multisensory hallucinations. Participants with psychosis were partitioned into groups with voices only (AVH; n = 50) versus voices plus hallucinations in at least one other sensory modality (AVH+; n = 50), based on their responses on the Scale for the Assessment of Positive Symptoms (SAPS). Basic demographic and clinical information was collected, and the Questionnaire for





Psychotic Experiences (QPE) was used to assess psychosis phenomenology. Relative to the AVH group, greater compliance to perceived commands, auditory illusions, and sensed presences was significantly elevated in the AVH+ group. The latter group also had greater levels of delusion-related distress and functional impairment and was more likely to endorse delusions of reference and misidentification. This preliminary study uncovered important phenomenological differences in those with multisensory hallucinations. Future hallucination research extending beyond the auditory modality is needed.

**Pinheiro, A. P., Schwartze, M., Amorim, M., Coentre, R., Levy, P., & Kotz, S. A. (2020).** [Changes in motor preparation affect the sensory consequences of voice production in voice hearers.](#) *Neuropsychologia*, *146*, 107531.

**BACKGROUND:** Auditory verbal hallucinations (AVH) are a cardinal symptom of psychosis but are also present in 6-13% of the general population. Alterations in sensory feedback processing are a likely cause of AVH, indicative of changes in the forward model. However, it is unknown whether such alterations are related to anomalies in forming an efference copy during action preparation, selective for voices, and similar along the psychosis continuum. By directly comparing psychotic and nonclinical voice hearers (NCVH), the current study specifies whether and how AVH proneness modulates both the efference copy (Readiness Potential) and sensory feedback processing for voices and tones (N1, P2) with event-related brain potentials (ERPs). **METHODS:** Controls with low AVH proneness ( $n = 15$ ), NCVH ( $n = 16$ ) and first-episode psychotic patients with AVH ( $n = 16$ ) engaged in a button-press task with two types of stimuli: self-initiated and externally generated self-voices or tones during EEG recordings. **RESULTS:** Groups differed in sensory feedback processing of expected and actual feedback: NCVH displayed an atypically enhanced N1 to self-initiated voices, while N1 suppression was reduced in psychotic patients. P2 suppression for voices and tones was strongest in NCVH, but absent for voices in patients. Motor activity preceding the button press was reduced in NCVH and patients, specifically for sensory feedback to self-voice in NCVH. **CONCLUSIONS:** These findings suggest that selective changes in sensory feedback to voice are core to AVH. These changes already show in preparatory motor activity, potentially reflecting changes in forming an efference copy. The results provide partial support for continuum models of psychosis.

**Niemantsverdriet, M. B. A., Slotema, C. W., van der Veen, F. M., van der Gaag, M., Sommer, I. E. C., Deen, M., & Franken, I. H. A. (2019).** [Sensory processing deficiencies in patients with borderline personality disorder who experience auditory verbal hallucinations.](#) *Psychiatry Research*, *281*(pagination), Article Number: 112545. Date of Publication: November 2019.

Auditory verbal hallucinations (AVH) are common in patients with borderline personality disorder (BPD). We examined two candidate mechanisms of AVH in patients with BPD, suggested to underlie sensory processing systems that contribute to psychotic symptoms in patients with schizophrenia; sensory gating (P50 ratio and P50 difference) and change detection (mismatch negativity; MMN). Via electroencephalographic recordings P50 amplitude, P50 ratio, P50 difference and MMN amplitude were compared between 23 borderline patients with and 25 without AVH, and 26 healthy controls. Borderline patients with AVH had a significantly lower P50 difference compared with healthy controls, whereas no difference was found between borderline patients without AVH and healthy controls. The groups did not differ on MMN amplitude. The impaired sensory gating in patients with borderline personality disorder who experience AVH implies that P50 sensory gating deficiencies may underlie psychotic vulnerability in this specific patient group. Patients with borderline personality disorder with or without AVH did not have problems with auditory change detection. This may explain why they are spared from the poor outcome associated with negative symptoms and symptoms of disorganization in patients with chronic schizophrenia.

**Thoma, R. J., Meier, A., Houck, J., Clark, V. P., Lewine, J. D., Turner, J., . . . Stephen, J. (2017).** [Diminished auditory sensory gating during active auditory verbal hallucinations.](#) *Schizophrenia Research*, *188*, 125–131. Auditory sensory gating, assessed in a paired-click paradigm, indicates the extent to which incoming stimuli are filtered, or "gated", in auditory cortex. Gating is typically computed as the ratio of the peak





amplitude of the event related potential (ERP) to a second click (S2) divided by the peak amplitude of the ERP to a first click (S1). Higher gating ratios are purportedly indicative of incomplete suppression of S2 and considered to represent sensory processing dysfunction. In schizophrenia, hallucination severity is positively correlated with gating ratios, and it was hypothesized that a failure of sensory control processes early in auditory sensation (gating) may represent a larger system failure within the auditory data stream; resulting in auditory verbal hallucinations (AVH). EEG data were collected while patients (N=12) with treatment-resistant AVH pressed a button to indicate the beginning (AVH-on) and end (AVH-off) of each AVH during a paired click protocol. For each participant, separate gating ratios were computed for the P50, N100, and P200 components for each of the AVH-off and AVH-on states. AVH trait severity was assessed using the Psychotic Symptoms Rating Scales AVH Total score (PSYRATS). The results of a mixed model ANOVA revealed an overall effect for AVH state, such that gating ratios were significantly higher during the AVH-on state than during AVH-off for all three components. PSYRATS score was significantly and negatively correlated with N100 gating ratio only in the AVH-off state. These findings link onset of AVH with a failure of an empirically-defined auditory inhibition system, auditory sensory gating, and pave the way for a sensory gating model of AVH.

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PURPOSE OF SEARCH		
Patient info/health & well being	X	Clinical decision making (inc. patient care)
Executive Team support		Research/Education/Professional development
Quality Improvement		Primary Care & Neighbourhoods Directorate support
KM/Management decision making		Other

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Nurses/Midwives		Other
Allied Health professionals		

HAS PERMISSION TO SHARE THE RESULTS BEEN OBTAINED FROM THE REQUESTOR?	
YES - share	NO – do not share

<b>KEY WORDS/SEARCH STRATEGY INCLUDING MESH HEADINGS</b>	<b>LIMITS USED</b>
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Sensory auditory hallucinations paracusias Auditory verbal hallucinations hearing voices	
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METADATA (TAGS)			

