AUDITORY VERBAL HALLUCINATIONS

By

Florian Bootsman

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Thesis

Auditory Verbal Hallucinations and Cognition: Neuropsychological measurement in a non-clinical sample

Florian Bootsman

Supervisors:

Martine J.E. van Zandvoort, PhD[1]

Iris E.C. Sommer, MD, PhD[2]

[1] *Utrecht University, Department of Psychonomics/ Helmholtz Institute, Utrecht, the Netherlands*
[2] *Departement of Psychiatry, Neuroscience Division, University Medical Center Utrecht, the Netherlands*

All our knowledge has its origin in our perceptions.

Leonardo Da Vinci

C O N T E N T S

F O R E W O R D

This master thesis is the end-result of a study conducted at the department of Psychiatry of the University Medical Centre of Utrecht. In 2006 an upscale research project into the dynamics of auditory verbal hallucinations (i.e. hearing voices) had started. Covering several scientific disciplines, the research team consisted of neuroscientists, psychiatrists, a medical biologist and a neuropsychologist. Each with their own area of interest related to auditory verbal hallucinations, varying from DNA and RNA-research to EEG-measures and temporal magnetic resonance imaging (fMRI) analysis of the hallucinating brain.

Despite these specialized interests, there was an additional need for a neuropsychological study of cognitive function in order to more comprehensively explain and study the phenomenon of auditory hallucinations. That is where I came in; a bachelor of science in Neuropsychology in search for a thesis project.

It seemed interesting to investigate whether language processing and other aspects of cognition were involved in the experience of hearing unexplainable voices. A steep plunge into the existing literature revealed that several attempts had been made to approach this concept, with contradictory outcomes. Some research has been done on verbal fluency in people suffering from schizophrenia, reporting both defective as well as proficient verbal fluency. Also, deficits in semantic memory and executive function have been subject of study in relation to verbal hallucinations, yet no conclusive theories have been posited in order to account for neuropsychological deficits sometimes seen in people who report hallucinatory experiences.

Much of the research conducted in this field focuses on schizophrenia, which constitutes a cesspool of individuals experiencing hallucinations in the auditory realm. The current study, however, required the participation only of non-clinical subjects with auditory verbal hallucinations as an isolated symptom. This study describes cognitive outcomes of executive function, memory, attention and verbal fluency in these individuals. The study was completed in May of 2008.

A B S T R A C T

Objective Individuals suffering from psychosis or schizophrenia often show great impairment in cognitive function. Specifically, decreased functioning in executive function, memory and attention has frequently been reported. The aim of the present study is to assess whether defective cognitive performance is also present in non-clinical individuals experiencing auditory verbal hallucinations (AVH) as an isolated psychiatric symptom.

Method 103 Participants were included for the present study and subsequently divided over two groups, healthy controls (59) and non-clinical hallucinators (44). They were administered a battery of neuropsychological tests to measure a wide range of cognitive functions. They were also clinically assessed by means of structured interviews and self-report measures. Participants suffering from a psychiatric condition, personality disorder or substance abuse were excluded.

Results Between-group comparisons of executive control, memory function and verbal fluency yielded no significant differences. Hallucinators did display, however, significant lower scores for a task measuring access to the mental lexicon – despite adequate verbal fluency - and had lower IQ's (despite being matched for level of education). Furthermore, they generated lower GAF-scores. Additionally, they displayed significantly higher schizotypal personality traits in comparison to non-hallucinating controls.

Conclusions No remarkable differences in cognitive function were observed between groups. However, group differences did arise in IQ and tasks measuring lexical access and abstract concept formation, which has also been found to occur in patients suffering from schizophrenia. Additionally, hallucinators also showed decreased psychosocial and professional functioning and showed more schizotypal personality traits than the control group. Further exploration of auditory verbal hallucinations needs to be undertaken in order to more comprehensively account for the functional, neuroanatomical and cognitive correlates of the phenomenon.

1. I N T R O D U C T I O N

1.1. Auditory (verbal) hallucinations

Imagine being at home, alone, cooking, for example, when suddenly you hear someone calling out your name. Most likely you will stop stirring the food and turn around, perhaps in a startled manner, to locate the source of the voice. After the necessary 'reality checking' has taken place you have limited plausible explanations left and realize that the voice might have sprung from your own mind. Imagination or reality?

Experiencing (auditory) hallucinations such as the one described could indicate mental illness, but this does not necessarily have to be the case. Although auditory hallucinations are a core symptom of psychosis and schizophrenia (e.g. Sadock & Sadock, 2003), they have been found to occur in the general non-clinical population as well (Aleman et al., 1999; Barrett & Etheridge, 1992 and Young et al., 1986). In their analyses of hallucinatory experiences, Slade and Bentall (1988) report that 65%-70% of schizophrenic patients experience auditory hallucinations. Sadock and Sadock (2003) report an average lifetime prevalence of 50% in schizophrenia patients. Within this diagnostic category, visual, tactile and olfactory hallucinations are also reported frequently but by no means approach the incidence of auditory hallucinations. About 20% of patients report visual hallucinations and about 5% report hallucinatory experiences in other modalities (Slade & Bentall, 1988). Auditory hallucinations also occur in other psychiatric disorders, including depression, bipolar disorder, borderline personality disorder, dementia and delirium (Sadock & Sadock, 2003). As much as 5 to 25% of people in the general, non-clinical population report hallucinatory experiences (Aleman et al., 1999; Barrett & Etheridge, 1992 and Young et al., 1986). Based on the reported occurrence of auditory hallucinations in the general population, it has been suggested that phenotype psychosis moves along a continuum whereby the clinically ill occupy one extreme of the spectrum whereas healthy people occupy the other (Johns et al. 2004; Strauss, 1969). Psychosis may therefore not be an all-or-nothing phenomenon. Investigating the presence of hallucinatory activity in the non-clinical inherently removes severe psychopathology from the equation thereby creating the opportunity to study auditory verbal hallucinations in a less confounded manner. But what exactly is an 'auditory verbal hallucination'?

The most widely used definition of auditory hallucinations is that they are *perceptual experiences in the absence of sensory stimulation while the individual is awake and where there is no voluntary control over the sensation of hearing something that is not really there.* Auditory hallucinations can vary from hearing unexplainable sounds to hearing one's own name being called out or hearing whole conversations. Perception of unexplainable voices is often referred to as having auditory verbal hallucinations (AVH) and is differentiated from hearing non-verbal sounds when there is a vocal quality to it (e.g. Aleman et al., 2003). The content of the voices heard can be positively or negatively valenced.

Several theories have been posited to contribute to our understanding of AVH. This paper explores the possible neuropsychological underpinnings of the aetiology and maintenance of hallucinatory experiences, evaluating research from both the neuroscientific as well as the cognitive sciences. First, an overview will be given on the cerebral mechanisms implicated in AVH. Specifically, the role of language related cerebral areas and lateralization of language in AVH will be discussed, as evidence to their involvement has been described. Secondly, an overview will be given on the cognitive aspects presumed to mediate AVH and will serve as the general framework in which the present study is embedded.

1.2. Functional and anatomical aspects of Auditory Verbal Hallucinations

Hallucinatory phenomena have been a frequent subject of study within the neuroscientific, cognitive and psychological sciences. As a consequence, several theories have been posited to provide a frame of reference with which they can be explained. As mentioned, verbal hallucinations are a hallmark symptom of schizophrenia and psychosis (e.g. Hijman et al.,2003; Sadock & Sadock, 2003) and as a result, most of the research that has been conducted on the subject employed participation of individuals who meet the diagnostic criteria for these disorders.

In AVH, the involvement of language related cerebral areas have been described, albeit in varying terms. Normal speech production and comprehension is mediated by Broca's and Wernicke's areas, respectively (e.g. Geschwind, 1970). In approximately 95% of healthy right handers, these language areas are located in the left hemisphere (Bryden et al., 1983; Levy, 1974). In about 22-24% of left-handed or ambidextrous-handed individuals, bilateral language activation has been reported where distribution of language areas was either symmetrical or right-dominant (Szaflarski et al., 2002; Pujol et al., 1999), which reflects a decrement in lateralization for language. Coincidentally, decreased lateralization of Broca's area has also been described in schizophrenic individuals and has been linked to increased severity of AVH (Weis et al., 2006; Sommer et al., 2001). Schizophrenia patients performing a covert verbal fluency task while undergoing an functional Magnetic Resonance Imaging (fMRI) procedure, showed increased activation of the right homologue of Broca's area (Weiss et al., 2004), which henceforth has been claimed to reflect bilateral language processing and may be representative of release from inhibition normally exerted by the left hemisphere (Weis et al., 2004; Sommer et al., 2003). Additionally, decreased language lateralization was found to be present in patients demonstrating psychotic symptomatology and was suggested not to be specifically related to schizophrenia but to psychosis in general (Sommer et al., 2007). Furthermore, the same group showed that increased severity of psychosis was not related to decreased language lateralization. They suggest a decrement in lateralization to be stable over time and independent of changing clinical symptoms. In light of this assertion and the fact that decreased lateralization is also present in monozygotic twins discordant for schizophrenia (Sommer et al., 2004), a decrement in dominance for language may reflect a genetic risk factor for psychosis (Sommer et al., 2007). This is in adherence with Crow (1997) who has postulated that observed loss of cerebral asymmetry in schizophrenia is related to a failure in establishing cerebral dominance for language, most likely under genetic control, where a locus of genetic aberration predisposing for schizophrenia may soon be identified (Crow, 1999).

Alternatively, some studies have specifically implicated the involvement of left hemisphere language areas in the aetiology and maintenance of hallucinatory activity of an auditory nature. McGuire et al. (1993), for example, found increased blood flow in Broca's area during AVH in schizophrenia patients. Other studies report elevated activity of speech perception areas in the superior temporal gyrus, often referred to as Hechl's gyrus, during AVH (Hoffman et al., 2007; Shergill et al., 2001, 2000; Woodruff et al., 1997). Additionally and in support of these findings, Hubl et al. (2007) report reduced sensitivity to external stimuli of the auditory cortex during verbal hallucinations. These results serve the suggestion hallucinatory activity to be resultant of internally generated speech which is not recognized as such due to dysfunctional verbal self-monitoring which, in turn, leads to inadequate activity in temporal speech perception areas (Shergill et al., 2004; Fu et al., 2001). It has been hypothesized that inner speech originating from right cerebral homologues of language areas leads to erroneous attribution of source whereby defective inhibitory mechanisms underlie disinhibition of language perception areas and are responsible for externalizing verbal thoughts to an alien source (Sommer et al., 2003).

Although cerebral differences between hallucinating and non-hallucinating individuals in both functional and anatomical domains may be key to unravelling the phenomenon, the proposition that impaired cognition might play an equally important role in the aetiology and maintenance of hallucinatory experiences has received considerable interest. Research efforts concerning AVH may converge to a unitary model where both neuroscientific findings as well as findings from cognitive studies may be combined in explaining hallucinatory presence in both the clinically ill as well as in non-clinical individuals. Therefore, the present study aims at providing a frame of reference regarding cognition in AVH.

1.3. Cognitive aspects of Auditory Verbal Hallucinations

Patients with schizophrenia often present with deterioration of cognitive function (for a review, see Hijman et al., 2003; Heinrichs et al., 1998). Several studies have demonstrated various cognitive deficits in schizophrenic populations (for a meta-analysis of cognitive dysfunction in schizophrenia, refer to Heinrichs and Zakzanis, 1998). Impaired domains included intellectual ability, verbal and visual memory, cognitive flexibility, abstract concept formation, attention and verbal fluency (Zakzanis et al., 1999; Heinrichs and Zakzanis, 1998). These studies explored cognitive function in schizophrenic populations, regardless of symptom cluster; there was no differentiation between negative and positive symptoms in relation to specific cognitive deficits. Results obtained from research conducted on the link between AVH and cognition are both scarce and contradictory. Also, research on positive symptomatology and cognition has drawn heavily from schizophrenic populations and may therefore be difficult to interpret from a phenomenological perspective. Nevertheless, at present, the aim is to establish a cognitive profile of the hallucinating individual in order to evaluate to what extent AVH can be associated with anomalous cognitive performance. Specifically, primary cognitive domains of interest in this study are executive function, memory and verbal fluency.

1.3.1. Inhibition and monitoring

The term Executive Function denotes a constellation of higher-order cognitive abilities present in humans. Luria (1966) and Lezak (1995) stressed that planning and regulation of behaviour are the primary aspects to which the term 'executive function' pertains. Shallice (1988) proposed several components to serve executive processing. In his model, he proposes *contention scheduling, lateral modulation* and *supervisory attention* to be among the most pertinent of executive mechanisms. Contention scheduling refers to conflict resolution in an automatic fashion whereby the stronger of two competing behavioural schemata's will prevail. Lateral modulation refers to lateral inhibition one schemata imposes on the other when there is incompatibility between them. Supervisory attention pertains to working memory in that its function is to select and guide certain behaviours when these behaviours can not rely on automatic processing. This latter working memory component was further described and defined by Baddeley (2000) as an executive control function. Furthermore, Ylvisaker (1998) distinguishes eight executive abilities: realization, goal-setting, planning, initiation, self-inhibition, self-monitoring, ability to shift set and strategic behaviour. Although the functional and anatomical correlates of executive processing remain largely unspecified, the prefrontal cortex is considered to be a primary cerebral region involved in such processes (e.g. Fuster, 1997; Luria, 1966). Also, Shallice (1988) found reduced executive planning and inhibition in patients with left-frontal lesions as compared to patients with right-frontal and posterior lesions.

To date, no unified theory on the cognition of AVH has been established. However, some have received support based on empirical findings. For example, Bentaleb and colleagues (2002) review two theoretical hypotheses that might contribute to the understanding of the aetiology of AVH. One such a theory stresses that AVH arises from the misinterpretation of inner speech while the other proposes it to be related to aberrant activation of the primary auditory cortex. These theories might not be mutually exclusive whereas defective internal monitoring and aberrant activation may both be responsible for the presence of AVH (Bentaleb et al., 2002). With respect to verbal self-monitoring and related executive processes, biases in attribution of source have received considerable interest in the study of hallucinations in the auditory modality. Individuals prone to AVH may be impaired in the ability to distinguish self-generated from external speech, which has been proposed to be fundamental to most cognitive models of auditory hallucinations (Seal et al., 2004; Frith & Done, 1988). In the same vein, Wegner (2002) notes that the tendency to externalize thoughts to an alien source is not limited to schizophrenia but might reflect a general mechanism present in hallucinators, whether they have been clinically diagnosed or not. Allen et al. (2007) argued differential responsiveness of the anterior cingulate and the left superior temporal gyrus to be at the core of faulty attribution of source in individuals prone to auditory verbal hallucinations. Here, activation patterns differed from those of the reference groups while evaluating the source of speech. Mechelli et al. (2007) report findings of an equal nature. Other reports, as mentioned before, also indicate involvement of temporal speech perception areas in dysfunctional verbal self-monitoring (Shergill et al., 2004; Fu et al., 2001).

Furthermore, the presence of AVH may additionally relate to poor intentional inhibitory control of intrusive irrelevant thoughts. There is an increasing tendency to acknowledge similarities between auditory verbal hallucinations and intrusive thoughts whereby several theories implicate intrusive cognition to play a central role (Morrison, 2001; Nayani & David, 1996). Intrusive thoughts are suggested to indicate inhibitory (executive) dysfunction in disorders such as Obsessive-Compulsive Disorder (Enright & Beech, 1993) and Post-Traumatic Stress Disorder (Vasterling et al., 1998). Although there is some evidence for a linkage between schizophrenia and deficits in inhibition (Beech et al., 1989; Brebion et al., 1996), the few studies that have investigated the role of inhibitory processes in auditory hallucinations by employing negative priming and interference (Peters et al., 2000; Brebion et al., 1998), have failed to demonstrate such an involvement. However, Waters et al. (2003) propose that failure to demonstrate the role of inhibition in AVH might have been caused by the fact that these studies did not incorporate intentional inhibition as a variable but solely employed unintentional inhibition (negative priming and interference). To this assertion, the same research group demonstrated increased severity of auditory hallucinations to be linked with deficits in *intentional inhibition* by measuring conscious suppression of irrelevant thoughts and memories. The failure to inhibit current associations and representations in memory was suggested to, at least in part, be the cause of the intrusive nature of the hallucinatory experience. It should be noted that this deficit was not linked with other positive symptoms of schizophrenia (Waters et al., 2003). Perhaps hypothesized disinhibition of right-hemisphere cerebral language areas (Weiss et al., 2004; Sommer et al., 2003) has negative implications for adequate inhibitory control.

1.3.2. Memory

Tulving (1972) described semantic memory as the general knowledge of concepts and facts. Several studies point to involvement of left frontal, temporal and parietal cortices in mediating semantic processes (for review refer to: Hart et al., 2002). Hart and Gordon (1990) showed that of multiple aphasic patients, the only three that demonstrated relatively isolated semantic processing deficits had common lesions that overlapped in the posterior superior temporal gyrus and inferior parietal lobule, and showed deficiencies in tasks involving category, property and synonym judgment and naming. Furthermore, impaired dorsolateral prefrontal cortex (DLPFC) function has been linked to impaired working memory in schizophrenia (Goldman-Rakic, 1999). In addition, Weber et al. (2007) showed that memory for verbal material is dependent upon degree of lateralization for language representation. Specifically, they found that subjects who have right language representation have a lateralization to the right medial temporal lobe for verbal memory.

AVH has been linked to altered memory function. For example, Kuperberg and Heckers (2000) argue that patients with auditory hallucinations may have particular problems with auditory source memory and that patients with positive thought disorder might have specific problems with semantic processing. Brebion et al. (2002) found memory errors to be correlated with hallucinations and also suggest difficulties in source memory to be involved. The same group demonstrated more recognition errors in their hallucinating group which they claim is causal to a deficit in reality-monitoring. Brewer et al. (2005) investigated cognitive function in individuals deemed at ultra high risk for psychosis and found reduced immediate memory in this group. They argue that efficient organization for accurate recall is compromised in those prone to psychosis and may reflect vulnerabilities in prefrontal cortical networks. Others have claimed disruption in frontotemporal pathways to be particularly detrimental to memory function (Ragland et al., 2004). Although these findings indicate memory error to be associated with AVH, they do not provide an explanation as to *how* memory contributes to the aetiology and maintenance of AVH. Some attempts have been made, however. As mentioned, a failure to inhibit current associations and representations springing from memory may be responsible for the intrusive nature of AVH (Waters et al., 2003). It could be argued that an enhanced associative capacity of memory in hallucinating individuals overruns the capacity to adequately inhibit rapidly generating representations which are subsequently interpreted as being unexplainable perceptual phenomena. Also, reported problems in auditory source memory (Brebion et al., 2002; Kuperberg & Heckers, 2000) may additionally contribute to AVH. Further elaborating, memories of auditory events may be activated randomly and unjustly be perceived as unexplainable voices because there is no recollection of the original source. If this is the case, memory may play an instrumental role in the aetiology of AVH. Consequentially, memory errors may therefore be causal to both a deficit in inhibitory control as well as to interference of intrusive, sometimes poorly sourced, representations arising from memory, which can be viewed in the same light as findings reported by David (1994) who suggested that in verbal hallucinations, overactivated lexical items unintentionally exceed a threshold level of activation

1.3.3. Verbal Fluency and aspects of Executive Function and Memory

Verbal fluency refers to the extent one is able to produce words in accordance with specific rules set by the experimenter. The ability to do so depends on multiple cognitive systems such as executive function, memory and attention (Henry et al., 2005; Stuss et al., 2002; Lezak, 1995). Stored knowledge about words and their semantic or phonemic relations to others needs to be activated, manipulated and produced in accordance with specific task demands upon successful task completion. Typically, these kinds of tasks require production of words that are phonemically or semantically related.

While phonemic fluency is thought to rely primarily on executive function (Henry et al., 2005; Lezak, 1995), the same is not necessarily true for semantic fluency. Although this type of verbal fluency, to some degree, also depends on executive functioning, there is some evidence suggesting that inaccurate performance is the result of dysfunctional semantic organization in memory storage components (Henry et al., 2005). While phonemic fluency *deficits* (reduced output compared to healthy controls) are quite consistently associated with the presence of negative symptoms (for example, Tsakanikos et al., 2005; Allen et al., 1993; Howanitz et al., 2000), research findings concerning the link between positive symptoms and verbal fluency performance are scarce and often contradictory. For example, an increase in phonemic fluency was found to be associated with AVH in schizophrenia patients (Tsakanikos et al., 2005; Kerns et al., 1999). Additionally, Kerns et al. (1999) demonstrated that disproportionate production of semantically related words in a phonemic fluency task was positively correlated with verbal hallucinations. They posit that semantic memory organization in individuals with high schizotypy is functionally different from healthy subjects without high schizotypy. Bowie et al. (2004), on the other hand, did not find an association between psychotic phenomena and verbal fluency performance. With respect to semantic fluency, Kiang and Kutas (2006) examined the relation between semantic fluency outcomes and positive schizotypy in a non-clinical sample and found that higher scores on the Schizotypal Personality Questionnaire (SPQ) correlated with the production of atypical category-related words during a semantic fluency task. As mentioned, David (1994) theorized that hallucinations relate to overactivated lexical items unintentionally exceeding a threshold level of activation. A different report suggests that hallucinations have a comparable semantic organization to the organization of extended discourse in schizophrenia (Hoffman et al., 1994). An additional point to be taken into account is that defective lexical access as seen in schizophrenia (Covington et al., 2005; Allen et al., 1993), may also be present in non-clinical hallucinators and could also affect verbal fluency performance.

1.4. The present study

1.4.1. Premise

Studies into the neuropsychological underpinnings of positive symptoms of schizophrenia and psychosis have been scarce and the few findings that are available are often of a contradictory and inconclusive nature, although overall decreased functioning in attention, memory and executive function in these diagnostic groups has been reported frequently (for an overview, see Hijman et al., 2003). While research efforts concerning AVH have primarily focused on patients suffering from schizophrenia, there is relatively little literature on cognitive functioning in individuals experiencing AVH as an isolated psychiatric symptom. In attempting to investigate AVH in isolation, the present study included only individuals whom had no clinical diagnosis, no substance abuse problems and no personality disorder. Inherently, confounds in the data as a result of underlying psychopathology, use of medication or hospitalisation could therefore be minimized. Nevertheless, similarities between non-clinical individuals and those diagnosed with a psychiatric condition, in which hallucinations are present, may exist. Perhaps minor deviations in inhibitory processing, self-monitoring and memory in non-clinical hallucinating individuals subtly relate to the more serious executive and memory deficiencies often observed in schizophrenia patients.

As summarized above, auditory verbal hallucinations have been associated with alterations in domains of cognitive functioning. When interpreting differential contributions of various cognitive mechanisms implicated in AVH, one could argue, based on the above, defective inhibitory control, verbal self-monitoring (and reality-monitoring) and enhanced associative capacity to be *instrumental* to errors in perception and hallucinatory presence. A cognitive model of verbal hallucinations should therefore include both inhibitory (executive) control and memory function as affected capacities.

1.4.2. Hypotheses on inhibition and monitoring

Behavioural mechanisms related to executive control are thought to be instrumental in the aetiology and maintenance of AVH. Adequately distinguishing inner speech from external speech may be compromised in those prone to AVH and are thought to relate to difficulties in verbal self-monitoring (Mechelli et al., 2007; Seal et al., 2004; Frith & Done, 1988). Self-generated vocal stimuli may not be recognized as such where misidentification of them as being unexplainable voices may ensue. Additionally, deficient inhibition of intrusive thoughts and memories may also contribute to the maintenance of AVH. Cognitive impairment of this nature is often seen in hallucinating populations (Costafreda et al., 2008; Brebion et al., 2002; Waters et al, 2003) and may also be present in non-clinical hallucinators. Therefore, at present, it is hypothesized that individuals experiencing hallucinatory phenomena will show subtle inhibitory and monitoring deficits when these are experimentally employed.

1.4.3. Hypotheses on memory

It has been claimed that memory organization in individuals with high schizotypy might be functionally different from healthy controls (Kerns et al., 1999) and that hallucinations may have a comparable semantic organization to the organization of extended discourse. Furthermore, immediate memory may be affected in hallucinating individuals who are at-risk for psychosis (Brewer et al., 2005). Although problems with memory function have been associated with hallucinations, as summarized above, its instrumental contribution to the aetiology of AVH remains poorly understood. Nonetheless, at present, it is hypothesized that enhanced associative generation of representations in memory may overrun the capacity to adequately inhibit these and may subsequently be interpreted as being unexplainable perceptual phenomena. Defective inhibition and exorbitant self-generated memory output may therefore both be instrumental in the intrusive nature of hallucinatory experiences.

Of equal importance is the suggestion that a problem with auditory source memory is associated with AVH. Inadequate memory of the source of an auditory event has been hypothesized to denote a reality-monitoring deficit which may reflect inadequate selective attention leading to improper encoding in memory (Brebion et al., 2002; Aleman et al., 2000; Kuperberg and Heckers, 2000) When the source of an earlier auditory event can not be adequately retrieved from memory, one might interpret its current perception as being a spontaneous unexplainable event or not belonging to the self, hence externalizing. With further reference to reality-monitoring, it has been implied that imagined events have similar phenomenological characteristics as perceived events, rendering the boundary between imagination and reality unclear (Brebion et al., 2002; Aleman et al., 2000). Inadequate discrimination may therefore lead to bizarre interpretations of auditory stimuli emerging from memory. Also, false memories may nurture hallucinatory experiences.

As a result of the above stated, experimental manipulation of memory function may lead to the observation of memory errors in hallucinating individuals due to interference of imagined events and self-generated representations and memories. Incorrect recollection of the source of presented stimuli may additionally lead to inaccurate recall. Stored items not learned during testing may partly replace the required items (intrusions).

1.4.4. Hypotheses on verbal fluency

Verbal fluency is a cognitive ability primarily dependent on executive function and memory function (Henry et al., 2005; Lezak, 1995). In the present study, verbal fluency is not hypothesized to be directly involved in the aetiology and maintenance of AVH but is rather suggested to reflect altered function in executive processes and memory function in hallucinating individuals. Monitoring what is considered to be correct output and thereby inhibiting competing incorrect alternatives may be impaired in hallucinating individuals. Inhibitory (executive) dysfunction is primarily hypothesized to underlie difficulties with phonemic fluency whereas reliance on memory capacity may result in adequate or even above average performance in semantic fluency. Semantic fluency output, where utterance of categorically related items is required, may be above par due to an enhanced associative capacity of hallucinating individuals. Rapidly spreading activation of lexical representations within memory nodes may therefore be at the core of above average performance. Experimental measurement of both phonemic and semantic fluency will be obtained in order to further explore the role of executive functioning and memory in AVH. Verbal fluency will be differentiated in phonemic and semantic fluency and subsequently compared between groups.

1.4.5. *Hypotheses on schizotypy and global functioning*

Although the hallucinating group is deemed healthy at present, they may be prone to psychosis and therefore display increased schizotypal personality as compared to non-hallucinating controls. Therefore, the assessment of schizotypy is warranted in the present study. In addition, global functioning in psychological, social and professional contexts will be assessed in an attempt to substantiate the hypothesis that hallucinatory presence is accompanied by decreased functioning in these domains. To this goal, GAF-scores (Global Assessment of Functioning) will be obtained.

2. M E T H O D

2.1. Participants

Exclusion criteria for both controls as hallucinators were as follows: 1) presence of a psychiatric disorder or significant history thereof (individuals with a history of psychotic symptoms were excluded, even when in remission), 2) presence of an axis II personality disorder, 3) drug use in the three months prior to assessment or a significant history thereof, 4) consumption of more than 15 units of alcohol-containing beverages a week, 5) presence of a neurological disorder or 6) IQ of 70 or below. 110 participants, matched for sex, age and level of education, were recruited through the use of a website, set up for this particular study (www.verkenuwgeest.nl). Seven of them were excluded due to the presence of a psychiatric condition or personality disorder (6) and absence of auditory verbal hallucinations (1). None of the included participants had a drug dependency at time of assessment, as they were toxicologically screened for this. Also, none exhibited alcohol abuses or had a history of psychiatric disorder, neurological disorder, head injury or alcohol or drug dependency. Furthermore, none of the control participants ever had the experience of hearing unexplainable voices or sounds or hallucinatory experiences in other modalities (visual, olfactory or tactile). The hallucinating group consisted of 12 males and 32 females, in the control group 20 males and 39 females were included. The included participants had a mean age of 44.50 years old (SD = 13.34). Mean age for the hallucinating group was 42.61 (SD= 12.23) and for the control group 45.92 years (SD= 14.05). Level of education was defined as numbers of years; the hallucinating group averaged 13.37 (SD = 2.67) years of education and the control group had a mean of 13.72 (SD = 2.62) years of education.

All participants gave their written informed consent.

2.2. Procedure

On the aforementioned website, visitors were asked to participate in an experiment concerning the perception of unexplainable voices. To this goal they were asked to fill out a questionnaire in order to register unusual (hallucinatory) experiences. In fact, the questionnaire employed, was an adaptation of the Launay Slade Hallucination Scale (LSHS). Based on preliminary analysis of the results we obtained from the LSHS, participants were assigned to one of two groups – a control group and a 'hallucinating' group – and were matched for gender, age and level of education. Subsequently they were invited to the department of Psychiatry of the University Medical Centre

Utrecht (UMCU). Upon arrival, the participant was informed that the experimenter needed to remain blind to group membership (control versus hallucination) until after neuropsychological testing had finished. It should be noted that all the participants complied with this request by omitting any clues during testing that could tip off the experimenter. In the testing room, a global explanation was provided by the experimenter as to how the experiment would be conducted, leaving out any detailed information as to what constructs or cognitive functions would be tested. After the participant was properly informed about the circumstances of the study and signed the informed consent, subjection to the neuropsychological battery of tests and psychiatric evaluation commenced.

2.2.1. Data handling

The person who administered the tests was blind to group-membership of the participants until after scoring of the individual tests had been completed. The raw cognitive data were scored and reviewed by two trained neuropsychologists in order to enhance reliability. First, all tests were scored by the administrator. Subsequently, the second rater, who was not present during testing and was also blind to experimental condition, evaluated the assigned scores and corrected them when necessary.

2.3. Neuropsychological Assessment

2.3.1. Inhibition and monitoring (executive function)

It was hypothesized that difficulties with inhibition and monitoring are instrumental to the aetiology of AVH. Therefore, three tasks that measure executive function have been employed to experimentally test this hypothesis. The first was a subtask of the BADS (Behavioural Assessment of the Dysexecutive Syndrome), the *Rule-Shift Card Game*. Twenty cards of an ordinary deck of playing cards were consecutively shown to the participant. In this task there were two rules reflecting two separate trials. With the first rule the participant had to respond “yes” when a shown card had a red colour and “no” when it was black. In the second trial the participant had to ignore the first rule and attend to a new one. He or she had to respond “yes” when a card was of the same colour as the preceding card and “no” when it was not. Thus, the participant had to inhibit responding to the first rule while attending to the second. Also, they needed to monitor the identity (colour) of preceding cards in order to respond correctly to new ones. Some patients with executive problems find it difficult to adapt to this rule shift and accuracy declines consequentially.

The second task that was administered regarding executive processing was the *Stroop Colour-*

Word Task. A task that measures higher-order cognitive function related to response inhibition and selective attention. More specifically, it measures the aptitude of the participant to successfully inhibit prepotent response to visually presented, verbal material. Where the names of colours are printed in a different colour from that which they refer to, the participant was required to name the colour of the print. Where one is automatically inclined to read aloud the word itself, the task is to inhibit this inclination and give priority to name the colour of ink the word is printed in.

A third task that was employed, the *backward Digit Span-task,* requires executive manipulation of presented stimuli. Here, participants were read aloud a string of digits which they were required to reproduce in backward fashion. This trial specifically recruited working memory function because the individual had to form an internal representation of the presented digits and, subsequently, had to cognitively manipulate the string, by reversing the order of the presented items, to successfully meet task demands. The number of digits in a string increased until the participant was no longer able to successfully reproduce. The number of correctly reproduced strings was used to compare groups.

2.3.2. Memory

Enhanced association and source memory dysfunction have been hypothesized to contribute to hallucinatory activity in the auditory modality. Experimentally, accurate recall of list items may be compromised due to intrusive associations and representations emerging from memory storage components. Furthermore, when the participant is unable to remember the source of lexical items in memory, recall of verbal material may be compromised. Both altered semantic memory organization as well as interference due to hallucinatory activity may additionally complicate successful task completion.

Assessment of short-term memory was achieved through appliance of the *forward Digit Span*-task and direct recall on the *Verbale Leer en Geheugen Test* (VLGT), the latter being a memory task specific to neuropsychological research conducted in the Netherlands. With the Digit Span task, participants were read aloud a string of digits which they were required to reproduce, immediately, in the same order they were presented in. The number of digits in the string increased until reproduction was no longer proficient. With the VLGT, participants were read a 16-item shopping list for a total number of five times. The list consists of 4 separate categories, 4 items per category, which were randomly presented. After each reading there was direct free recall of the list in any order the participant wished. The amount of correctly recalled items constituted the measure of comparison between groups.

Long-term verbal memory was also assessed by administration of the VLGT. After five consecutive readings of the 16-item list a second, different, shopping list was read aloud to the participant where, again, direct free recall was required. Then the participant was asked to name the items that were on the first list. After these free recall trials, memory organization was assessed through means of cued recall. Participants were required to name specific items of the first list that pertained to a certain category. They were given the name of a category and were required to name the items belonging to these separate categories. After twenty minutes, again, there is both free and cued delayed recall of the first list. Here as well, the amount of correctly recalled items constituted the measure of comparison between groups.

A measure of non-verbal long-term memory was also obtained by administration of the *Complex Figure of Rey-Osterrieth*. The participant was shown a drawing of a complex figure and was instructed to copy the drawing with utmost precision. After twenty minutes, there was delayed recall of the figure from memory. Crude scores on both trials served as comparison variables.

2.3.3. Lexical access and abstract reasoning

Two WAIS III task were administered in order to assess lexical access and abstract reasoning. The Vocabulary test required the participant to access the mental lexicon upon providing adequate definitions of 33 words (increasing in difficulty as the list advanced). The Similarities test required one to indicate in which way two concepts are similar to one another. Here too, difficulty increased as the list advanced.

2.3.4. Verbal Fluency

In hallucinating individuals, verbal fluency may be differentially affected whereby semantic (categorical) fluency is hypothesized to be intact or superior, relative to phonemic fluency, in comparison to healthy controls. Both phonemic and categorical fluency were assessed. With phonemic fluency, in two separate trials, participants were required to utter as many words as possible beginning with a certain letter. In the first trial, the utterance of words beginning with an 'N' was required. In the second trial, the uttered amount of words beginning with an 'A' was measured. Measurement time in both trials was one minute. Any word that came to mind could be pronounced except for the names of people, countries or cities. With respect to categorical (semantic) fluency, participants were again subjected to two separate trials. In the first trial the participant had to name as many professions as possible during two minutes. In the second trial one had to name as many animals as possible during two minutes. The number of words produced during both phonemic and semantic fluency represented the fluency measures that were compared between groups.

2.3.5. Intelligence Correlates

In order to control for interpersonal variability regarding intellectual ability, IQ was assessed by employing the Dutch adaptation of the *National Reading Test for Adults (NART)*. Non-verbal IQ was assessed using the *Raven's Advanced Progressive Matrices*. Here, participants were required to choose between eight pieces of a puzzle in order to complete the target puzzle. Logical thinking needed to be applied for successful task completion.

2.4. Psychiatric Assessment

2.4.1. Launay Slade Hallucination Scale (LSHS)

In order to assess to what extent individuals experience unexplainable phenomena such as hearing voices, visitors of our website were asked to fill out a questionnaire, the Launay Slade Hallucination Scale. This questionnaire was primarily used to assign potential participants to one of two conditions, control or experimental, prior to extensive examination on location at the department of Psychiatry of the UMC Utrecht.

2.4.2. Comprehensive Assessment of Symptoms and History (CASH)

All participants, both controls and hallucinating participants, were subjected to a Comprehensive Assessment of Symptoms and History-interview (CASH). The CASH is a psychiatric interview designed to assess an individual's history with respect to psychiatric illness and was first published by Andreasen et al. (1985). The interview was conducted by a staff psychiatrist whereas the author was present as second rater. Psychiatric assessment was purposefully implemented to make sure none of the participating subjects were currently experiencing emotional or psychiatric problems. If so, they were excluded from analysis. Confounding of the data due to underlying pathology was thus removed prior to examination of cognitive measures. Also, if there were any doubts concerning the genuineness of the reported hallucinations, the participant was excluded from the study.

2.4.3. Schizotypal Personality Questionnaire (SPQ)

All participants were required to fill out the Schizotypal Personality Questionnaire (SPQ). The SPQ registers to what degree schizotypal personality traits are present in the individual. Although participants in the AVH group might not suffer from a psychiatric condition, it was hypothesized they might display schizotypal personality traits. For consistency and scientific merit, SPQ scores were also obtained from control participants.

2.4.4. Global Assessment of Functioning (GAF)

An observational tool was used to indicate the level of psychological and social functioning. This was achieved by means of the GAF-scale (Global Assessment of Functioning). Although the hallucinating group was deemed healthy, there may be differences compared to healthy controls with respect to the aforementioned behavioural dimensions.

2.4.5. Assessment of Hallucinatory Experience

Participants from both groups were subjected to an interview assessing both the presence and nature of the hallucinatory experience. It was expected that the control group would not have any experiences of this sort but were screened for AVH anyway. A questionnaire was designed specifically for the hallucination study – of which this thesis is one of few – in order to describe the experiences of the participants with regard to the hearing of voices.

2.5. Statistical analyses

The data were analyzed with the Statistical Package for the Social Sciences (SPSS, version 15.0). Between-group comparison on several cognitive measures was achieved through both univariate as well as multivariate analysis of covariance (ANCOVA and MANCOVA), applying a General Linear Model procedure. Also, stepwise multiple regression analyses were performed with GAF-score and SPQ-score as the dependent variables; several cognitive measures were employed as predictor variables. Finally, Pearson correlations (r^2) between variables were computed in order to define covariates that needed to be controlled for.

3. R E S U L T S

3.1. Demographic variables

103 participants were included for the study (44 AVH versus 59 controls). They were matched for sex, age and years of education. The hallucinating group consisted of 12 males and 32 females whereas in the control group 20 males and 39 females were included. The groups were not of identical size due to both a higher drop-out rate of hallucinators prior to assessment at the psychiatry department as well as a higher exclusion rate. With respect to age, there was no significant difference between groups (F (1, 103) =1.55, p= .22). A one-way ANOVA (analysis of variance) revealed a significant difference in IQ estimation between groups (F (1, 103) = 12, 35, p = .01), despite nearly equal number of years of education. Mean number of years for the hallucinating group was 13.37 whereas the control group averaged 13.72 years of education. This difference was not significant (F (1, 76) = .339, p = .562). Table 1 shows the mean age, estimated IQ and number of years of education for both groups.

Table 1. *Mean age, IQ and years of education (and standard deviations) for the hallucinating (AVH) and the non-hallucinating group*

Measure	**AVH**		**Control**		**Total**		**Group comparison**
	Mean	(SD)	Mean	(SD)	Mean	(SD)	
• Age	42.61	(12.23)	45.92	(14.05)	44.50	(13.34)	F = 1.55
• IQ	104, 75	(10,92)	111,59	(8,83)	108,67	(10,31)	F= 12.35
• Education	13.37	(2.67)	13.72	(2.62)	13.56	(2.63)	F = .339

SD = Standard deviation

With respect to the Raven's Advanced Progressive Matrices test, the hallucinating group had a mean score of 9.02 (SD = 2.32) whereas the control group had a mean score of 9.12 (SD = 2.21). These scores on the Raven's Advanced Progressive Matrices test, a measure of logical thinking – sometimes employed as non-verbal IQ, were not significantly different between groups (F (1, 103) = .045, p = .832).

3.1.1. Choice of covariates

In order to control for influential factors that are not of primary interest in the present study, covariates were identified as such when a variable maintained a significant and linear relationship with the dependent variable and was significantly different between groups. This meant that in most analyses, IQ and age served as the covariates.

3.2. Cognitive domains

3.2.1. Response inhibition and monitoring (executive function)

It was expected that the hallucinating group, in comparison to the control group, would show impaired performance on tasks measuring intentional inhibition (selective attention) and working memory function. With the Stroop-task, response inhibition was measured as the amount of time between the average scores on the Word and the Colour cards and the time needed to complete the Colour-Word card of the Stroop task. ANCOVA with IQ and age as the covariates did not yield a significant difference between groups on this measure ($F (1, 103) = .899$, $p = .345$). Performance on a different task measuring response inhibition, the Rule-Shift Card Game, was analyzed through a one-way ANOVA ($F (1, 103) = .52$, $p = .474$). Also, analysis of covariance of scores on the backward Digit Span as a measure of working memory was carried out as well ($F (1, 103) = .52$, $p = .473$). Here, IQ was employed as covariate. Table 2 displays the results of analyses of variance and covariance.

Table 2. *Mean scores (and standard deviations) for three executive tasks.*

Task	**AVH** (N = 59)		**Control** (N= 44)		**Group comparison**
	Mean	(SD)	Mean	(SD)	
• Stroop	40.50	(21.01)	34.90	(15.02)	F =.899
• Rule-Shift	3.66	(.65)	3.75	(.58)	F = .52,
• Digit Span (Backward)	6.41	(2.20)	7.14	(2.04)	F = .52,

Note. Scores for the Stroop task refer to time in seconds, scores for the Rule-Shift task refer to categorical (ordinal) nominations (1 (minimum) through 4 (maximum)).
Scores for the backward digit span task refer to number of strings successfully reproduced.
SD = Standard deviation

The hypotheses pertaining to inhibitory control and monitoring were not supported by the findings as there were no significant differences on these executive measures. At present, they do not seem to be associated with hallucinatory experiences in the auditory modality. Working memory also does not differ between hallucinators and non-hallucinators.

3.2.2. Memory

It was hypothesized that intrusive associations and representations in memory storage components as well as an insufficient source memory faculty would interfere with accurate recall of verbal material. In attempting to substantiate this prediction, both short-term and long-term memory function were assessed. *Short-term memory* was measured as number of words (VLGT-measure) and number of digits (forward Digit Span) immediately recalled after presentation. There was a significant Pearson correlation between age and direct recall on the VLGT shopping list items ($r^2 = -.307$, $p < .01$). Also, a significant correlation between IQ and forward Digit Span was found ($r^2 = .258$, $p < .01$). An ANCOVA procedure with VLGT-direct recall as the dependent variable and age as the covariate did not result in a significant difference between groups ($F(1, 103) = .908$, $p = .343$).. A one-way ANCOVA with IQ as the covariate and forward Digit Span as the dependent variable also did not result in a significant difference between groups ($F(1, 103) = .089$, $p = .766$).

Age also correlated significantly with delayed free recall ($r^2 = -.213$, $p < .05$) and delayed cued recall ($r^2 = -.235$, $p < .05$) of presented words. IQ did not. Multivariate analysis of covariance (MANCOVA) employing age as the only relevant covariate revealed no difference between groups on these measures of *long-term memory*. In addition, a one-way ANOVA performed on recognition scores also showed no difference between groups ($F(1, 103) = .010$, $p = .919$).

Table 3. *Group comparison of direct and delayed recall of verbal material*

Task	**AVH** (N= 59) Mean (SD)	**Control** (N= 44) Mean (SD)	**Group comparison**
Direct recall			
•VLGT - free recall	54 (11.16)	55.12 (10.46)	F = .908
•Digit Span (forward)	8.66 (1.52)	9.03 (1.75)	F = .089
Delayed recall			
•VLGT			
• Free recall	11.95 (2.96)	12.08 (2.67)	F = .26,
• Cued recall	12.57 (2.61)	12.59 (2.37)	F = .124
• Recognition	14.86 (1.37)	14.90 (1.20)	F = .010

Note. Mean scores refer to the number of words (VLGT) or number of strings reproduced (Digit Span).
SD = Standard deviation

Although the focus of the present study on verbal memory may be paramount, both groups were also administered a non-verbal, long term memory task. Applying ANCOVA with age as the covariate, free reproduction of the Complex Figure of Rey-Osterrieth was not significantly different between groups, however ($F(1,102) = .212$, $p = .646$). Table 3 shows the results of between-group comparison of memory performance.

Hallucinating participants were expected to attain lower scores for measures of short-term and long/term memory, in comparison to non-hallucinating controls. As shown, groups did not differ significantly with regard to immediate or delayed reproduction of verbal material. The hypothesized decrease in memory functioning of hallucinating participants, as compared to non-hallucinators, was thus not supported by the results.

3.2.3. Lexical access and abstract concept formation

Univariate analysis of covariance (ANCOVA) on a measure of lexical access (retrieval of word definitions) rendered a significant difference between groups on lexical access ($F(1,103)= 4,64$, $p= .034$). Because there was a significant difference in IQ between groups and a significant, linear Pearson correlation (r^2) of .676 with the dependent variable ($p< 0.01$), IQ was employed as the covariate. Table 4 shows the mean scores on these measures for both groups.

Table 4. *Mean scores (and standard deviations) for hallucinating and non-hallucinating participants on the WAIS III vocabulary and similarity tests*

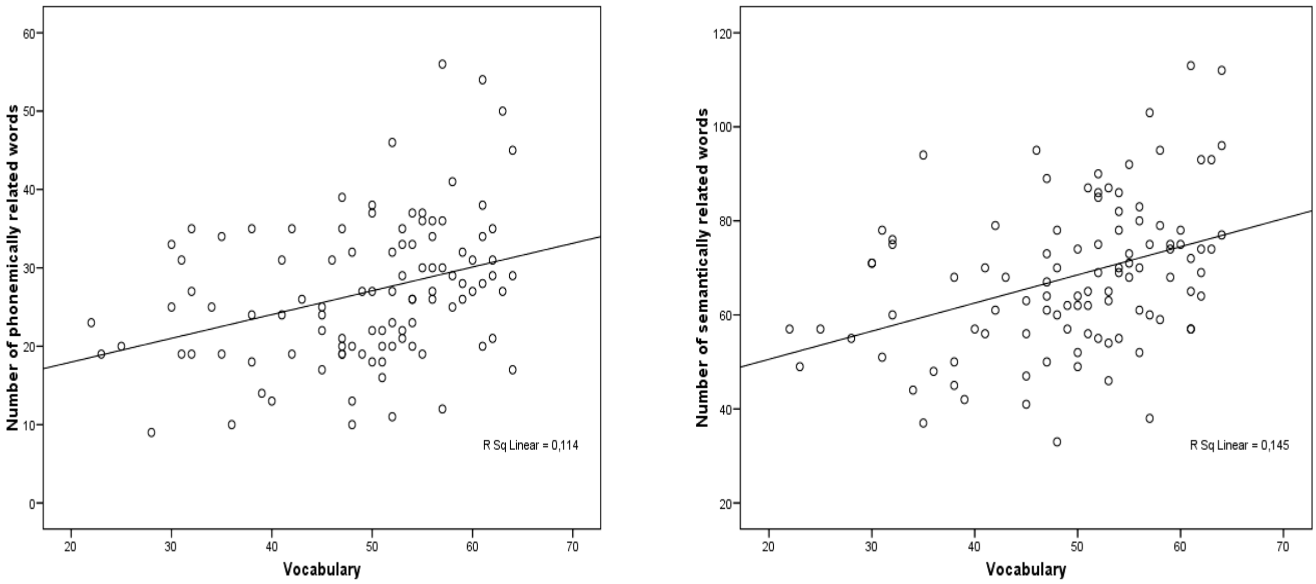
Task	**AVH** (N= 59) Mean (SD)	**Control** (N=44) Mean (SD)	**Group comparison**
•Vocabulary	45 (11.93)	52.56 (7.17)	F = 4.64
•Similarities	25.4 (5.07)	27.6 (3.96)	F = .94

Note. Maximum scores are 66 for Vocabulary and 33 for Similarities

A one-way ANOVA rendered a significant difference in abstract concept formation between groups. Controlling for IQ, however, no longer yielded a significant effect. Again, a significant linear correlation with the dependent variable necessitated the implementation of IQ as the covariate ($r^2 = .462$, $p < .01$). Age did not correlate with vocabulary or abstract concept formation.

3.2.4. Verbal Fluency

The observed significant difference on the WAIS subtests may be indicative of retrieval difficulties regarding lexical processing. As lexical access is vital to adequate verbal fluency performance and impaired lexical access is often seen in schizophrenia, an overall decrease in verbal fluency may be present in hallucinating, at-risk individuals.



(a) (b)

Figure 1a and 1b. *Correlations between vocabulary and phonemic (a) and semantic (b) fluency performance.*

Therefore, Pearson correlations between vocabulary and verbal fluency were calculated. A significant medium correlation between the WAIS III vocabulary test and both phonemic ($r^2 = .338$, $p < .01$) and semantic ($r^2 = .381$, $p < .01$) fluency was observed (figure 1).

Applying multiple linear regression with WAIS III Vocabulary as the predictor variable yielded a significant prediction of the dependent variables phonemic ($t = 3.41$, $p = .01$) and semantic fluency ($t = 4.03$, $p < .01$). As there appears to be a relation between these measures and groups differed with respect to vocabulary, the question remains whether groups also differ with respect to verbal fluency.

In addition, reduced inhibitory control and enhanced associative ability of memory store in hallucinating individuals may also lead to differences between groups in verbal fluency outcome. More specifically, superior categorical fluency in hallucinating individuals relative to controls may exist. Overactivation of lexical items in memory store may contribute to this outcome. Phonemic fluency in hallucinating individuals may be differentially affected resulting in reduced performance compared to healthy controls whereas semantic fluency may be increased in comparison to the control group. Analysis of verbal fluency was carried out applying MANCOVA with IQ as the covariate, because of significant correlations with the dependent measures (phonemic and semantic fluency) and a difference between groups in intellectual ability. However, MANCOVA revealed that neither phonemic fluency ($F(1, 103) = .002$, $p = .965$) nor semantic fluency performance ($F(1, 103) = .006$, $p = .937$) differed between groups.

3.2.5. Domain scores

When lumping together all the crude scores of both executive and memory measures, domain-specific scores can be calculated and compared between groups. Because there were 1.34 times as many controls (59) as hallucinating individuals (44), the summarized domain-scores for the hallucinating group were multiplied by this number in order to obtain a projected number for the hallucinating group as if it were of equal size of the control group. Short-term memory domain pertained to direct recall on the VLGT and direct recall on the forward Digit Span. Long-term memory domain pertained to the delayed recall of words (free and cued recall, recognition) and total semantic fluency output.

Table 5 shows the absolute total number of words or digit strings recalled.

Table 5. *Absolute total scores for both groups on separate cognitive domains*

Domain	**AVH** (N= 59)	**Control** (N=59)
• Short-term memory	3695	3785
• Long-term memory	6235	6431
• Executive function	1576	2277

Note. Memory scores refer to the addition of total number of words or digit strings accurately recalled. Executive scores refer to addition of ordinal scores on the Rule-Shift, number of digit strings recalled backward and number of words pronounced in a phonemic fluency trial.
All corrected for the difference in group sizes.

As shown, the total domain scores did not differ greatly between groups, although the control group consistently attained higher scores. A one-way ANOVA with short-term memory domain as the dependent variable did not result in a significant difference ($F(1, 103) = .452$, p

= .503). Neither did a one-way ANOVA employing long-term memory domain as the dependent variable (F (1, 103) = .842, p = .361). The executive function domain pertained to the Rule-Shift test, backward Digit Span and Phonemic Fluency output. Here, the control group showed higher total score as well although the difference was not significant (F (1, 103) = 1.871, p = .174). With regard to the Stroop task, the hallucinating group needed a projected total of 2388 seconds to complete this task in comparison to the 2059 seconds needed for the control group. Again, the control group did better although not significantly (F (1, 103) = .899, p = .345).

3.3. Clinical ratings

3.3.1. Schizotypal Personality Questionnaire (SPQ)

It was expected that hallucinating individuals, despite their non-clinical status, would show higher scores of schizotypy. Indeed, the hallucinating group displayed significantly higher schizotypal personality traits compared to non-hallucinating controls (F (1, 76) = 57.45, p < .000). Total mean SPQ scores for both groups are depicted in figure 2. As with total GAF-score, stepwise multiple linear regression analysis was performed on total SPQ-score, employing several cognitive variables as predictor variables.

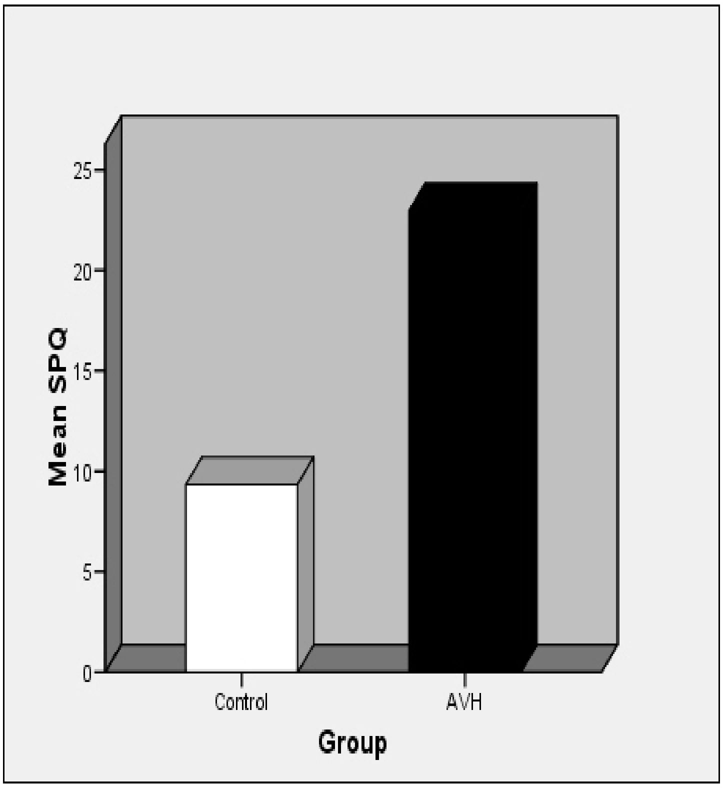


Figure 2. *Mean SPQ-scores for both groups*

This was done in order to assess whether cognition had predictive value of schizotypy. Regression analysis revealed that only backward digit span had a significant prediction of SPQ score (t = 2.67, p = .009). Oddly enough, higher scores on this task predicted higher ratings of schizotypy as there was a positive (but not significant) correlation between these measures. Considering it was expected that decreased executive (and working memory) function would be associated with AVH and is associated with schizophrenia, increased schizotypy should logically also be associated with decreased functioning within these domains.

3.3.2. Global Assessment of Functioning (GAF)

Global daily functioning in psychological, social and professional domains was evaluated with the GAF-scale. The hallucinating group had a mean GAF-score of 82.50 and the control group had a mean of 86.22. Because this was a significant difference ($F(1, 75) = 5.36$, $p = .023$) and decreased cognitive performance may have an effect on psychosocial functioning, multiple linear regression analysis was applied in order to ascertain to what extent cognitive performance would predict GAF score. Regression analysis revealed that of all the 'cognitive' variables only the Vocabulary test ($t = 2.88$, $p = .005$) and the Raven's Advanced Progressive Matrices test ($t = 2.62$, $p = .011$) had significant predictive value.

3.3.3. Frequency

Because increased frequency may be associated with higher schizotypy and might pose a greater risk for clinical dysfunction, frequency of AVH in the 44 included hallucinating participants was analyzed. Perhaps frequency is also correlated with cognitive performance. With 6 of the hallucinators we were unable to establish frequency. Participants from the AVH group were defined as frequent hallucinators when the hallucinations were present at least once a day. Lower frequency of AVH was deemed non-frequent. Frequency was thus employed as a dichotomous, non-parametric variable. Following this procedure, 6 high-frequency and 32 low-frequent hallucinators were identified. Spearman correlations (r_s) between cognition, clinical measures and frequency of AVH were calculated. Table 5 shows the correlations of 7 variables that correlated with frequency. Variables that had correlations between .1 and -.1 were excluded from this table because they were deemed irrelevant.

Table 5a. *4 highest correlating cognitive variables.*

	Frequency (high-frequent versus low frequent)
Vocabulary	**-.16**
Rey-O (delayed)	**-.24**
Rule-Shift	**.124**
Phonemic fluency	**-.13**

Note. None of the above correlations were significant at the .05 or .01 level.

Table 5b. *3 highest correlating non-cognitive variables.*

Non-cognitive variables	
IQ	**-.142**
SPQ	**.211**
GAF	**-.114**

Note. None of the above correlations were significant at the .05 or .01 level.

As shown, the correlations between variables were not significant. Nevertheless, SPQ-score correlates positively with frequency of AVH, which exposes a small trend where hallucinatory experiences may be accompanied by higher schizotypy. Although a one- way ANOVA with SPQ as the dependent variable yielded no difference of significance between high-frequent and low-frequent hallucinators, the high frequency group averaged 6 SPQ-points above low-frequency hallucinators. Perhaps employing larger groups would show greater within-group variability with regards to cognition and schizotypy when frequency of hallucinations is taken into account.

Interestingly, increased frequency of AVH did not lead to a significant difference in daily psychological, social and professional functioning as a one-way ANOVA failed to demonstrate differing GAF-scores between high- and low-frequency hallucinators ($F(1, 31) = .124$, $p = .728$). Although a lack of statistical power is undisputed, this result is ample evidence to indicate increased frequency not to be a burden of interference in daily functioning, which, in turn, is concordant with self-reported lack of nuisance of hallucinatory presence.

However, a small negative correlation was found between these measures which may indicate deteriorated daily functioning to be associated with increased frequency of AVH when larger groups are employed.

With respect to cognition, as small negative correlation ($r_s = -.24$) with delayed recall of the Complex Figure of Rey-Osterrieth was observed. It is interesting, however, that both phonemic fluency and delayed reproduction of the Rey-Osterrieth task correlated negatively with frequency, tasks that are served by executive processing. In others words, there is a tendency showing higher frequency of hallucinatory activity to be related to decreased function in executive domains, although the Rule-Shift task correlated positively with frequency.

4. DISCUSSION

4.1. Summary and Conclusions

The aim of the present study was to assess specific aspects of cognitive function in non-clinical individuals experiencing auditory verbal hallucinations (AVH). Moreover, it was hypothesized that the presence of AVH in this population could be related to specific defective inhibition and internal monitoring (and broader executive dysfunction). Also, subtle memory dysfunction may be present in these individuals as well. At present, cognitive output was employed by subjection to standardized, validated neuropsychological tests targeting specific cognitive domains. Although deficits in monitoring the source of speech and intentional inhibition of intrusive thoughts have been suggested to play a role in the maintenance of AVH, experimental manipulation of these executive sub-domains did not result in the strengthening of this premise as inhibitory and monitoring deficits were not found in the hallucinating group. It was expected that hallucinators would display poorer inhibitory control (and verbal monitoring) in comparison to the control group. The present study failed to substantiate this hypothesis. Although non-clinical hallucinating individuals may be more at risk for clinical and cognitive dysfunction than their non-hallucinating counterparts, isolated hallucinatory presence was not solely indicative of deficiencies in inhibition and monitoring and, in extension, may not be indicative of cerebral pathology in the current group. On the other hand, increased frequency of hallucinations may very well be concomitant with deviant executive processing given the results of the present study show a small relation in support of such a hypothesis. Perhaps truly deviant executive processing predisposes for a more dominant and intrusive presence of AVH than that observed in the present group.

Regarding AVH, memory was also hypothesized to play a role. Although the specific contribution of memory to the aetiology of AVH remains poorly understood, several research groups have suggested auditory source memory to be involved. Inadequate memory of the source of a previous auditory event may contribute to the presence of AVH. Emerging memories of auditory events may be perceived as unfamiliar and subsequently be identified as being unexplainable perceptual phenomena. Essentially, this denotes a reality-monitoring deficit, as exemplified by inaccurate discrimination between reality and imagination. Furthermore, it was hypothesized that lexical associations and representations dominantly arising from memory may predispose for the subjective experience of hearing unexplainable voices. As a result of the above stated, the experimental group was - in comparison to healthy controls - expected to show a decrement in recall of verbally presented material. The aforementioned problems with auditory source memory and interference due to current associations and representations emerging from memory storage components were hypothesized to be particularly detrimental to satisfactory recall of verbal material. However, inaccurate immediate and delayed recall was not found in the hallucinating group. Perhaps true, more widespread psychopathology needs to be present to cause significant memory dysfunction, as often seen in schizophrenia (Zakzanis et al., 1999; Heinrichs and Zakzanis, 1998). Alternatively, the reported intactness of monitoring and inhibitory mechanisms could have prevented intrusion of vivid, self-generated memory output and thereby minimizing interference when recalling verbal material. Furthermore, auditory source memory may simply not have been degraded in hallucinating participants and thus not have interfered with recollection of list items nor be responsible for the presence of AVH.

A significant difference between groups did arise, however, in abstract concept formation and lexical access. This is in accordance with theories on impaired lexical access in schizophrenia, as reviewed by Covington et al. (2005). On the other hand, truly deficient lexical access should also manifest itself in poorer verbal fluency performance (Allen et al., 1993), as access to the lexicon is clearly vital to successful task completion. Results from the present study failed to expose such a decrease, however, and can therefore not fully support the notion of clinically impaired lexical access in people experiencing isolated AVH. Nevertheless, the minor deficit in lexical access may be viewed as a 'traitlike' marker for schizophrenia in individuals experiencing isolated AVH.

Regarding verbal fluency, there was no differentiation in verbal fluency performance between groups. Both groups scored on equal levels. In the hallucinating group, phonemic fluency was not differentially decreased in comparison to semantic fluency. Because executive processing was not impaired in the hallucinating group, absence of defective phonemic fluency is not surprising. Semantic fluency output was also not significantly different between groups; increased fluency of this sort was partially expected with the hallucinating group as a vivid, enhanced associative memory capacity may have been beneficial to this outcome. Perhaps the hallucinating participants simply did not possess such a capacity, given that recall from memory was not hindered, as mentioned earlier.

In the hallucinating group lower IQ's were observed, compared to non-hallucinating controls. However, this was not of true clinical significance as their mean IQ's were at the population mean and only differed a mere 7 points with the average IQ of the control group. Nonetheless, because there was no significant difference in years of education between groups, this decrease in IQ is interesting. Therefore, the reported level of education may in fact have been different between groups. Some of the hallucinating participants received training at unconventional, sometimes unsubstantiated, higher-educational institutes, majoring in more 'magical' and out of the ordinary subjects which were, they claim, on equal levels with the more mainstream curriculums available. However, this was not taken into account when recording the number of years of education they had received. Therefore, level of education may very well have been of a less challenging quality with these individuals. A different interpretation is that intact cognition as observed in the hallucinating group may have prevented lesser functioning and served as a protective quality. The above stated aside, significantly lower IQ-scores in schizophrenic populations have been consistently reported (Hijman et al., 2003). Perhaps lower intellectual ability can be viewed as being associated with psychotic symptomatology and 'comes with the territory'. Furthermore, it may very well be that intellectual ability in hallucinators may have decreased over the course of their lives. Perhaps positive symptomatology has a negative effect on the stability of IQ whereas IQ in healthy controls may not have been instable. Unfortunately, this hypothesis can not be substantiated by empirical findings as IQ earlier in life was unknown, rendering longitudinal analysis of intellectual ability impossible.

Regarding clinical assessment, there was a difference in psychosocial and professional daily functioning between groups, as hypothesized. Hallucinators attained significantly lower scores on the GAF-scale, despite these being well within healthy range. Cognitively, performance on the Vocabulary task and the Raven task had predictive value with respect to GAF whereas other cognitive variables did not. However, when truly significant cognitive dysfunction is present in hallucinating individuals, its predictive value of GAF may increase as adequate cognitive ability obviously contributes to increased levels of daily functioning in social and professional domains. Additionally, the hallucinating group showed higher scores of schizotypy than the control group, which was also expected. Linear regression analysis revealed a significant prediction of SPQ-score with backward digit span as the predictor variable. This is a particularly interesting finding given that there was a positive correlation between variables. Longer digit span is therefore associated with higher schizotypy.

Lastly, increased frequency of AVH was negatively correlated with global functioning and positively correlated with schizotypy, which indicates clinical dysfunction to be associated with more frequent hallucinatory activity. Clinically, hallucinating individuals may therefore be on a steeper precipice than their non-hallucinating counterparts when defining psychosis in terms of being the extreme of a gliding scale or continuum.

The fact that significant cognitive impairment regarding executive function and memory was absent in the hallucinating group, could be viewed as confirmation of the reported healthiness of these participants, at least with respect to cognition. The singular presence of AVH did not relate to deviant cognitive function whereas additional clinical pathology may be held responsible for the loss of cognitive adequacy observed in schizophrenia or other disorders of perception. In general psychiatry, cerebral dysfunction in fronto-subcortical networks are often at the core of deviant working memory function, central executive function and related problems with supervisory attentional systems (e.g. Eling & de Haan, 2004). In light of the present findings, isolated hallucinatory experiences may therefore not be wholly indicative of cerebral pathology and therefore probably not synonymous with cognitive disturbance in executive control and memory function. Alternatively, when there is a genetic predisposition for schizophrenia and psychotic symptomatology in the hallucinating group, the present findings may be proof of the protective nature of intact cognition in individuals with genetic vulnerability for psychosis. On the other hand, these results do provide reference to the fragility of mental health as hallucinatory experiences tend to be more associated with clinical illness than no illness, given that they are considered a hallmark symptom of schizophrenia (Hijman et al., 2003; Sadock & Sadock, 2003, for example). It seems to be a small step from satisfactory cognitive ability to significant impairment, often seen in the disease.

Although GAF-scores for the hallucinating group were well within healthy range, there was a difference compared to non-hallucinating controls. Hallucinators also showed higher schizotypy. These findings are in support of the notion that a continuum of psychotic psychopathology seems to exist whereby hallucinatory individuals may be defined as a group at-risk for psychosis. Despite the fact that the present study was unable to demonstrate AVH to be singularly predisposing for clinical or cognitive dysfunction, the presence of hallucinatory activity may serve as a reference point to this outcome.

4.2. Limitations and Recommendations

A limitation of the present study was that it did not derive results from neuroimaging procedures. Decreased language lateralization in schizophrenia might account for the aberrant cognition often present in the disease. Further attempts to unravel cognitive performance in relation to AVH may seek to include healthy participants with a known decrease in lateralization for language as they might be more prone to psychosis and schizophrenia than those who do not show such a decrement. In addition, the same can be done with less lateralized, hallucinating clinical patients from differing diagnostic populations. A correlation between language lateralization and cognitive dysfunction in hallucinating individuals may exist, independent of clinical symptoms. Perhaps hypothesized impairment could then be observed in both memory and executive function.

Another limitation of the present study is that there was a large inter-individual variability in both the frequency of perceived voices as well as the total number of voices present. Some of the hallucinating participants only heard one voice a couple of times a month whereas others heard several voices at least once a day. This within-group variability was not handled as an influential variable prior to inclusion and therefore a distinction was not made. Although modest analyses of frequency with respect to cognition and clinical dimensions were performed anyway, a lack of statistical power limited the conclusions that could be drawn from these. Follow-up studies exploring cognitive functioning in hallucinating individuals could benefit greatly from the inclusion of large groups of high-frequent voice hearers. It could very well be that increased frequency of hallucinations indicates higher risk for clinical dysfunction and could therefore signify more direct effects of aberrant cognition. An additional note is that valence of the reported voices plays a role when assessing clinical and cognitive functioning. In the present study, none of the hallucinating participants indicated the presence of AVH to be a burden of interference in their lives. Additionally, less than 5% of them reported derogatory content of their hallucinations. Schizophrenic patients, however, often report hearing threatening, demanding and authoritative voices (Aleman et al., 2003). Negative valence may therefore be associated with more significant psychopathology. A study conducted at our department showed decreased Broca lateralization in participants hearing negatively valenced voices (Sommer et al., 2008, submitted). Perhaps when employing cognitive performance with individuals solely experiencing negatively valenced voices and concomitant decreased Broca lateralization, if present, significant cognitive decreases may be found. However, it is foreseeable that this may be accompanied by graver clinical dysfunction, undermining the ambition to assess hallucinatory activity independent of psychopathology.

A final notion is that it might be that subtle differences in cognitive function do exist but require larger groups to be detected. The groups in the present study may have been too small to yield significant results regarding the effects sought. Further study into the cognitive aspects of AVH may therefore be employed with larger groups.

Given the high incidence and negative impact of hallucinatory presence in both the general population as well as clinical populations, the study of AVH is a relevant endeavour with implications for both theoretical and practical purposes. Further investigation into the functional, neuroanatomical, cognitive and emotional features of hallucinatory phenomena needs to be undertaken to more fully understand the mechanisms involved, in order to resolve the negative implications of their presence.

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