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# Did you Hear That?

## *An Exploration of Auditory Hallucinations in Schizophrenia Disorder*

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**H**ave you ever heard your name when no one uttered a word? Or perhaps thought you heard a friend's voice in a crowded area when they weren't there? While these occasional auditory hallucinations are typical for many individuals, they become a constant and debilitating nuisance for those with schizophrenia.

For neurological disorders, "positive" symptoms induce certain behaviors, thoughts, or feelings, while "negative" symptoms reduce other behaviors, thoughts, and feelings. Schizophrenia is a neurological disorder characterized by negative symptoms such as loss of emotional capacity or mobility, and positive symptoms such as disorganized speech, delusions, and hallucinations—a defining trait of schizophrenia, as approximately 60-70 percent of those diagnosed will experience them. Auditory hallucinations are most

frequently experienced, though visual, tactile, and even gustatory and olfactory hallucinations also occur. These hallucinations can have significant and detrimental effects on people's lives, because they are unable to properly understand the world around them. As with all disorders, in order to alleviate the burden of hallucinations, we must first understand what causes them.

There have been several proposed theories for the development of hallucinations. One theory is that those with schizophrenia rely on their expectations over what is actually occurring. When we perceive sensory stimuli, our perceptions incorporate a myriad of factors which are separated into two categories of processing: bottom-up and top-down. Bottom-up processing refers to components about the sensory stimuli themselves, such as their intensity, spatial relationship, and temporal relationship. Top-down

processing refers to the modulation of our perception due to our own characteristics or experiences. Examples of this would be influences from our memory or emotional state, and the attention we give to stimuli. The influence of expectation in hallucinations would be reflective of individuals ignoring the bottom-up or objective features of stimuli and instead allowing their expectations to take precedence.

This theory surrounding the cause of hallucinations in schizophrenic individuals is supported by recent research. For instance, Albert Powers, a psychiatrist at the Connecticut Mental Health Center, and his clinical team published a study in 2017 that looked at how strong the influence of previous associations was on schizophrenic individuals' perceptions. In the study, participants with and without schizophrenia were trained to associate a flash and a beep together after exposure to both the stimuli repeatedly. The researchers then adjusted the environment such that only the flash was presented and asked participants if they heard a beep. While, initially, both sets of individuals heard the beep, over time those without psychosis were significantly less likely to report hearing the beep than those with schizophrenia. This discrepancy indicates that prior associations play a bigger role in the perceptions of schizophrenic individuals than in neurotypical individuals.

Another recent study further corroborates the involvement of abnormalities during top-down processing that cause hallucinations. In 2016, Jean-Paul Noel, Ryan Stevenson, and Mark Wallace lead a study focussed on the underlying mechanisms of sensory perception in individuals with schizophrenia. Neurotypical and schizophrenic individuals were exposed to temporally disparate simple-speech stimuli (i.e., a video in which the voice came before the mouth began moving) and were asked to assess if the voice and the mouth were synchronized. This type of procedure permits the analysis of the role of different modulations to sensory processing. Noel and colleagues found that schizophrenic participants were less able to accurately assess temporal disparities between the mouth and the voice than neurotypical individuals. This difference in performance could be attributed to alterations in prior likelihood to assume synchronicity (which for simplicity is shortened to "prior"). The prior acts as a proxy for the influence of higher-order processing in the top-down modulation of sensory perception. Thus, these findings further support the role that deviations in top-down processing, such as expectations, play in the sensory perception and hallucinations of schizophrenic individuals.

As with any neurological disorder, efforts have also been made to connect the associated symptoms with specific abnormalities in brain regions. While we may have evidence that expectations and top-down modulations play a role in hallucinations, there is more uncertainty about the parts of the brain that contribute to this atypical nature. This uncertainty is difficult to resolve, given the highly variable nature of different brain regions from one individual to another, as well as the intrusive and expensive nature of examining the brain. Nonetheless, a few brain regions are implicated in the hallucinogenic aspects of schizophrenia.

A recent review published by Patricia Boksa, who works in the Department of Psychiatry at McGill University, found that the brain area most frequently associated with hallucinations is the superior temporal gyrus—which includes the primary and secondary auditory cortices of the brain. These areas are respectively responsible for processing the frequency or pitch of auditory waves and localizing or analyzing complex sounds. Many

studies have found that there is decreased gray matter in this gyrus of schizophrenic patients who have auditory hallucinations. Meaning, they have fewer neuronal cell bodies to process the sensory information that they experience. While these are relatively low-level areas of sensory processing, they still receive inputs from various higher-order areas of sensory perception.

There are also several other areas in the brain that are implicated in the development of hallucinations of schizophrenic individuals. Recently a large study found a reduction in the size of the dorsolateral prefrontal cortex—which is associated with higher-order processes, such as decision making, action planning, and behavior. This would indicate not only a decrease in the cell bodies of this area but also a decrease in connectivity to other regions of the brain. Finally, actively hallucinating schizophrenic individuals have increased activation in regions of the brain that are associated with speech and language perception. Overall, we see modulations and deviations in areas associated with a diverse range of functions and levels in the processing of auditory stimuli.

It would be a natural conclusion that medication used to decrease hallucinations targets the aforementioned parts of the brain; this is not the case. Typically, a type of medications called second-generation antipsychotics is used to treat

While we may have evidence that expectations/top-down modulations play a role in hallucinations, what part of the brain is contributing to this atypical nature?

disorganized speech, delusions, and hallucinations in patients with schizophrenia. These medications specifically target the pathway for dopamine between the nucleus accumbens and the ventral tegmental area. Dopamine is a neurotransmitter associated with movement, reward, and learning. The ventral tegmental area has neurons which extend into the nucleus accumbens. These neurons will typically release dopamine, which binds to many receptors. The binding of dopamine to receptor D2 is particularly relevant to schizophrenia, as antipsychotics are D2 receptor antagonists in that they inhibit the ability of dopamine to bind to this receptor. The use of antipsychotics significantly reduces hallucinations, indicating that these brain areas also play a pivotal role in integration despite the lack of research directly associating these areas with hallucination. However, second-generation antipsychotics are also associated with severe effects on metabolic functioning by increasing a patient's risk for weight gain, diabetes, stroke, and heart disease. Ultimately more research is necessary to improve current medications.

There is still much to learn about the functional cause of hallucinations in schizophrenic patients. While there is empirical support for certain theories and associated brain regions, each fails to provide a holistic picture of hallucinations. Given the complexity of the schizophrenia and the brain itself, it is not surprising that we have yet to determine the exact cause. That said, neuroimaging is improving as new technologies and techniques emerge with each passing day. And thus, with each passing day, we come closer and closer to understanding why hallucinations occur and what we can do to help those who experience them. ●●●