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Short Communication

A linguistic comparison between auditory verbal hallucinations in patients with a psychotic disorder and in nonpsychotic individuals: Not just what the voices say, but how they say it

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ABSTRACT

Background: Auditory verbal hallucinations (AVH) in psychotic patients are associated with activation of right hemisphere language areas, although this hemisphere is non-dominant in most people. Language generated in the right hemisphere can be observed in aphasia patients with left hemisphere damage. It is called "automatic speech", characterized by low syntactic complexity and negative emotional valence. AVH in nonpsychotic individuals, by contrast, predominantly have a neutral or positive emotional content and may be less dependent on right hemisphere activity. We hypothesize that right hemisphere language characteristics can be observed in the language of AVH, differentiating psychotic from nonpsychotic individuals.

Method: 17 patients with a psychotic disorder and 19 nonpsychotic individuals were instructed to repeat their AVH verbatim directly upon hearing them. Responses were recorded, transcribed and analyzed for total words, mean length of utterance, proportion of grammatical utterances, proportion of negations, literal and thematic perseverations, abuses, type-token ratio, embeddings, verb complexity, noun-verb ratio, and open-closed class ratio.

Results: Linguistic features of AVH overall differed between groups $F(13,24) = 3.920$, $p = 0.002$; Pillai's Trace 0.680. AVH of psychotic patients compared with AVH of nonpsychotic individuals had a shorter mean length of utterance, lower verb complexity, and more verbal abuses and perseverations (all $p < 0.05$). Other features were similar between groups.

Conclusion: AVH of psychotic patients showed lower syntactic complexity and higher levels of repetition and abuses than AVH of nonpsychotic individuals. These differences are in line with a stronger involvement of the right hemisphere in the origination of AVH in patients than in nonpsychotic voice hearers.

1. Introduction

Auditory verbal hallucinations (AVH), hearing voices, is a cardinal feature of psychosis (David, 1999). AVH are the most common positive symptom in schizophrenia, with a one-year prevalence between 64 and 83 percent (Bauer et al., 2011; Thomas et al., 2007). They also occur in individuals who do not experience any psychiatric or neurological disorder, with reported prevalences ranging from 0.6% to 84% (median: 13.2%), depending on the method of investigation (Johns et al., 2014). AVH in nonpsychotic and psychotic individuals are similar in terms of loudness, personification and number of voices heard, but the emotional content differs with a preponderance towards negative valence content in patients (Daalman et al., 2011).

To gain insight into the pathophysiology of AVH, the language component of this symptom is a rich source of information. Both hemispheres are capable of producing language, but in most people language production largely stems from left hemisphere activation (Kuperberg et al., 2000). This is most likely the result of active inhibition of right hemisphere language areas (Karbe, Herholz, Halber, & Heiss, 1998). Reduced language lateralization may be a result of decreased inhibition and is observed in patients with schizophrenia and is associated with AVH (Sommer et al., 2008). In these patients, increased activation in language-related areas

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of the right hemisphere may be related to the generation of AVH. Neuroimaging studies have established that neural activation is lateralized to the right hemisphere during AVH in psychotic patients. This was first reported by Woodruff and colleagues, who found activity in the right inferior frontal and temporoparietal areas in a patient with schizophrenia who experienced hallucinations during functional magnetic resonance imaging (fMRI) (Woodruff et al., 1995). This finding was replicated in a large sample by our group (Sommer et al., 2008). It has been suggested that activation of right hemisphere language areas is specific to psychotic AVH, whereas right hemisphere language areas may be less involved during AVH in non-psychotic individuals (Diederen, De Weijer, et al., 2010). However, a direct comparison of activation during AVH between 21 people with a psychotic disorder and 21 nonpsychotic individuals, showed no significant differences (Diederen et al., 2011). This does not preclude the presence of more subtle differences which could be detectable in fairly large samples.

Contribution of right hemisphere language areas in patients with schizophrenia may be reflected in the form and content of their AVH. Right hemisphere language is distinctive, as the right hemisphere is involved in some semantic processing, but not in syntactic processing (Menenti, Segaert, & Hagoort, 2012). The left hemisphere dominates syntactic functions, and, to a lesser extent, sentence-level and word-level semantic processing (Friederici, 2011; Grodzinsky, 2000). In split-brain patients, the right hemisphere was only capable of recognizing object names, but incapable of processing tenses, singularity versus plurality, or the relations between subject, verb and object (Gazzaniga & Hillyard, 1971). Likewise, patients with left hemisphere stroke were capable of semantics but were impaired in their syntactic functions (Tyler et al., 2011; Wright, Stamatakis, & Tyler, 2012). In aphasic patients with left hemisphere lesions, familiar phrases or automatic speech are relatively preserved (Van Lancker & Kempler, 1987) and thematic perseverations are common (Sandson & Albert, 1984). These findings explain why speech produced in right hemisphere language areas is characterized by low linguistic complexity and high levels of repetition (Code, 1982; Kuperberg et al., 2000).

In addition, right hemispheric activation is associated with swearing and threats (Copolov et al., 2003; Pell, 1999). In a previous study we found that the level of right hemisphere activation while experiencing AVH was associated with the negative emotional valence of the hallucinations (Sommer et al., 2008). This may imply that the predominant activation of right hemisphere language areas during AVH in psychotic patients underlies the distinct negative emotional content of the AVH. Furthermore, it has been hypothesized that a lack of synchronization between right hemisphere language areas leads to patients erroneously interpretating this emotional speech activity as coming from an external source (Curcic-Blake et al., 2013). By contrast, in nonpsychotic individuals, AVH rarely have a negative emotional content, being mostly neutral or positive (Daalman et al., 2011).

Since the right hemisphere areas are suggested to play an important role in producing AVH in psychotic patients (Jardri, Pouchet, Pins, & Thomas, 2011), the syntactic characteristics of the AVH are expected to be limited. The linguistic features may therefore differ from AVH in nonpsychotic persons. The aim of the current study is to investigate the phenomenological reflections of right hemisphere language, by comparing the content and linguistic properties of AVH between psychotic and nonpsychotic subjects. For this purpose, we recorded "shadows" of AVH, which are verbatim reproductions of the AVH as uttered by the individuals directly upon experiencing them (Hoffman, Oates, Hafner, Hustig, & McGlashan, 1994; Hoffman, Varanko, Gilmore, & Mishara, 2008). We hypothesize that AVH in psychotic patients are characterized by more negative emotional content and reduced syntax, but a similar use of nouns, compared to AVH in nonpsychotic persons.

2. Methods

2.1. Participants

A total of 36 participants with AVH were included, 17 patients with a psychotic disorder and 19 nonpsychotic persons. All participants were native Dutch speakers and did not have any known hearing or speech deficits. Patients with a psychotic disorder were outpatients from the University Medical Center Utrecht and were referred by their psychiatrist. Ten patients had a diagnosis of schizophrenia (56%), four had schizoaffective disorder (24%), three psychosis not otherwise specified (18%). The nonpsychotic individuals with AVH were recruited and selected through a Dutch website (www.verkenuwgeest.nl) (Sommer et al., 2010). The questionnaire on the website was based on the Launay and Slade Hallucinations Scale (LSHS) (Larøi, Marczewski, & Van Der Linden, 2004), a self- report questionnaire designed to quantify the tendency to hallucinate in healthy individuals. Subjects with high scores on items 8 ("In the past, I have had the experience of hearing a person's voice and then found that no-one was there") and 12 ("I have been troubled by voices in my head") of the LSHS were selected. They did not meet criteria for a DSM-IV diagnosis, as defined by a psychiatrist using the Comprehensive Assessment of Symptoms and History (CASH) interview (Andreasen, Flaum, & Arndt, 1992) and the Structured Clinical Interview for Personality Disorder (SCID-II) (First, Spitzer, Gibbon, & Williams, 1995). For more details about selection and assessment procedure see previous studies by our group (Daalman et al., 2011; Sommer et al., 2010). All participants experienced AVH at least once every day.

All participants gave written informed consent. The study was approved by the medical ethics committee of the University Medical Center Utrecht and was performed in accordance with the Declaration of Helsinki.

2.2. Shadow procedure

The participants were instructed to literally repeat their AVH directly upon hearing them during one minute, with the same intonation, loudness, and pronunciation as the voice they perceive. The verbatim responses were recorded using a voice recorder. This shadow procedure was repeated three times per participant, for three different AVH episodes. This resulted in three separate minutes of shadowed AVH. Voice recording was started with the onset of the AVH and was stopped after one minute. Some participants experience AVH almost continuously, while others had less frequent AVH. On average, the shadow procedure lasted between ten and thirty minutes. One patient was excluded due to the infrequency of his AVH. All other participants experienced AVH during three full minutes. The recorded utterances were transcribed manually by a neuropsychologist and verified by JB. The transcriptions were used for analyses.

2.3. Linguistic features

The recordings were analyzed with respect to content and linguistic complexity. All recordings were scored by the same person who was blinded for the diagnosis of the individual. The content was scored for literal and thematic perseverations and invectives. Furthermore, verbal abuses were counted. Linguistic complexity was examined by scoring the following characteristics: total words produced, type-token ratio, mean length of utterance, proportion of grammatical utterances, mean number of embeddings, verb

Table 1
Definitions and meaning of linguistic features.

Linguistic feature	Definition
Total number of words	Total words used in the three minutes of AVH combined
Utterance	Uninterrupted series of words. Utterance boundaries were determined on the basis of prosodic and semantic coherence
Mean length of utterance	Number of words per utterance
Proportion of grammatical utterances	Number of grammatical utterances divided by total number of utterances Utterances were scored as grammatical if they were syntactically well-formed, even if they were semantically anomalous
Sentence	Utterances that contained a subject and a predicate
Proportion of negated sentences	Number of negated sentences divided by the total number of sentences A negated sentence contains a negator (e.g. no, not, none, never)
Literal perseverations	Exact repetitions of a minimum of three words, of which at least two are open class words
Total thematic perseverations	Reappearance of a content or theme
Positive thematic perseverations	Reappearance of advice and reassurances
Negative thematic perseverations	Reappearance of derogatory demands, threats, commands, comments on behavior, and invectives
Verbal abuses	Invectives and curses
Type-token ratio	Number of different words used (types) divided by total number of words used (tokens) *Measure of lexical variety and vocabulary*
Embedding index	The mean number of embeddings per sentence An embedding is a clause included in another clause. Zero was entered for one clause sentences *Measure of hierarchical syntactical structure*
Verb complexity score	Each element of the verbal complex (auxiliary, main verb, modal, inflection or negative element) is assigned a point that increases the verb's score from a baseline of 1. The mean score of all verbs is calculated *Measure of morphological complexity*
Noun-verb ratio	Number of nouns divided by number of verbs. A high noun-verb ratio means that relatively more nouns are used, which indicates lower processing cost, suggestive for more difficulties in semantic processing *Measure of semantic processing*
Open-closed class ratio	Number of words from open classes (sum of all nouns, verbs, adjectives, and adverbs) divided by the number of words from closed classes (sum of all remaining words, such as pronouns and conjunctions). Open class words have a referential meaning (i.e. referring to an object, event, person, etc.), whereas closed class words are functional *Measure of use of semantic content*

complexity, noun-verb ratio, open -closed class ratio, and proportion of negations. The linguistic characteristics were calculated according to the procedures of Saffran (Saffran, Berndt, & Schwartz, 1989) and Thompson (Thompson & Shapiro, 1995). An overview of all studied features is presented in Table 1.

2.4. Statistical analysis

Characteristics were compared between groups with analysis of variance for continuous variables and χ^2 tests for proportions. First, in order to verify whether the performance of participants was similar between the three separate 1 min transcripts, correlations were calculated between the three minutes for measures of quantity of speech (total number of words, mean length of utterance, and literal perseverations), for the whole study sample. A between-group comparison on the linguistic features of AVH was accomplished through multivariate analysis of variance (MANOVA), applying a General Linear Model. Subsequently, in posthoc analyses, linguistic features were compared between groups one by one. Furthermore, correlations were calculated between features of syntactic complexity (total words produced, mean length of utterance, type-token ratio, proportion of grammatical sentences, embedding index, and verb complexity score) and negative emotional content (negative thematic perseverations and verbal abuses). For both syntactic complexity and negative emotional content, a sum score was calculated based on z-scores of the individual features, and the correlation between these sum scores was calculated. Also, correlations were calculated between the individual features and sum scores and years of education.

3. Results

Demographics and clinical details are shown in Table 2. The groups did not differ with regard to sex, age, years of education, or hand preference.

Table 2
Characteristics of patients with a psychotic disorder and nonpsychotic individuals.

	Patients with a psychotic disorder (n = 17)	Nonpsychotic individuals (n = 19)	*p*-value
Male sex, n (%)	7 (41%)	8 (42%)	0.611
Age in years, mean ± sd	41.4 ± 9.9	49.3 ± 12.9	0.055
Years of education, mean ± sd	11.9 ± 2.4	13.4 ± 2.5	0.077
Hand preference, n (%)			0.421
Right	10 (67%)	12 (71%)	
Left	1 (6%)	3 (18%)	
Ambidexter	4 (24%)	2 (12%)	
Diagnosis, n (%)			
Schizophrenia	10 (59%)		
Schizoaffective disorder	4 (24%)		
Psychosis not otherwise specified	3 (18%)		

sd, standard deviation.

Measures of quantity of speech correlated significantly between the three minutes for total number of words (Pearson's r ranging from 0.43 to 0.76, all $p < 0.05$), for mean length of utterance (Pearson's r ranging from 0.58 to 0.80, all $p < 0.05$), and a trend was found for literal perseverations Pearson's r ranging from 0.30 to 0.73, all $p < 0.10$). This indicates similar performance over the three minutes, therefore the three samples were together considered as one for each participant.

The AVH varied from isolated words to full conversations, both in patients with a psychotic disorder and in the nonpsychotic group. Examples of one minute AVH as produced by a patient with a psychotic disorder and a non-psychotic individual are presented in Appendix A. Examples of AVH experienced by patients with a psychotic disorder are presented in sentences (1), (2) and (3):

(1)	Je	moet	vanavond	brandbommetjes	gaan	maken	om	het
	You	*must.2sg*	*tonight*	*fire boms*	*go.AUX.inf*	*make*	*to*	*the*

	gemeentehuis	in	de	fik	te	steken	*en*	*het*	*is*	*erg*	*belangrijk*
	town hall	*in*	*DET.def*	*fire*	*to*	*set.in*	*and*	*it*	*is*	*very*	*important*

	om	de	wereldorde	te	veranderen.
	to	*DET.def*	*world order*	*to*	*change.inf.*

'*Tonight you need to make fire bombs to set the town hall on fire and it is very important to change the world order.*'

(2)	Jij	kan	het	helemaal	niet.
	You	*can.2sg*	*it*	*at all*	*not.*

'You can't do it at all.'

(3)	We	worden	knettergek.
	We	*become.3pl*	*ADJ-crazy.*

'We're going crazy as hell.'

Examples of AVH as produced by a nonpsychotic person are presented in sentences (4) to (6).:

(4)	Je	moet	je	zus	gauw	helpen.
	You	*must.2sg*	*your*	*sister*	*soon*	*help.inf.*

'You need to help your sister soon.'

(5)	Ik	zat	maar	te	wachten	en	wachten	of	ik	nou
	I	*sat*	*but*	*to*	*wait.inf*	*and*	*wait.inf*	*whether*	*I*	*now*

	eindelijk	iets	mocht	zeggen.
	finally	*something*	*allowed.1sg*	*say.inf.*

'I was waiting and waiting whether I was finally allowed to say something.'

(6)	Ik	heb	hier	in	het	ziekenhuis	gelegen.
	I	have.AUX.1sg	here	in	the	hospital	lain.

'I have been admitted to this hospital.'

The groups differed significantly on the combined dependent variables, $F(11,23) = 3.091$, $p = 0.011$; Pillai's Trace 0.596.

In an analysis of the variables considered separately (Table 3), the AVH of patients with a psychotic disorder had lower mean length of utterance and lower verb complexity score than the AVH of nonpsychotic individuals.

Typical AVH experienced by patients with a psychotic disorder consisted of little more than a noun, a verb and an object, see for example (7) and (8).

(7)	Het	is	weer	stil
	It	*is.3sg*	*again*	*quiet.*

'It's quiet again.'

(8)	Het	gaat		goed
	It	goes.PRES.3sg	well.	

'It is going well.'

These examples clearly show the short length of the utterances and the low verb complexity, mostly consisting of a simple verb in the present tense. Regarding the content of the AVH, verbal abuses, literal perseverations, total thematic perseverations, and negative thematic perserverations were higher in AVH experienced by patients than in AVH of nonpsychotic participants. Both groups were similar with regard to type-token ratio, noun-verb ratio, open-closed class ratio, and total proportion of positive thematic

Table 3
Post hoc comparison of linguistic characteristics of auditory verbal hallucinations between patients with a psychotic disorder and nonpsychotic individuals.

	Patients with a psychotic disorder ($n = 17$)	Nonpsychotic individuals ($n = 19$)	p-value
Total number of words	155.5 ± 98.4	193.3 ± 128.0	0.332
Mean length of utterance	4.87 ± 1.84	7.71 ± 3.30	0.004*
Proportion of grammatical utterances	0.67 ± 0.24	0.79 ± 0.15	0.077
Proportion of negated sentences	0.03 ± 0.04	0.02 ± 0.02	0.342
Literal perseverations	4.24 ± 4.62	0.95 ± 1.51	0.006*
Total thematic perseverations	7.53 ± 6.35	3.22 ± 3.84	0.020*
Positive thematic perseverations	0.76 ± 1.56	1.67 ± 2.41	0.213
Negative thematic perseverations	6.76 ± 6.49	0.75 ± 1.81	0.001*
Verbal abuses	1.29 ± 2.47	0.06 ± 0.24	0.042*
Type-token ratio	0.52 ± 0.15	0.60 ± 0.16	0.174
Embedding index	0.21 ± 0.22	0.44 ± 0.45	0.068
Verb complexity score	2.16 ± 0.60	2.99 ± 1.36	0.026*
Noun-verb ratio[a]	0.72 ± 0.73	0.54 ± 0.31	0.345
Open-closed class ratio	0.89 ± 0.45	0.80 ± 0.29	0.475

* Indicates $p < 0.050$.
[a] A higher noun-verb ratio indicates lower processing cost, suggestive for more difficulties in semantic processing.

perseverations. Furthermore, a non-significant trend was found towards a lower proportion of grammatical utterances and a lower embedding index in the AVH of psychotic patients compared with nonpsychotic participants. However, statistical power was low due to the relatively small sample size, which precludes firm conclusions. The ungrammatical utterances were mostly incomplete utterances, see for example (9). As Dutch is not a pro-drop language, (9) is ungrammatical due to the absence of a subject.

(9)	∗Daar	komen	∅.
	There	*come.3pl*	∅

'There come.'

In addition, some sentences were ungrammatical due to their word order. Consider for instance (10), in which the infinitive verb should have been sentence final. Still other sentences were ungrammatical due to a missing determiner (11) or were incorrect in their gender congruence (12).

(10)	∗Hij	moet	pakken	die	kak.
	He	*must.3sg*	*take.inf*	*that*	*shit.*

'He must take that shit.'

(11)	∗Help,	∅	dokter	verzuipt.
	Help,	∅-DET	doctor	drowns.PRES.3sg.

'Help, doctor is drowning'.

(12)	∗Vieze	vette	varken.
	Dirty.MASC/FEM	fat.MASC/FEM	pig.NEU

'Dirty fat pig.'

Correlations between measures of complexity of the syntax and amount of negative emotional content revealed that measures encompassing a sum score are highly correlated, whereas measures across sum scores show low correlations. No significant correlation (Pearson's $r = -0.10$, $p = 0.59$) was found between the sum scores complexity of the syntax and amount of negative emotional content. Full correlations are depicted in the appendix (Table A.1). Correlations with years of education were nonsignificant for all measures (all $p > 0.05$) (Table A.1).

4. Discussion

The present study compared the content and linguistic properties of AVH between patients with a psychotic disorder and nonpsychotic individuals who frequently hallucinate. In comparison to the AVH in the nonpsychotic group, AVH in patients were characterized by a shorter mean length of utterance and a higher number of literal and negative thematic perseverations. In addition, the number of embeddings and the proportion of grammatical utterances were lower in the patient group. However, these differences were not significant. No differences were found for the scores on verb complexity, noun-verb ratio, type-token ratio and positive thematic perseverations.

In this study, it was hypothesized that language areas of the right hemisphere are more involved in the AVH of patients with a psychotic disorder than of nonpsychotic individuals. Therefore, the AVH in psychotic patients were expected to be less syntactically complex than in nonpsychotic individuals. Indeed, group differences were found mostly in syntax and repetition, and less in semantics. This is in line with our hypothesis, as syntax was found to be represented almost exclusively by the left hemisphere (Friederici, 2011; Grodzinsky, 2000), whereas several semantic functions can take place in the right hemisphere (Coulson, Federmeier, Van Petten, & Kutas, 2005; Gazzaniga & Hillyard, 1971; Jung-Beeman, 2005). Furthermore, right hemisphere speech is characterized by high levels of repetition and more swearing and threats (Code, 1982; Copolov et al., 2003; Kuperberg et al., 2000; Pell, 1999) which is in line with the higher numbers of perseverations and verbal abuses found in patients. Our data show a comparable proportion of negated sentences between groups. This is in concordance with the involvement of the right hemisphere in the production of AVH, as the right hemisphere is capable of comprehending the affirmative-negative dimension (Gazzaniga & Hillyard, 1971). Taken together, our data provide indirect support for the hypothesis that the right hemisphere is more involved in the production of AVH in psychotic patients than in nonpsychotic individuals. However, whether this is actually true has yet to be confirmed in further studies. Although it was previously reported that lateralization of language was lower in patients with a psychotic disorder than in those with frequent AVH without a diagnosis (Diederen, De Weijer, et al., 2010), no differences in lateralization were observed when comparing brain activation of psychotic and nonpsychotic individuals (Diederen et al., 2011). Also, the fact that no correlation was observed between the amount of negative content and complexity of syntax implies that the interaction is more complex than just the presumed right hemisphere explanation would suggest. A potential confounding factor is that some negative content was not scored, due to lack of context. Single words or short sentences could be ambiguous with regard to negativity (for example 'pig'). They were regarded as negative only if they could be unmistakably interpreted as such. Therefore, especially in individuals with AVH without complex syntax, negative content may be underestimated.

Another possible explanation is that all spoken language differs between psychotic patients and nonpsychotic individuals, not just the language of their AVH. Speech of patients with schizophrenia is associated with various linguistic impairments such as reduced embeddings, lower phrase length and more grammatical errors (Fraser, King, Thomas, & Kendell, 1986; Morice & McNicol, 1986). This is in line with our finding that psychotic patients have a lower proportion of grammatical utterances and a lower embedding index than nonpsychotic individuals, although these differences did not reach statistical significance. However, the higher numbers of literal and negative thematic perserverations and verbal abuses that we found were not reported in previous studies on schizophrenic speech (Covington et al., 2005; DeLisi, 2001). This suggests that the language of AVH in psychotic patients differs from their everyday speech. The differences we found between the AVH of patients and nonpsychotic participants are thus not likely to be explained by general language deficits in schizophrenia alone. In addition, years of education was unrelated to language characteristics, which implies that the observed differences in language characteristics can not be explained by differences in education level between groups.

Low syntactic complexity and negative emotional content of AVH were unrelated in the present study, although both are thought to be associated with right hemisphere activation. This suggests that the interaction is more complex than just the presumed right hemisphere explanation would suggest. A pontential confounding factor is that some negative content was not scored, due to lack of context. Single words or short sentences could be ambiguous with regard to negativity (for example 'pig'). They were regarded as negative only if they could be unmistakably interpreted as such. Therefore, especially in individuals with AVH without complex syntax, negative content may be underestimated.

This study has some limitations. First, the majority of the patients used antipsychotic medication, which may have influ-

enced the form and content of the AVH in this group (Goldberg, Dodge, Aloia, Egan, & Weinberger, 2000). Antipsychotic medication, when only partly suppressing AVH, might cause the AVH to be linguistically deficient. Second, the sample size was modest, which has decreased the sensitivity to detect statistical group differences. Still, with the current sample, we were able to obtain meaningful differences that support our hypothesis of right hemisphere involvement in AVH of psychotic patients, but larger power might have resulted in more significant results. Also, the patient group was not homogeneous as it included three diagnoses within the schizophrenia spectrum: schizophrenia, schizoaffective disorder, and psychosis not otherwise specified. However, when only patients with schizophrenia were included in the analyses, this did not affect the results (data not shown). Third, all recordings were scored by the same person, which may have introduced some subjectivity in the scoring of the features. Fourth, no measures of overt language complexity were taken, and the linguistic values for both groups cannot easily be compared to spoken Dutch language in general. These linguistic characteristics vary between speakers due to for instance gender, education or dialect, but also within speakers due to setting (e.g. dialogue versus monologue) or the length of the speech sample. Therefore, no conclusions can be drawn on the relation between the language of AVH and everyday speech. Fifth, we did not examine the influence of intelligence in this study. However, all humans learn to speak their native language well, and about as well as everyone else (Gee, 2004), regardless of intelligence. Intelligence is associated with vocabulary and language processing speed, but not with proficiency of the mother tongue. Therefore, is it unlikely that differences in intelligence influenced our results. Finally, it is uncertain whether participants truly repeated every word the voices said. Participants may have felt embarrassed to repeat their AVH, and paranoid patients may have withheld information for their own perceived safety. The lower mean length of utterances in psychotic patients could also be explained by the nature of their current psychosis (Gee, 2004).

A strength of the present study is that we extensively examined both the content and the form of AVH. Recently, the phenomenology of AVH in both psychotic and otherwise healthy individuals was addressed (Woods, Jones, Alderson-day, Callard, & Fernyhough, 2015). In our study, linguistic analyses were used to test hypotheses about the etiology of AVH, reaching beyond phenomenology.

Our results can have clinical value. The finding that the language of the voices is of relatively low syntactic quality, and are thus relatively 'easy' could help patients to cope with their voices. For instance, patients can learn to take their voices less seriously or place themselves in a superior rather than inferior position as compared to their voices, by judging the messages as being 'easy' or 'childish' based on their complexity. Furthermore, the fact that the voices show a higher proportion of grammatical errors may help patients to realize that their voices make mistakes sometimes; that it is thus not always 'correct' or 'true' what they say.

The current study adds to the discussion whether AVH should be interpreted as a spectrum, where voices experienced by psychotic individuals and nonclinical voice hearers are on a continuum with normality (Ford et al., 2014; Johns et al., 2014). Badcock and Hugdahl warn against uncritical acceptance of such models (Badcock & Hugdahl, 2012) and propose categorical models such as lateralization models instead (Diederen, Neggers, et al., 2010; Royer et al., 2015; Sommer et al., 2008) to explain these positive psychotic symptoms. In these lateralization models, different underlying substrates for pathological and nonpathological AVH are recognized, which is supported by our results.

In conclusion, differences were observed in syntactic complexity and levels of repetition between the AVH experienced by patients and healthy individuals. This might be explained by more involvement of right hemisphere areas in patients compared with nonpsychotic voice hearers and suggests distinct pathophysiological mechanisms. Furthermore, psychoeducation about linguistic features of the voices can be incorporated into psychoeducation treatment for psychotic patients with AVH.

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Contributors

JN de Boer collected and analyzed the data and wrote the first draft of the manuscript.

SM Heringa aided in data analysis and finalized the manuscript.

JN de Boer and SM Heringa contributed equally to the manuscript.

E van Dellen contributed to the writing of the manuscript.

FNK Wijnen served as a consultant of the study and contributed to the writing of the manuscript.

IEC Sommer designed the study and supervised the project.

All authors contributed to and have approved the final manuscript.

Conflict of interest

All authors declare that they have no conflicts of interest.

Appendix A. Full minute examples

1. One minute AVH example of a psychotic patient

(1)	Je	moet	vanavond	brandbommetjes		gaan	maken	om het	
	You	*must.2sg*	*tonight*	*fire boms*		*go.AUX.inf*	*make*	*to the*	
	gemeentehuis	in	de	fik	te steken	en	het	is	erg
	town hall	*in*	*DET.def*	*fire*	*to set.inf*	*and*	*it*	*is*	*very*
	belangrijk	om	de	wereldorde		te veranderen.			
	important	*to*	*DET.def*	*world order*		*to change.inf.*			

'Tonight you need to make fire bombs to set the town hall on fire and it is very important to change the world order'

(2)	Als	je	dat	niet	doen	worden	je	ouders	ziek	en
	If	you	that	not	do.inf	be.PASS.3pl	your	parents	ill	and

kan	de	vakantie	niet	doorgaan.
AUX.3sg	*the*	*vacation*	*not*	*go-trough. inf.*

'If you don't, your parents get ill and the vacation is off.'

(3)	Je	moet	het	gemeentehuis	gewoon in	de	fik	steken.
	You	*must.2sg*	*the*	*town-hall*	*just in*	*DET.def*	*fire*	*set.inf*

'You just have to set the town hall on fire.'

(4)	Je	moet	het	gemeentehuis	gewoon in	de	fik	steken.
	You	*must.2sg*	*the*	*town-hall*	*just in*	*DET.def*	*fire*	*set.inf*

'You just have to set the town hall on fire.'

(5)	Dat	is	gewoon	noodzakelijk.
	That	is.3sg	just	necessary.

'That's just necessary.'

(6)	Je	moet	het	gemeentehuis	gewoon	in	de	fik	steken.
	You	*must.2sg*	*the*	*town-hall*	*just*	*in*	*DET.def*	*fire*	*set.inf*

'You just have to set the town hall on fire.'

(7)	Als	je	dat	niet	doet	gebeurt	er	iets	ergs
	If	*you*	*that*	*not*	*do.2sg*	*happen.3sg*	*COMP*	*something*	*bad*

en	kan	je	niet	op	vakantie.
and	*can.2sg*	*you*	*not*	*on*	*vacation.*

'If you don't, something bad happens and you can't go on vacation.'

(8)	Je	moet	vanavond	het	gemeentehuis	gewoon	in	de	fik	steken.
	You	*must.2sg*	*tonight*	*the*	*town-hall*	*just*	*in*	*DET.def*	*fire*	*set.inf*

'You just have to set the town hall on fire tonight.'

2. One minute AVH example of a non-psychotic individual

(1)	Je	moet	je	zus	gauw	helpen.
	You	*must.2sg*	*your*	*sister*	*soon*	*help.inf.*

'You need to help your sister soon.'

(2)	Ik	heb	gezegd	dat	ik	altijd	hoopte,	dat
	I	have.1sg	said	that	I	always	hoped.1sg	that

je	voor	haar	zou	blijven	zorgen.
you	*for*	*her*	*would*	*continue*	*care.inf.*

'I said that I always hoped you would continue to care for her.'

(3)	Help		haar.
	Help.imp		*her.*

'Help her.'

(4)	Zij	zit	tegen	een	scheiding	aan	en
	She	*sits.3sg*	*AGAINST*	*a*	*divorce*	*ON*	*and*

	dat	nieuwe	huis	gaat	toch	niet	door.
	that	*new*	*house*	*goes.3sg*	*after-all*	*not*	*through.*

'She is about to get a divorce and that new house won't go through after all.'

(5)	Ik	mag	niets	zeggen	maar	dat	kind	van	hun
	I	*may.1sg*	*nothing*	*say.3sg*	*but*	*that*	*child*	*of*	*theirs*

	heeft	toch	wel	een	behoorlijke	invloed	op	hun
	AUX.3sg	*SURELY.adv*	*SURELY.adv*	*a*	*significant*	*impact*	*on*	*their*

	relatie,	maar	dat	komt	omdat	zij	van
	relationship,	*but*	*that*	*AUX.3sg*	*because*	*they*	*from*

	opvoeden	beiden	geen	verstand	hebben.
	raising-children.inf	*both*	*no*	*clue*	*have.inf.*

'I shouldn't say anything, but that child of theirs does have quite a significant impact on their relationship, but that's because neither of them has a clue about raising children.'

(6)	De	angst	dat	je	denkt	dat	je	vader	overlijdt
	The	*fear*	*that*	*you*	*think.2sg*	*that*	*your*	*father*	*dies.3sg*

	hoef	je	niet	te	hebben,	want	die	haalt
	need.2sg	*you*	*not*	*to*	*have.inf,*	*because*	*PRO.sg*	*gets.3sg*

	een	[familienaam]	leeftijd.
	a	*[family name]*	*age.*

'The fear that you think your father will pass away, you don't have to have, because he will live to the age of a [family name].' (see Table A.1).

Table A.1
Correlations between measures of syntactic complexity, negative emotional content, and years of education.

	Total number of words	Mean length of utterance	Proportion of grammatical utterances	Type-token ratio	Embedding index	Verb complexity score	Negative thematic perseverations	Verbal abuses
Syntactic complexity								
Total number of words	–	0.65* (<0.001)	0.34* (0.04)	−0.62* (<0.001)	0.60* (<0.001)	0.62* (<0.001)	0.17 (0.34)	0.15 (0.40)
Mean length of utterance	0.65* (<0.001)	–	0.53* (0.001)	−0.19 (0.28)	0.89* (<0.001)	0.90* (<0.001)	−0.11 (0.56)	−0.19 (0.28)
Proportion of grammatical utterances	0.34* (0.04)	0.53* (0.001)	–	0.05 (0.77)	0.28 (0.10)	0.33* (0.050)	0.29 (0.10)	−0.29 (0.09)
Type-token ratio	−0.62* (<0.001)	−0.19 (0.28)	0.05 (0.77)	–	−0.22 (0.21)	−0.27 (0.11)	−0.20 (0.26)	−0.05 (0.80)
Embedding index	0.60* (<0.001)	0.89* (<0.001)	0.28 (0.10)	−0.22 (0.21)	–	0.89* (<0.001)	−0.10 (0.57)	−0.01 (0.94)
Verb complexity score	0.62* (<0.001)	0.90* (<0.001)	0.33* (0.050)	−0.27 (0.11)	0.89* (<0.001)	–	−0.10 (0.58)	−0.12 (0.51)
Negative emotional content								
Negative thematic perseverations	0.17 (0.34)	−0.11 (0.57)	0.29 (0.10)	−0.20 (0.26)	−0.10 (0.57)	−0.10 (0.58)	–	0.31 (0.08)
Verbal abuses	0.15 (0.40)	−0.19 (0.28)	−0.29 (0.09)	−0.05 (0.80)	−0.01 (0.94)	−0.12 (0.51)	0.31 (0.08)	–
Years of education	−0.04 (0.81)	0.20 (0.25)	−0.08 (0.66)	0.18 (0.31)	0.18 (0.30)	0.27 (0.11)	−0.24 (0.17)	−0.13 (0.47)

* Indicates $p < 0.050$.

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