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The influence of semantic top-down processing in auditory verbal hallucinations

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ABSTRACT

Background: Auditory verbal hallucinations (AVH) are one of the most prominent symptoms of schizophrenia but have also been reported in the general population. Several cognitive models have tried to elucidate the mechanism behind auditory verbal hallucinations, among which a top-down model. According to this model, perception is biased towards top-down information (e.g., expectations), reducing the influence of bottom-up information coming from the sense organs. This bias predisposes to false perceptions, i.e., hallucinations.
Methods: The current study investigated this hypothesis in non-psychotic individuals with frequent AVH, psychotic patients with AVH and healthy control subjects by applying a semantic top-down task. In this task, top-down processes are manipulated through the semantic context of a sentence. In addition, the association between hallucination proneness and semantic top-down errors was investigated.
Results: Non-psychotic individuals with AVH made significantly more top-down errors compared to healthy controls, while overall accuracy was similar. The number of top-down errors, corrected for overall accuracy, in the patient group was in between those of the other two groups and did not differ significantly from either the non-psychotic individuals with AVH or the healthy controls. The severity of hallucination proneness correlated with the number of top-down errors.
Discussion: These findings confirm that non-psychotic individuals with AVH are stronger influenced by top-down processing (i.e., perceptual expectations) than healthy controls. In contrast, our data suggest that in psychotic patients semantic expectations do not play a role in the etiology of AVH. This finding may point towards different cognitive mechanisms for pathological and nonpathological hallucinations.

1. Introduction

Auditory verbal hallucinations (AVH) are among the most prominent symptoms of schizophrenia but have also been reported in other psychiatric disorders as well as in a significant minority of the general population (for reviews, see Beavan et al., 2011; Aleman and Larøi, 2008). AVH have been suggested to lie on a continuum (Verdoux and van Os, 2002), ranging from non-psychotic and otherwise healthy individuals with AVH on one end to psychotic patients on the other. On the phenomenological level, some differences between AVH in these groups were reported, mostly related to the emotional valence and associated distress (Daalman et al., 2011a), but there is also a substantial overlap in AVH on both ends of this continuum: loudness, number of voices, personification and location of voices were rather similar.

On the neurobiological level, brain activation during AVH measured with fMRI was found to be similar in non-psychotic and psychotic individuals (Diederen et al., 2011). However, increased striatal dopamine, known to play a key role in AVH in psychosis, was absent in non-psychotic individuals with frequent AVH (Howes et al., 2012). It so far remains unclear if similar or different processes underlie hallucinations at either ends of the continuum.

Different cognitive models have tried to explain the mechanism(s) behind AVH. A possible mechanism accounting for the vulnerability to hallucinate is increased reliance on top-down processing. In normal perception, bottom-up information coming from the senses is combined with top-down information that regards implicit prior knowledge based on previously encountered situations, leading to perceptual expectations (Behrendt, 1998; Meyer, 2011). The balance between bottom-up and top-down processing can be distorted in such a way, that it is influenced to a higher degree by top-down factors, which may trigger perceptual experiences in the absence of corresponding external stimulation, i.e., hallucinations (Behrendt, 1998; Grossberg, 2000).

The aim of this study was to investigate whether both psychotic and non-psychotic individuals with AVH indeed make more top-down errors, compared to healthy controls. A previous study revealed an increased number of top-down errors in university students selected for

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Table 1
Demographic characteristics of the participants: psychotic patients, non-psychotic individuals with AVH and healthy control subjects.

Group	Patients with AVH	Non-psychotic individuals with AVH	Healthy controls	Difference (significance)
n	40	40	40	
Male	21	17	18	$\chi^2=0.871$; $df=2$; $p=0.647$
(%)	(52.5%)	(40%)	(45%)	
Mean age	37.60	47.63	45	$F=6.77$; $df=2$; $p<0.01$
(SD)	(12.17)	(10.48)	(14.87)	
Total years of education	13.15	13.75	13.60	$\chi^2=1.677$; $df=2$; $p=0.432$
(SD)	(2.60)	(2.12)	(2.37)	

hallucination-proneness compared to students without a proneness towards hallucination (Vercammen and Aleman, 2010). That is, subjects with higher levels of hallucination proneness were more likely to report hearing a word that fitted the sentence context, when it was not actually presented. The present study investigated whether such a finding would extend to a sample of people from the general population who experience AVH and to patients with schizophrenia and AVH. Investigating this effect in non-psychotic individuals with AVH as well as in patients with AVH would provide further evidence for the top-down model in AVH. To this end, three groups of participants were included: 40 healthy control subjects, 40 non-psychotic individuals with AVH and 40 psychotic patients with AVH. Patients are hypothesized to make more top-down errors than non-psychotic individuals with AVH, since they experience AVH more frequently (Daalman et al., 2011a). In addition, the Launay-Slade Hallucination Scale (LSHS; Larøi et al., 2004) was used to measure whether hallucination proneness would be associated with more top-down errors in the non-psychotic groups. For the patient group, the association between number of top-down errors and hallucinatory behavior (item P3 of the Positive and Negative Syndrome Scale; PANSS, Kay et al., 1987) was determined.

2. Methods

2.1. Participants

A total of 120 participants were included: 40 psychotic patients with AVH, 40 non-psychotic individuals with AVH and 40 non-hallucinating control subjects. The healthy control subjects and non-psychotic individuals with AVH did not meet criteria for a DSM-IV diagnosis, as assessed by an independent psychiatrist with the Comprehensive Assessment of Symptoms and History (CASH) interview (Andreasen et al., 1992) and the Structured Clinical Interview for Personality Disorder (SCID-II) (First et al., 1995). Depressive disorder in complete remission was not an exclusionary criterion. Additional exclusion criteria for all groups were alcohol abuse and drug abuse. For the non-psychotic individuals and psychotic patients with AVH, the minimum frequency to experience AVH was once a month and the minimum duration since onset of AVH was 1 year.

Both the non-psychotic individuals with AVH and the healthy controls were recruited with the help of a Dutch website called 'explore your mind' (www.verkenuwgeest.nl). An extended description of the recruitment and selection procedure is provided in prior studies by our group (Diederen et al., 2010; Sommer et al., 2010; van Lutterveld et al., 2010; Daalman et al., 2011a; de Weijer et al., 2011; Diederen et al., 2011).

The outpatients with a psychotic disorder were recruited from the University Medical Centre Utrecht. These patients visited our clinic for regular treatment for psychosis. In this group, clinical diagnoses were confirmed by an independent psychiatrist using the CASH interview. Twenty-five patients (62.5%) were diagnosed with paranoid schizophrenia, 6 (15%) with schizoaffective disorder, and 9 (22.5%) with psychosis not otherwise specified. Demographic and clinical details are shown in Table 1; the three groups were matched for gender and total years of education but differed on age. For a detailed overview of medication use in the three groups, see Supplementary Table 1.

The study was approved by the Humans Ethics Committee of the University Medical Center Utrecht. After complete description of the study to the subjects, written informed consent was obtained.

2.2. Measurements

2.2.1. Experimental tasks

2.2.1.1. Hearing task. To ensure proper hearing, a test was developed in which tones of various frequencies were presented (300 Hz, 500 Hz, 700 Hz, 900 Hz and 1100 Hz) at 65 dB. Participants were asked to press a response button when a tone was presented. After completing the test, the results were immediately calculated before proceeding to the semantic task. In case of an accuracy score below 75%, the experiment was aborted, since the performance on the top-down task would be influenced too much by a hearing deficiency. No participants had to be excluded because of this criterion.

2.2.1.2. Semantic expectation task. The semantic expectation (top-down processing) task was previously used by Vercammen and Aleman (2010). The task contained 150 Dutch sentences, in which the last word was masked by noise ($N=100$) or the last word was replaced by noise ($N=50$). Of the 100 masked stimuli, 50 ended with a word which was to be expected given the context of the sentence (e.g., The sailor sells his *boat*), whereas the other 50 of the sentences ended in an unpredictable manner (e.g., The sailor sells his *chair*). The participants were seated in front of a computer and listened to the task through headphones. After hearing a sentence, participants were asked to indicate with a button response whether they heard a word during the noise, and if so, to type in which word they had heard. In case of doubt, the participants were given the option of stating he or she had heard a word but that they were unsure about the answer. This way, participants were discouraged to guess and instead, only to report words they actually perceived.

Consequently five types of responses were possible: correct; missing (hearing only noise when in fact a word was presented); unsure (hearing a word but not knowing which); top-down (hearing a word that was predictable when in fact an unpredictable word or noise was presented); confabulation (hearing an incorrect word that was not predicted).

Responses on the task were all scored by two raters, both blind for condition/type of participant. To investigate whether patients would give more idiosyncratic responses (that did not fit in the sentence but were also not expected and would thus not count as a top-down error but could be due nevertheless to aberrant top-down processing) responses were also rated on "strangeness" on a 5-point scale (see supplementary material).

2.2.2. Questionnaires

2.2.2.1. Hallucination proneness. Participants filled out a modified version of the Launay-Slade Hallucination Scale (LSHS; Larøi et al., 2004), a 16-item self-report questionnaire designed to quantify the tendency to hallucinate in healthy individuals. It has been proven to be reliable in both clinical and nonclinical populations (Bentall and Slade, 1984; Levitan et al., 1995; Larøi et al., 2004). Two patients did not fill out this questionnaire.

For the patient group, hallucinatory behavior was measured with item P3 (amount of hallucinatory behavior) of the Positive and Negative Syndrome Scale (PANSS; Kay et al., 1987). Although the PANSS assesses hallucinations in all modalities, the *auditory* hallucinations in the patient group were that frequent and severe that the score on this item was mainly influenced by these AVH (leading to a minimum score of 4).

2.2.2.2. Auditory verbal hallucinations. To describe phenomenological characteristics of AVH in the psychotic patients and the non-psychotic individuals, the PSYRATS Auditory Hallucination Rating Scale (AHRS) (Haddock et al., 1999) was administered. This questionnaire consists of 11 items that describe the AVH with the help of a Likert scale (0–4). For the use of this questionnaire in non-psychotic individuals, the range of the frequency scale is extended to 0–6 (also covering options 'at least once every month' and 'at least once every 3 months' since AVH are experienced less often than once a week (the original minimum score of this item). This questionnaire was administered by trained psychologists. Due to high correlations between several of these items, two new variables were computed: The variable 'emotional valence of content' was operationalized as the sum of three items from the AHRS: 'amount of negative content of voices', 'degree of negative content' and 'amount of distress'; i.e., an ordinal variable expressing overall burden of voices with negative content. The variable 'total distress' was operationalized as the sum of two items from the AHRS: 'intensity of distress', and 'disruption to life caused by voices'. As a result, the following items were used in this study: frequency, duration, location, loudness, beliefs re-origin of voices, controllability, emotional valence of content and total distress.

2.3. Statistical analyses

The primary analysis concerned the question whether the three groups differ on the number of top-down errors made in the semantic task, while correcting for overall accuracy. An ANCOVA was performed, with the number of correct answers as a covariate to ensure that overall test performance has not biased the results. Age was associated with group membership and was therefore also entered as a covariate in this analysis. Pairwise comparisons, Bonferroni corrected for multiple testing, were used to explore between-group differences.

Furthermore, to test whether the score on the Launay-Slade Hallucination Scale is positively correlated with the number of top-down errors in the non-psychotic groups, a Spearman's rank or Pearson's correlation coefficient was calculated, depending on the distribution of the variables. In the psychotic patients, we calculated a Spearman's rank or Pearson's correlation coefficient for the number of top-down errors and the score on item P3 (amount of hallucinatory behavior) of the PANSS, depending on the distribution of the variables.

All data were analyzed with the Statistical package for the Social Sciences (SPSS, version 15.0).

3. Results

3.1. Description of AVH characteristics

Table 2 illustrates the characteristics of the voices in both AVH groups based on the PSYRATS items. Mean scores are provided as well as a description of its closest anchor in the questionnaire.

3.2. Top-down errors corrected for overall accuracy

The total of top-down errors showed a significant main effect for group, after correcting for overall task accuracy (correct answers) and age ($F_{2,117}=3.549$, $P=0.032$). Mean number of top-down errors in the healthy controls was 10.55 (SD 8.29), in the non-psychotic individuals with AVH 16.75 (SD 12.13) and in the psychotic patients with AVH 12.68 (SD 8.70). Pairwise comparisons (significant at 0.05 level, Bonferroni adjusted) showed that the non-psychotic individuals with AVH differed significantly from the healthy controls ($F_{1,78}=5.700$, $P<0.027$). No difference was observed between non-psychotic individuals with AVH and psychotic patients ($F_{1,78}=3.386$, $P=0.448$), and between psychotic patients and healthy controls ($F_{1,78}=2.314$, $P=0.944$).

For an overview of the errors that were made during the task in the three groups, means and standard deviations see Supplementary Table 2. Also described in the supplementary results is a secondary analysis concerning idiosyncratic answers that were given in the three groups, on which the groups did not differ.

3.3. Hallucination proneness and top-down errors in nonpsychotic groups

The means of the total score on the Launay Slade Hallucination scale per group are healthy controls 6.03 (SD 5.15), non-psychotic individuals with AVH 40.43 (SD 12.15) and psychotic patients with AVH 36.08 (SD 12.71). However, as this questionnaire was designed to screen for hallucination proneness in healthy individuals, patients' scores were obtained purely for descriptive purposes and not entered in the analysis. The number of top-down errors significantly correlated with the total score on the LSHS in the non-psychotic individuals with AVH and healthy controls ($r=0.349$, $P<0.01$).

Table 2
Characteristics of AVH in 40 healthy individuals with AVH and 40 patients with psychosis.

	Patients Mean (SD)	Description of closest anchor	Non-psychotic individuals with AVH Mean (SD)	Description of closest anchor
Frequency (0–6)	5.15 (0.89)	Voices at least once an hour	3.65 (0.98)	Voices at least once a day
Duration (0–4)	2.73 (1.20)	Voices last for at least an hour	1.53 (0.68)	Voices last for several minutes
Location (0–4)	2.08 (1.00)	Outside head, close to ears and inside head	2.35 (1.27)	Outside head, close to ears and inside head
Loudness (0–4)	1.95 (0.85)	Same loudness as own voice	1.95 (0.50)	Same loudness as own voice
Beliefs origin (0–4)	2.35 (1.12)	<50% conviction that voices have external cause	3.03 (1.10)	≥50% conviction that voices have external cause
Controllability (0–4)	3.13 (1.02)	Occasional control over voices	2.03 (1.63)	Half of the time control over voices
Emotional Valence of content (0–12)	8.88 (2.64)	Most of the voices are negative and unpleasant	1.15 (2.28)	Hardly any voices are negative or unpleasant
Total distress (0–8)	4.78 (1.70)	Voices cause considerable distress	0.43 (1.22)	Voices cause no distress
Age of onset	19.83 years old (11.05)		14.40 years old (15.04)	

3.4. Hallucinatory behavior and top-down errors in psychotic patients

The number of top-down errors did not correlate significantly with the amount of hallucinatory behavior (item P3 of the PANSS) in patients ($r = 0.027$, $P = 0.866$).

4. Discussion

The aim of this study was to compare the influence of top-down processing between hallucinating individuals with and without a clinical psychotic disorder and healthy controls. Non-psychotic individuals with auditory verbal hallucinations (AVH) made significantly more top-down errors than healthy controls. Psychotic patients obtained intermediate scores which were not significantly different from either group. The total score on the LSHS questionnaire in the two non-psychotic groups was associated with the number of top-down errors that are made: the higher the hallucinations proneness, the more top-down errors were made. When investigating the association between top-down errors and the severity of hallucinatory behavior in psychotic patients, no significant association was found.

Our results corroborate and extend the findings reported by Vercammen and Aleman (2010), who observed more top-down errors using the same semantic expectation task in undergraduates with high scores on the LSHS compared to undergraduates with low scores. Speculatively, one could argue that attentional top-down processes only play a pivotal role in the generation of AVH in the non-psychotic individuals and not in the patient group. This may suggest different cognitive mechanisms for pathological and nonpathological hallucinations and may thus point to a more categorical view on hallucinations. Indeed, whereas researchers are increasingly using a continuum to describe psychotic phenomena such as AVH, David (2010) recently advocated a critical view on the use of such a continuum. Although the hypothesis of a continuum in hallucinatory experiences across the general population has received strong empirical support, it remains unclear whether it can acknowledge the pathological or disruptive nature of hallucinations in a clinical context. David suggests that we should define beforehand what results would imply continuity and discontinuity. In addition, Luhrmann (2011) describes three fundamentally different patterns (categories) within individuals experiencing AVH. He states that AVH in psychosis are quite universal and therefore least influenced by culture, other types of AVH are more shaped by expectations and culture. He suggests that 'cultural ideas and practices can affect mental experience so deeply that they lead to override of ordinary sense perception'. In other words, perhaps AVH can be viewed in the light of a hierarchical model: a biological basis determines if hallucinations can arise, next cognitive factors determine whether this experience is perceived as a hallucination. This raises the question whether both types of AVH can indeed be viewed as similar phenomena. Although substantial overlap is found on clinical and neuroimaging measures, the etiology of AVH is complex, making it likely that different cognitive processes play parts in this phenomenon. A different age of onset in both groups (Daalman et al., 2011a) supports this hypothesis. In addition, the absence of increased striatal dopamine turn-over in non-psychotic individuals with AVH (Howes et al., 2012) confirms the idea of different underlying mechanisms. While increased striatal dopamine turn-over may be an important biological factor in hallucinations in psychosis (Kapur, 2003) cognitive factors, such as strong expectations, may be the main contributing factor in non-psychotic individuals with AVH.

Indeed, Vercammen and Aleman (2010) also found that increased reliance on top-down processes is present in individuals with a high degree of hallucination proneness. However, other studies suggested that attentional top-down processing may be stronger in hallucinating *patients* compared to non-hallucinating patients (Schneider and Wilson, 1983; Aleman et al., 2003; Vercammen et al., 2008). However, the experimental tasks used in these studies were not based on semantic expectations, but on signal detection. One could argue that patients maybe did have stronger top-down processing in our task, but that they gave idiosyncratic responses due to aberrant semantic processing. For example, Hoffman et al. (1999) showed that patients with AVH confabulate numerous words after being presented with multiple speech streams ("speaker babble") that have been intermingled and are hence unintelligible. We could not confirm this in the present semantic expectation task, however, as patients did not respond with "stranger" words than the other groups.

The current finding of increased top-down processing in non-psychotic individuals with AVH is consistent with studies suggesting enhanced perceptual attention in hallucination-prone subjects. For example, Van Lutterveld et al. (2010) found that non-psychotic individuals with AVH score higher than healthy controls on measures of effortful attention, which can also be viewed as a measure of top-down processing In addition, using fMRI Lewis-Hanna et al. (2011), found enhanced cortical effects of auditory stimulation and auditory attention in healthy individuals prone to auditory hallucinations during partial wakefulness. Finally, Daalman et al. (2011b) reported that non-psychotic individuals with AVH showed aberrant inhibition compared to healthy controls as measured with standard cognitive tasks, and too much top-down processing can be viewed as having insufficient inhibition.

4.1. Limitations

The absence of increased top-down processing in patients may be associated with specific task characteristics. The stimuli applied in the present study were neutral sentences, with no distinct positive or negative emotional valence. Psychotic patients hear predominantly negative voices whereas non-psychotic individuals with AVH hear primarily positive or neutral voices (Daalman et al., 2011a). Possibly, stimulus material with a more negative content could have led to a higher number of top-down errors in the patient group. Indeed, Morrison and Haddock (1997) found that emotional valence of a source monitoring task affects external attributions in hallucinating and not in non-hallucinating control groups. Another task-related explanation for the lack of deviant top-down processing in patients is that the top-down task used in this study might be too difficult for the psychotic population, although total years of education is *not* significantly different in the three groups. Possibly, cognitive decline that is associated with psychosis might have influenced task performance. However, the analysis included overall accuracy (number of correct responses) as a covariate. In addition, medication might have influenced task-performance. Most patients and only a few non-psychotic individuals and controls used psychoactive medication; as such the effects might be most prominent in the patient-group. One could argue that this might have normalized their amount of top-down processing and explain why no significant difference in top-down errors was found between the psychotic patients and healthy control subjects. If this were the case, hallucinations in both psychotic and non-psychotic individuals could be explained by similar cognitive mechanisms. However, if medication would have influenced the attentional top-down processes it would also have affected the hallucinations, yet all psychotic patients still experienced frequent AVH. For future research, we recommend including a group of psychotic patients without AVH. Comparing performance of this group with the AVH group could more specifically clarify the role of semantic top-down processing in the experience of AVH.

In conclusion, the current results suggest that top-down processing may be associated with the experience of AVH in non-psychotic individuals, but it does not seem an important factor in psychotic patients with hallucinations. Other cognitive and neurobiological processes may underlie AVH in psychotic patients. We should therefore more critically investigate the use of the continuum hypothesis in psychosis.

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Contributors

KD contributed to the design of the study, collected the subjects, organized the acquisition of data, analyzed the data and wrote the manuscript. SV contributed to the design of the study, contributed to acquisition and organization of the data, provided comments on the manuscript and revised it for publication. EMD contributed to the statistic analyses the data and provided comments on the manuscript and revised it for publication. AA designed the study, contributed to the interpretation of the data, provided comments on the manuscript and revised it for publication. IECS contributed to the interpretation of the data, provided comments on the manuscript and revised it for publication. All authors contributed to and have approved the final manuscript.

Conflict of interests

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.schres.2012.06.005.

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