

University of Groningen

A data-driven linguistic characterization of hallucinated voices in clinical and non-clinical voice-hearers

Corona Hernández, Hugo; Brederoo, Sanne; de Boer, Janna; Sommer, I. E. C.

Published in:
Schizophrenia Research

DOI:
[10.1016/j.schres.2022.01.055](https://doi.org/10.1016/j.schres.2022.01.055)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2022

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Corona Hernández, H., Brederoo, S., de Boer, J., & Sommer, I. E. C. (2022). A data-driven linguistic characterization of hallucinated voices in clinical and non-clinical voice-hearers. *Schizophrenia Research*, 241, 210-217. <https://doi.org/10.1016/j.schres.2022.01.055>

Copyright

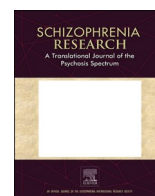
Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.



A data-driven linguistic characterization of hallucinated voices in clinical and non-clinical voice-hearers

H. Corona-Hernández^{a,*}, S.G. Brederoo^{a,b}, J.N. de Boer^{a,c}, I.E.C. Sommer^{a,b}

^a Department of Biomedical Sciences of Cells & Systems, University Medical Center Groningen, University of Groningen, the Netherlands

^b Department of Psychiatry, University Medical Center Groningen, University of Groningen, the Netherlands

^c Department of Psychiatry, University Medical Center Utrecht, Utrecht University & Brain Center Rudolf Magnus, Utrecht, the Netherlands

ARTICLE INFO

Keywords:

Auditory verbal hallucinations
Clustering
Linguistics
Phenomenology
Schizophrenia
Voice-hearers

ABSTRACT

Background: Auditory verbal hallucinations (AVHs) are heterogeneous regarding phenomenology and etiology. This has led to the proposal of AVHs subtypes. Distinguishing AVHs subtypes can inform AVHs neurocognitive models and also have implications for clinical practice. A scarcely studied source of heterogeneity relates to the AVHs linguistic characteristics. Therefore, in this study we investigate whether linguistic features distinguish AVHs subtypes, and whether linguistic AVH-subtypes are associated with phenomenology and voice-hearers' clinical status.

Methods: Twenty-one clinical and nineteen non-clinical voice-hearers participated in this study. Participants were instructed to repeat verbatim their AVHs just after experiencing them. AVH-repetitions were audio-recorded and transcribed. AVHs phenomenology was assessed using the Auditory Hallucinations Rating Scale of the Psychotic Symptom Rating Scales. Hierarchical clustering analyses without a priori group dichotomization were performed using quantitative measures of sixteen linguistic features to distinguish sets of AVHs.

Results: A two-AVHs-cluster solution best partitioned the data. AVHs-clusters significantly differed in linguistic features ($p < .001$); AVHs phenomenology ($p < .001$); and distribution of clinical voice-hearers ($p < .001$). The “expanded-AVHs” cluster was characterized by more determiners, more prepositions, longer utterances (all $p < .01$), and mainly contained non-clinical voice-hearers. The “compact-AVHs” cluster had fewer determiners and prepositions, shorter utterances (all $p < .01$), more negative content, higher degree of negativity (both $p < .05$), and predominantly came from clinical voice-hearers.

Discussion: Two voice-speech clusters were recognized, differing in syntactic-grammatical complexity and negative phenomenology. Our results suggest clinical voice-hearers often hear negative, “compact-voices”, understandable under Broca's right hemisphere homologue and memory-based mechanisms. Conversely, non-clinical voice-hearers experience “expanded-voices”, better accounted by inner speech AVHs models.

1. Introduction

Auditory verbal hallucinations (AVHs) are understood as the experience of hearing voices in absence of corresponding stimuli. Nowadays, their presence across psychiatric disorders is well recognized, as is the fact that they also occur in non-clinical populations, with estimated lifetime frequencies in the 5–15% range (Beavan et al., 2011; Majjer et al., 2018). In recent years, the appreciation of heterogeneous features in AVHs has increased, both within and across different populations (Larøi et al., 2012; Waters and Fernyhough, 2017; Woods et al., 2015). For instance, while loudness and number of voices are similar between

clinical and non-clinical voice-hearers, these two groups differ in frequency of and control over their AVHs (Daalman et al., 2011). It has been suggested that, to fully understand AVHs and their origin, this heterogeneity may require the study of potential underlying subtypes of AVHs (Jones, 2010; McCarthy-Jones et al., 2014a, 2014b; Sommer et al., 2018). In previous research, some support was found for five AVHs subtypes, namely hypervigilant subtype, autobiographical memory subtype, inner speech subtype, epileptic subtype, and deafferentation subtype (McCarthy-Jones et al., 2014a). So far, data-driven support for this subdivision is lacking. In addition, negative emotional content and form (e.g., commands) were identified as dimensional constructs that

* Corresponding author at: Department of Biomedical Sciences of Cells & Systems, University Medical Center Groningen, Antonius Deusinglaan 1, 9713 AV Groningen, the Netherlands.

E-mail address: h.corona.hernandez@umcg.nl (H. Corona-Hernández).

<https://doi.org/10.1016/j.schres.2022.01.055>

Received 13 January 2021; Received in revised form 11 January 2022; Accepted 24 January 2022

Available online 9 February 2022

0920-9964/© 2022 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

vary across subtypes (McCarthy-Jones et al., 2014a). Altogether, distinguishing subtypes of AVHs can have important implications for both clinical practice and research, such as developing treatments for AVHs and informing neurocognitive models of AVHs (David, 2010; McCarthy-Jones et al., 2014a; Sommer et al., 2018).

Until now, studies on AVHs subtypes have mostly relied on phenomenological and etiological features, scarcely including linguistic characteristics (Chang et al., 2015, 2009; McCarthy-Jones et al., 2014a, 2014b; Stephane et al., 2003). Moreover, most studies on AVHs subtypes have focused exclusively on clinical AVHs (Chang et al., 2009; McCarthy-Jones et al., 2014b; Stephane et al., 2003). Therefore, to arrive at a more comprehensive understanding of AVHs subtypes, a linguistic approach to AVH heterogeneity in both clinical and non-clinical voice-hearers is warranted.

The language of AVHs or “voice-speech” from clinical voice-hearers presumably has linguistic characteristics that distinguish it from other registers of speech (Tovar et al., 2019). Specifically, it has been suggested that clinical voice-speech displays unpleasant and recurrent semantic content, short utterances lacking syntactical errors or grammatical connectivity, and a low use of the grammatical first person (Frank et al., 1980; Hoffman et al., 1994; Tovar et al., 2019; Turkington et al., 2019). Importantly, when comparing voice-speech between clinical and non-clinical voice-hearers, both similarities and dissimilarities in linguistic features have been found (de Boer et al., 2016). Dissimilarities include shorter mean length of utterance, lower verb complexity, and more verbal abuses and perseverations in the voice-speech of individuals with a clinical status (de Boer et al., 2016). This raises the question whether different linguistic subtypes of AVH can be identified, and whether these subtypes are present in both clinical and non-clinical voice-hearers. Therefore, the main aim of the present study was to investigate how linguistic features can be used to distinguish subtypes of AVHs. Specifically, we studied how AVHs linguistic subtypes might be characterized in terms of phenomenology, and whether they are associated with participants' clinical status. To achieve this, we used a data-driven approach to overcome possible limitations of a priori dichotomization of clinical and non-clinical voice-hearers.

2. Methods

2.1. Participants

A total of 21 clinical and 19 non-clinical voice-hearers participated in this study. The majority of this sample was previously described in de Boer et al. (2016). Four clinical voice-hearers were added in the current study. Inclusion criteria for all participants were: (a) being a native Dutch speaker, (b) experiencing verbal hallucinations at least once per month, (c) at least three months free of alcohol or drugs abuse, and (d) absence of a chronic somatic disorder. Patients were recruited via the University Medical Center Utrecht. Non-clinical voice-hearers were recruited via a website (www.verkenuwgeest.nl), and were required to pass an online screening about hallucinations, a telephone interview about the inclusion criteria, and the face-to-face psychiatric screening. All participants were screened for a psychiatric disorder using the Comprehensive Assessment of Symptoms and History (CASH) (Andreasen et al., 1992) and the Structured Clinical Interview for Personality Disorder (SCID-II) (First et al., 1995). Participants were classified as non-clinical voice-hearers when they did not meet the criteria for a psychiatric disorder, and as clinical voice-hearers when they did.

2.2. Procedures

Registrations of the AVHs were collected from all participants using the shadowing procedure. This consisted of instructing each participant to “shadow” (i.e., repeat verbatim) her/his AVHs just after experiencing them (de Boer et al., 2016). The verbatim repetitions were recorded on a voice recording device. This procedure was repeated three times, each

recording lasting a minimum of 1 min, resulting in a total of at least 3 min of “shadows” per participant. Similar to previous reports (de Boer et al., 2016; Tovar et al., 2019), the recording time required for obtaining the sound recordings spanned between a couple of minutes and half an hour, depending on the frequency and duration of the hallucinations. All sound recordings of the “shadows” were orthographically transcribed by consensus rating of three Dutch native, linguistics graduate students. They successfully identified blurry sounds as either verbal or non-verbal units, disentangled specific words, and differentiated “shadows” from self-talk (see also Linguistic data preprocessing in Supplementary materials). The Auditory Hallucinations Rating Scale (AHRS) and the Psychotic Symptom Rating Scales (PSYRATS) (Haddock et al., 1999) were used to assess eleven phenomenological features of the AVHs. Procedures were approved by the ethical committee of the University of Utrecht, and participants provided written informed consent before participation. Declaration of Helsinki's principles were followed throughout all steps of the research.

2.3. Linguistic features

Sixteen features were analyzed: two types of pronouns (nominative first-person singular, and relatives), three verbal time expressions (simple past, present, and future tenses), three content-and-structure measures (mean length of utterance or MLU, mean word length, and moving-average type-token ratio), four function-word classes (definite and indefinite articles, prepositions, and subordinating conjunctions), and four content-word classes (attributive adjectives, locative adverbs, plural and singular nouns) (see definitions and examples in Table 1). This choice was informed by work about spoken Dutch from Grieve et al. (2017). Based on it, and following Biber's (1988) procedure to retain only salient linguistic variables for analysis, these 16 features were identified as the most suited to explore differentiating patterns in spoken Dutch.

Relative frequencies of the linguistic features were calculated by dividing each absolute frequency by the total number of words of the corresponding shadow file and then multiplying the quotient by 10,000. In order to prevent absolute frequencies of zero from remaining zero in relative frequencies, one unit was added to all relative frequencies. The

Table 1
Linguistic features for analysis in the AVHs.

Linguistic feature	Description
Attributive adjective	Word conveying properties of or adding features to a given noun, e.g., “pretty”.
Definite article	Determiner for identifiable entities, e.g., “the”.
Indefinite article	Determiner for non-identifiable entities, e.g., “a” or “an”.
Locative adverb	Word for details of place or position, e.g., “homeward”.
Mean length of utterance	The average number of words forming an utterance.
Mean word length	The average number of letters forming a word.
Moving-Average Type-Token Ratio	A ratio that expresses the number of different word forms relative to the total number of words.
Nominative first-person singular pronoun	Word standing for the grammatical first person functioning as singular subject, i.e., “I”.
Plural noun	Word standing for concrete or abstract entities, e.g., “tables”.
Preposition	Word usually placed before a noun phrase and typically indicating spatial or temporal relations, e.g., “at” and “in”.
Relative pronoun	Word that depends on an antecedent and that both introduces and plays a role in a new sentence, e.g., “who”.
Simple future	Grammatical value of a later time, e.g., “will”.
Simple past	Grammatical value of a previous time, e.g., “did”.
Simple present	Grammatical value of a current time, e.g., “have”.
Singular noun	Word standing for a concrete or abstract entity, e.g., “table”.
Subordinating conjunction	Word linking an independent clause to a dependent clause, e.g., “because”.

Table 2
Demographic characteristics of participants.

Characteristic	Clinical voice-hearers (n = 21)	Non-clinical voice-hearers (n = 19)	Statistic value	p-Value
Age in years, mean (SD)	43.2 (11.38)	50.7 (16.19)	t (38) = 1.70	.09
Diagnosis, n (%)				
Bipolar disorder	1 (5%)			
Psychosis not otherwise specified	5 (24%)			
Schizoaffective disorder	3 (14%)			
Schizophrenia	12 (57%)			
Females, n (%)	8 (38%)	8 (42%)	χ^2 (1) = 0.06	.79
Medication ^a , n (%)				
None	2 (11%)			
Only antipsychotic	9 (50%)			
Both antipsychotic and antidepressant	7 (39%)			
Years hearing AVHs ^b , mean (SD)	19.3 (15.2)	40.4 (18.56)	t (33) = 3.86	<.001

n = sample size, SD = standard deviation.

^a Data available only for 18 clinical voice hearers.

^b Data available only for 18 clinical and 17 non-clinical voice-hearers.

Moving-Average Type–Token Ratio (MATTR) was computed by means of the Quantitative Analysis of Textual Data tool version 2.0.1 (Benoit et al., 2018) implementing logarithm with base ten and a moving window with a size of ten words as parameters. MATTR (Covington and McFall, 2010) was chosen over Type-Token Ratio (TTR) (Richards, 1987) as it is more robust in dealing with the influence of text length on the ratio calculation (Brezina, 2018; Covington and McFall, 2010).

2.4. Statistical analysis

We used hierarchical clustering analyses to classify the participants into groups based on linguistic characteristics of their AVH. Specifically, different subgroups of AVHs were distinguished by grouping according to standardized linguistic features, using Canberra distance and Ward's method. A two-step procedure was conducted to assess AVHs-cluster validity implementing both relative and internal criteria. First, the number of AVHs-clusters was estimated by means of the R 'NbClust' package (Charrad et al., 2014). Secondly, a Sequential Minimal Optimization algorithm (SMO) (Platt, 1999) was implemented along with polynomial kernel and ten-fold cross-validation in order to evaluate the AVHs-clusters' partitions as labels for classification categories. The Waikato Environment for Knowledge Analysis software (Weka) (Witten et al., 2016) was used only for the classification task.

Chi-square tests of independence without continuity correction were carried out to test for differences in the distribution of clinical status and sex. Two-tailed independent t-tests were performed to test for differences in age and years hearing AVHs. One-way non-parametric multivariate analysis of variance (MANOVA) (Burchett et al., 2017) was done independently to test for the presence of significant differences on both the combined linguistic variables and the combined phenomenological features between AVHs-clusters. Non-parametric two-tailed independent Wilcoxon rank sum tests with continuity correction were carried out for analyzing possible differences in both individual linguistic quantitative measures and individual phenomenological features between AVHs-clusters. Non-parametric two-tailed Spearman bivariate correlations were conducted in order to assess possible relations between individual linguistic features and individual phenomenological features. In both Wilcoxon and correlation tests, Holm correction for multiple comparisons was applied to control for false positive results. This method was used because it is suited for exploratory studies (Menyhart et al., 2021).

For all analyses, after correcting for multiple comparisons, statistical results with p-values <.05 were considered to be significant. All analyses were performed in RStudio version 1.2.5019 (RStudio Team, 2019) running R version 4.0.2 (R Core Team, 2020).

3. Results

Clinical voice-hearers were diagnosed either with a schizophrenia-

spectrum (95%) or a bipolar (5%) disorder. Clinical and non-clinical voice-hearers were similar in age (ranging from 21 to 75) and sex (both p > .05), but differed in years hearing AVHs (p < .001) (Table 2). General characteristics of their AVHs are presented in Table 3.

The data-driven hierarchical clustering procedure showed that a two-AVHs-cluster solution best partitioned the data. AVHs-clusters' validation showed that the percentage of correctly predicted instances was 92.5% (Cohen's kappa coefficient = 0.85). There were no significant differences between the two AVHs-clusters regarding age, sex, and years hearing AVHs. The AVHs-clusters differed significantly in terms of distribution of participants with and without a psychiatric disorder (see Table 4), with one AVHs-cluster consisting mainly of non-clinical voice-hearers, and the other predominantly of clinical voice-hearers (p < .001).

Multivariate analysis of variance indicated the presence of significant differences on the combined linguistic variables between AVHs-clusters, $F(9.05,340.34) = 7.42, p < .001$. Follow-up comparisons showed that the AVHs-clusters differed on four linguistic features. Compared to the other cluster, AVHs in the cluster with mainly clinical voice-hearers were characterized by fewer definite and indefinite articles, less prepositions and shorter utterances. Henceforth, the AVHs from this cluster will be called "compact-AVHs". In contrast, the AVHs from the cluster made out of mainly non-clinical voice hearers, being richer in articles and prepositions and showing longer utterances, will henceforth be called "expanded-AVHs" (see Table 5). Illustrative fragments of compact-AVHs and expanded-AVHs are given in Fig. 1.

Table 3
Details of the AVHs' shadows per group of voice-hearers.

Feature	Voice-hearers	
	Clinical (n = 21)	Non-clinical (n = 19)
Frequency of AVHs, mean (SD) ^a	3.2 (0.89)	2.4 (1.28)
Description ^b	Voices occur at least once an hour	Voices occur at least once a day
Number of different word forms (types)		
Mean (SD)	77.4 (45.21)	97.1 (53.56)
Total	690	795
Number of running words (tokens)		
Mean (SD)	176.2 (122.96)	199.6 (139.14)
Total	3701	3794
Recording time		
Mean (SD)	5 m 47 s (2 m 54 s)	3 m 19 s (1 m 38 s)
Total	2 h 1 m 35 s	1 h 3 m 4 s

^a This information was available only for 35 out of 40 participants.

^b According to the Psychotic Symptom Rating Scales (PSYRATS) (Haddock et al., 1999).

Table 4
Characteristics of the participants per cluster of AVHs.

Characteristic	Cluster with n = 18	Cluster with n = 22	Statistic value	p-Value	Cramer's V effect size
	Mean (SD) or n (%)	Mean (SD) or n (%)			
Age in years	47.2 (14.70)	46.5 (14.14)	t (38) = 0.14	.88	
Clinical voice-hearers	4 (22.22%)	17 (77.27%)	χ^2 (1) = 12.03	<.001	0.54
Diagnosis					
Bipolar disorder		1 (4.54%)			
Psychosis not otherwise specified	1 (5.5%)	4 (18.18%)			
Schizoaffective disorder	1 (5.5%)	2 (9.09%)			
Schizophrenia	2 (11.11%)	10 (45.45%)			
Medication ^a					
None	1 (5.5%)	1 (4.54%)			
Only antipsychotic	3 (16.6%)	6 (27.27%)			
Both antipsychotic and antidepressant		7 (31.81%)			
Sex (female)	6 (33.33%)	10 (45.45%)	χ^2 (1) = 0.60	.43	
Years hearing AVHs ^b	33 (18.5)	26.3 (19.64)	t (33) = 1.02	.31	

n = sample size, SD = standard deviation.

^a Data available only for 18 clinical voice hearers.

^b Data available only for 18 clinical and 17 non-clinical voice-hearers.

Furthermore, compact-AVHs and expanded-AVHs differed significantly in terms of phenomenology, $F(4.28,141.19) = 5.34, p < .001$. Compact-AVHs showed a larger amount of negative content and a higher degree of negativity than expanded-AVHs (Table 6).

There were no significant correlations between linguistic and phenomenological variables (all $\rho(p) < 0.4$, all $p > .05$).

As the possibility exists that AVHs in patients with schizophrenia-spectrum disorders are different from those in another psychiatric disorder, we duplicated our analyses with the exclusion of the patient who was diagnosed with bipolar disorder. Compared to the above-mentioned results, this did not lead to substantial changes (see Supplementary Tables S1–S3).

4. Discussion

In this study we investigated whether linguistic features can be used to recognize different subtypes of AVHs, and whether this links to AVHs phenomenology and presence or absence of a clinical diagnosis. The cluster analysis revealed a two-cluster solution. The expanded-AVHs cluster mainly contained non-clinical voice-hearers' AVHs, while the compact-AVHs cluster mostly had clinical voice-hearers' AVHs. In comparison with expanded-AVHs, compact-AVHs had fewer determiners and prepositions, as well as shorter MLU. Regarding phenomenology, compact-AVHs showed a larger amount of negative content and higher degree of negativity. Linguistic features and phenomenology were not correlated, emphasizing the importance of a role of language in characterizing our sample of AVHs.

4.1. Linguistic characterization of the AVHs

Compared to expanded-AVHs, compact-AVHs had fewer determiners overall. Determiners identify referents, either as concrete (e.g., *the country you live in*) or abstract entities (e.g., *the topic of this text*) (Giacalone Ramat and Andorno, 2006; Juvonen, 2006). This smaller number of determiners was unlikely due to fewer noun phrases in compact-AVHs, since both singular and plural nouns did not differ significantly between AVHs-clusters. Post-hoc qualitative assessment of our results gave rise to a few possible explanations. First, compact-AVHs were found to have a larger proportion of singular proper nouns (see Supplementary Table S4), which never require a determiner in Dutch (Hanks, 2006; Oosterhoff, 2015). Second, the Dutch indefinite article “*een*” can form adverbial constructions of degree (e.g., *een beetje*; “a bit”) (Klein, 1998), and the proportion of this type of constructions was smaller in compact-AVHs (see Supplementary Table S5). Third, compact-AVHs had a larger proportion of countable indefinite plural nouns (e.g., *Ø stemmen*; “voices”), which always lack a determiner

(Oosterhoff, 2015) (see Supplementary Table S6).

Furthermore, our results suggest that prepositional constructions were more frequent in expanded-AVHs compared to compact-AVHs. Prepositions typically form locational/positional, temporal or directional/movement constructions (Kurzon, 2006; Svenonius, 2007). Importantly, prepositional constructions often specify information in connection with verbs (Svenonius, 2007; Talmy, 2000). For instance, someone can either “live” *in a house*, “eat” *at lunchtime*, or “walk” *toward a door*. Indeed, a post-hoc exploratory evaluation of our data showed

Table 5
Linguistic variables across the two clusters of AVHs.

Linguistic variable	Expanded-AVHs cluster (n = 18), mean (SD)	Compact-AVHs cluster (n = 22), mean (SD)	Statistic		r effect size
			W	Adj. p-Value	
Attributive adjectives	150.1 (141.56)	134 (168.32)	225.5	.98	
Definite articles	545.3 (187.24)	224.7 (191.85)	356	<.001	0.68
Indefinite articles	207.7 (140.26)	46.8 (64.63)	346	<.001	0.64
Locative adverbs	190.3 (214.43)	109.3 (179.63)	273.5	.42	
Mean length of utterance	8.6 (4.44)	5.3 (2.74)	323.5	.008	0.53
Mean word length	4.4 (0.49)	4.3 (0.66)	249.5	.98	
Moving-Average Type-Token Ratio	0.9 (0.02)	0.9 (0.09)	245	.98	
Nominative first-person singular pronoun	254.3 (289.92)	333.7 (272.15)	158	.98	
Plural nouns	229.6 (207.74)	139.3 (173.78)	278	.36	
Prepositions	718 (304.43)	292.2 (236.70)	366	<.001	0.72
Relative pronouns	38.1 (44.33)	12.2 (22.68)	266	.42	
Simple future	49.4 (80.68)	13.8 (38.06)	249.5	.54	
Simple past	99.6 (207.28)	143.6 (204.01)	150.5	.98	
Simple present	1623.8 (447.25)	1770.6 (391.56)	128.5	.54	
Singular nouns	1305.3 (601.49)	1027 (503.72)	253	.96	
Subordinating conjunctions	397.5 (323.62)	290.5 (246.76)	239	.98	

p-Values were adjusted using Holm correction.
n = sample size, SD = standard deviation.

Compact-AVHs excerpts																			
Example 1																			
•Dutch	<i>Ja</i>	<i>het</i>	<i>wordt</i>	<i>toch</i>	<i>niks</i> .														
•Gloss	Yes	it	become.3SG	still	not.														
•Feature of interest	simple present																		
•Translation	“Yes, it won’t work”.																		
Example 2																			
•Dutch	<i>Allemaal</i>	<i>negatieve</i>	<i>dingen</i> .																
•Gloss	All	negative	things.																
•Feature of interest	attributive adjective											plural noun							
•Translation	“All negative things”.																		
Expanded-AVHs excerpts																			
Example 3																			
•Dutch	<i>Ik</i>	<i>mag</i>	<i>niets</i>	<i>zeggen</i>	<i>maar</i>	<i>dat</i>	<i>kind</i>	<i>van</i>	<i>hun</i>	<i>heeft</i>	<i>toch</i>	<i>wel</i>	<i>een</i>	<i>behoorlijke</i>	<i>invloed</i>	<i>op</i>	<i>hun</i>	<i>relatie</i> .	
•Gloss	NOM.1SG	to be allowed to.1SG	nothing	say.INF	but	that	child	of	them	have.3SG	still	indeed	a	considerable	influence	on	their	relationship.	
•Feature of interest	first-person pronoun	simple present					singular noun	preposition	simple present			indefinite article	attributive adjective	singular noun	preposition	singular noun			
•Translation	“I should not say anything, but that child of theirs surely has a considerable influence on their relationship”.																		
Example 4																			
•Dutch	<i>Dan</i>	<i>hoef</i>	<i>je</i>	<i>er</i>	<i>niet</i>	<i>meer</i>	<i>uit</i>	<i>te</i>	<i>zien</i>	<i>als</i>	<i>die</i>	<i>oude</i>	<i>vrouw</i>	<i>die</i>	<i>toen</i>	<i>in</i>	<i>dat</i>	<i>verpleeghuis</i>	<i>lag</i> .
•Gloss	Then	have.2SG	you	PARTITIVE	not	more	PREP.PREF	PAR	look.INF	like	that	old	woman	who	at that time	in	that	nursing home	lay.3SG.IMP.P
•Feature of interest	simple present											attributive adjective	singular noun	relative pronoun	preposition	singular noun	Simple past		
•Translation	“Then you no longer have to look like that old woman who laid in that nursing home at that time”.																		

Fig. 1. Examples of both compact-AVHs and expanded-AVHs. The excerpts belong to a single participant per cluster. IMP = imperfect aspect; INF = infinitive verb; NOM = nominative case; P = past tense; PAR = particle; PREP = prepositional; PREF = prefix; SG = singular; 1 = first grammatical person; 2 = second grammatical person; 3 = third grammatical person.

Table 6
Phenomenological features of the two clusters of AVHs.

PSYRATS item	Phenomenological feature of the AVHs	Expanded-AVHs cluster, description of median [median]	Compact-AVHs cluster, description of median [median]	Expanded-AVHs (n = 18), mean (SD) ^a	Compact-AVHs (n = 22), mean (SD) ^b	Statistic		r effect size
						W	Adj. p-Value	
1	Frequency	Voices occur at least once an hour [3]	Voices occur continuously or almost continuously [4]	2.5 (1.23)	3.1 (1.04)	111.5	.70	
2	Duration	Voices last for several minutes [2]	Voices last for at least 1 h [3]	2.2 (1.03)	2.8 (1.20)	110	.70	
3	Location	Voices outside the head, but close to ears or head [2]	Voices outside the head, but close to ears or head [2]	1.9 (1.03)	2.1 (1.04)	134	.99	
4	Loudness	About same loudness as own voice [2]	About same loudness as own voice [2]	1.6 (0.70)	1.9 (0.87)	125	.97	
5	Origin	More than 50% but less than 100% of voices originate from external causes [3]	Less than 50% of voices originate from external causes [2]	2.7 (1.25)	2.6 (1.29)	162.5	.99	
6	Amount of negative content	No unpleasant content [0]	More than 50% of voice content is unpleasant or negative [3]	0.8 (1.36)	2.5 (1.47)	62	.01	−0.52
7	Degree of negative content	Not unpleasant or negative [0]	Personal verbal abuse relating to self-concept [3]	0.8 (1.36)	2.6 (1.20)	55	.009	−0.56
8	Amount of distress	Voices not distressing at all [0]	More than 50% but less than 100% of distressing voices [3]	1.1 (1.69)	2.8 (1.47)	73	.05	
9	Intensity of distress	Voices not distressing at all [0]	Voices are distressing to a moderate degree [2]	0.9 (1.34)	2 (1.19)	80.5	.09	
10	Disruption to life	No disruption to life [0]	Voices cause moderate amount of disruption to life [2]	0.7 (1.25)	2 (1.28)	75.5	.05	
11	Control	Some control most of the time [1]	Only occasional control [3]	1.7 (1.72)	2.8 (1.34)	96	.31	

p-Values were adjusted using Holm correction.

n = sample size, SD = standard deviation.

^a This information was available only for 17 of 18 participants.

^b This information was available only for 18 of 22 participants.

that expanded-AVHs had a larger proportion of verbs of location/position, time, and direction/movement (see Supplementary Table S7).

MLU was also significantly different between the AVHs-clusters, with compact-AVHs consisting of shorter MLU than expanded-AVHs. It can be reasonably assumed that fewer determiners and prepositions underlie this shorter MLU of compact-AVHs. However, correlations between MLU and both determiners and prepositions did not remain significant after correction for multiple comparisons, leaving this hypothesis unconfirmed. Notwithstanding, our finding that compact-AVHs had shorter MLU and were more often experienced by individuals with a psychiatric disorder is in line with previous studies that found a shorter MLU in clinical AVHs (de Boer et al., 2016) and reduced grammatical connectivity in clinical voice-hearers' AVHs (Tovar et al., 2019).

Interestingly, our results showed that the occurrence of the nominative first-person singular pronoun was not different between AVHs-clusters. This is intriguing, since this feature has been shown to be characteristic of clinical AVHs (McCarthy-Jones et al., 2014b). When including other linguistic functions and also counting its plural forms, the grammatical first person could still typify clinical AVHs (Tovar et al., 2019). The pronoun “ik” (i.e., “I”) represents only one of several forms and functions in which the grammatical first person can be indicated in Dutch. Therefore, our results would suggest that, rather than the nominative first-person singular pronoun, other forms and functions of the grammatical first person could be more important in distinguishing linguistic sets of AVHs across clinical and non-clinical voice hearers.

4.2. Phenomenological characterization of the AVHs

We found that compact-AVHs, which had a higher proportion of AVHs from clinical voice-hearers, were associated with a larger amount and a higher degree of negative content. This is consistent with previous research showing that AVHs are experienced to be more negative by clinical voice-hearers, although non-clinical voice-hearers also report some negative AVHs (Baumeister et al., 2017; Daalman et al., 2011; Larøi et al., 2019; Nayani and David, 1996). It is noteworthy that we failed to find a relation between the amount and degree of negative content on the one hand, and linguistic features on the other hand, as both differed between the two AVHs-clusters. However, this absence of an association is not surprising, since emotional valence of words is mainly grounded in adjectives, nouns, and verbs, as shown by affective norms for words (e.g., Moors et al., 2013), rather than in determiners, prepositions, or MLU that emerged from our linguistic analysis.

4.3. Neurocognitive models of AVHs

Inner speech/self-monitoring AVH models (Frith and Done, 1988; Jones and Fernyhough, 2007; McGuire et al., 1995) suggest that AVHs arise from inner speech, which is substantiated by neuroimaging studies (Allen et al., 2008, 2007). In comparing characteristics of inner speech to our subtypes of AVHs, a few points are of note. Fernyhough (2004) describes two types of inner speech, namely expanded and condensed inner speech. Expanded inner speech represents an internalization of overt dialogue (Fernyhough, 2004). As such, it might commonly display locational, temporal, and directional information (Yule, 1996), much like expanded-AVHs. In contrast, condensed inner speech retains few of these features (Fernyhough, 2004), similarly to compact-AVHs. However, compact-AVHs differ from condensed inner speech in their negative phenomenology. This is in line with previous research showing that clinical voice-speech contains more unpleasant and more controlling words than inner verbal thoughts (Turkington et al., 2019). While expanded-AVHs might instantiate what Fernyhough (2004) calls “expanded inner speech”, our results suggest that this is not the case for all AVHs. Specifically, the inner speech-model seems to accommodate some linguistic characteristics, but not the negative valence of compact-AVHs.

Meta-analytic evidence consistently relates activation of Broca's area

right homologue to experiencing AVHs (Zmigrod et al., 2016). Importantly, it is likely the source of AVHs with negative phenomenology and relatively simple linguistic features (de Boer et al., 2016; Larøi et al., 2019; Sommer and Diederer, 2009). Since compact-AVHs displayed features like these, it can be hypothesized that they are triggered by activation of Broca's homologue in the right hemisphere.

Another possibility is that compact-AVHs are in fact memories of previously heard speech, which is no longer recognized as such (Waters et al., 2006). Deficits in binding contextual cues (Waters et al., 2006) might also underlie the scarce identification through determiners and the few locational, temporal, and directional information shown by compact-AVHs. Moreover, misattributed recalled memories might trigger negative affect (Waters et al., 2006), and this would be reflected in compact-AVHs' negative phenomenology.

Alternatively, compact-AVHs' linguistic features might arise from disruptions in generative circuits of language-related mechanisms (Brown and Kuperberg, 2015), which tallies with the observation that referential systems are disrupted in schizophrenia-spectrum disorders (van Schuppen et al., 2019; Zimmerer et al., 2017). Çokal et al. (2018) and Sevilla et al. (2018) showed that speech of patients with schizophrenia-spectrum disorders and formal thought disorder is characterized by aberrant use of definite, but not of indefinite articles. This suggests that referentiality deficits in formal thought disorder may be linked to linguistic definiteness (Çokal et al., 2018). Our results are surprising in this respect, as both definite and indefinite articles were less frequent in compact-AVHs than in expanded-AVHs. As mentioned earlier, this does not necessarily imply anomalous referentiality in compact-AVHs, since these had more proper nouns, which by definition are referential words (Hanks, 2006). However, to date no direct comparison has been made between linguistic characterizations of spontaneous speech of voice-hearers, on the one hand, and the content of their voices, on the other. For this reason, it remains an open question to what extent our diverging findings may be explained by referentiality differences in spontaneous speech compared to AVHs.

4.4. Future directions

It has been pointed out that shared mechanisms may account for different subtypes of AVHs (McCarthy-Jones et al., 2014a). This possibility is partially supported by a recent study showing that, in non-clinical voice-hearers, different AVHs show both common and distinct brain activation (Lin et al., 2020). This is in line with the claim that multiple mechanisms could be at the root of AVHs subtypes (McCarthy-Jones et al., 2014a), which is related to meta-analytic evidence on plurality of mechanisms in AVHs (Rollins et al., 2019). It remains an open question whether expanded-AVHs and compact-AVHs can be explained by a unique neurocognitive model, or whether different models are needed to explain the emergence of these different linguistic subtypes of AVHs. Future research must address this controversy, taking into account that both linguistic features and phenomenology of AVHs subtypes should be consistently integrated with findings on other levels of explanation (Hugdahl and Sommer, 2018).

Our findings on expanded-AVHs and compact-AVHs can benefit personalized psychological therapies for AVHs. For example, expanded-AVHs displayed more identification through determiners, and richer locational, temporal, and directional information. These features are important for conversation (Yule, 1996). Thus, the Voice Dialogue method (Stone and Stone, 1989) and derivatives thereof (e.g., Corstens et al., 2012) may be indicated for voice-hearers with expanded-AVH. Those features were less present in compact-AVHs, and these AVHs were also shorter. In treating compact-AVHs, dialogue therapies would then face obstacles similar to those of trying to talk to someone who violates communicative principles (Clark, 2004; Grice, 1975). Besides, compact-AVHs had overall negative phenomenology. Considering all this, a psychological treatment for compact-AVHs might rather take advantage of voice-hearers' metalinguistic skills (Basturkmen et al.,

2002; Bialystok and Ryan, 1985; Gombert, 1993) in judging linguistic properties of their voice-speech. Just as people display attitudes toward speakers' features of speech (Dragojevic et al., 2020), voice-hearers with compact-AVHs can be taught to do so with their voices. Research shows that perceived power and superiority of the AVHs plays a large role in the resulting distress (Chadwick and Birchwood, 1994). Hence, meta-linguistic therapy reflecting on the “poor” linguistic quality of compact-AVHs could help voice-hearers to counter with the perceived status of the voices. This might also deviate their attention from the negative phenomenology, possibly alleviating distress.

Finally, as some languages do not have determiners (e.g., Finnish) nor prepositions (e.g., Pilagá, spoken in Argentina) (Dryer, 2013a, 2013b), part of our results may not be replicable in those languages. In that case, the analysis will have to be focused on elements or mechanisms that may fulfill the corresponding typological linguistic functions of determiners, prepositions and/or referential units.

4.5. Limitations

A first limitation of the present study is that we constrained our analyses to 16 linguistic variables, while of course more aspects of language could have been assessed. A related matter is that our sample size was relatively small, and there was no homogeneity in clinical voice-hearers' diagnosis nor in non-clinical voice-hearers' phenotype (Baumeister et al., 2017). This might have reduced statistical power and added variation to the data, increasing the difficulty of finding linguistic patterns in our relatively small sample. On the other hand, this heterogeneity does best reflect clinical practice and could therefore make the generalization of our results easier, since the differences we found between compact-AVHs and expanded-AVHs in both linguistic and phenomenological features had either a medium or a large effect size.

Secondly, there is no way of knowing whether the “shadows” of the participants' AVHs are a perfect reflection of the AVHs they heard. For instance, due to embarrassment of the AVHs content, some participants might have been hesitant in fully repeating their AVHs. Moreover, personal (e.g., mood and cognitive abilities) and situational factors (e.g., distractions in the room) might have influenced participants' performance in repeating their AVHs verbatim. In parallel, AVHs data from clinical voice-hearers might have been constrained by their verbal repetition skills, since results from a simulated shadow-task showed that patients with schizophrenia or schizoaffective disorder have poorer performance when compared to controls (Fuentes-Claramonte et al., 2019). Furthermore, we did not control for medication use. As anti-psychotic medication can influence language production (de Boer et al., 2020; Salomé et al., 2000), the possibility that medication effects underlie some characteristics of the clinical voice-hearers' AVHs as repeated by them cannot be ruled out.

5. Conclusions

To conclude, using a data-driven approach with linguistic features, two clusters of voice-speech could be recognized. Linguistically, these AVHs-clusters, which we named “compact” and “expanded”, mainly differed in their use of referential information and syntactic complexity. Phenomenologically, the amount of negative content and degree of negativity were the most important differences between the AVHs-clusters. Our data show that, compared to expanded-AVHs, compact-AVHs were mainly experienced by clinical voice-hearers. These findings can inform neurocognitive models of AVHs, and also be useful in developing treatments for people with a specific subtype of AVHs.

Role of the funding source

The founding sources had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

CRedit authorship contribution statement

H. Corona-Hernández: Conceptualization, Data curation, Formal analysis, Methodology, Writing-Original draft. **S. G. Brederoo:** Conceptualization, Methodology, Writing-Review & editing. **J. N. de Boer:** Conceptualization, Methodology, Writing-Review & editing. **I. E. C. Sommer:** Funding Acquisition, Supervision, Writing-Review & editing.

Declaration of competing interest

All authors declare that they have no conflicts of interest.

Acknowledgement

This project was supported by ZonMW mental health (GGZ) call, project number 636310010. HCH was additionally supported by the Consejo Nacional de Ciencia y Tecnología (CONACyT, Mexican Government, scholarship number 739604).

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.schres.2022.01.055>.

References

- Allen, P., Aleman, A., McGuire, P.K., 2007. Inner speech models of auditory verbal hallucinations: evidence from behavioral and neuroimaging studies. *Int. Rev. Psychiatry* 19, 409–417.
- Allen, P., Larøi, F., McGuire, P.K., Aleman, A., 2008. The hallucinating brain: a review of structural and functional neuroimaging studies of hallucinations. *Neurosci. Biobehav. Rev.* 32, 175–191.
- Andreasen, N.C., Flaum, M., Arndt, S., 1992. The Comprehensive Assessment of Symptoms and History (CASH): an instrument for assessing diagnosis and psychopathology. *Arch. Gen. Psychiatry* 49, 615–623.
- Basturkmen, H., Loewen, S., Ellis, R., 2002. Metalanguage in focus on form in the communicative classroom. *Lang. Aware.* 11, 1–13.
- Baumeister, D., Sedgwick, O., Howes, O., Peters, E., 2017. Auditory verbal hallucinations and continuum models of psychosis: a systematic review of the healthy voice-hearer literature. *Clin. Psychol. Rev.* 51, 125–141.
- Beavan, V., Read, J., Cartwright, C., 2011. The prevalence of voice-hearers in the general population: a literature review. *J. Ment. Health* 20, 281–292.
- Benoit, K., Watanabe, K., Wang, H., Nulty, P., Obeng, A., Müller, S., Matsuo, A., 2018. Quanteda: an R package for the quantitative analysis of textual data. *J. Open Source Softw.* 3, 774.
- Bialystok, E., Ryan, E.B., 1985. Toward a definition of metalinguistic skill. *Merrill-Palmer Q.* 31, 229–251.
- Biber, D., 1988. *Variation Across Speech And Writing*. Cambridge University Press, New York, NY.
- Brezina, V., 2018. *Statistics in Corpus Linguistics: A Practical Guide*. Cambridge University Press, New York, NY.
- Brown, M., Kuperberg, G.R., 2015. A hierarchical generative framework of language processing: linking language perception, interpretation, and production abnormalities in schizophrenia. *Front. Hum. Neurosci.* 9, 1–23.
- Burchett, W.W., Ellis, A.R., Harrar, S.W., Bathke, A.C., 2017. Nonparametric inference for multivariate data: the R package nrmv. *J. Stat. Softw.* 76, 1–18.
- Chadwick, P., Birchwood, M., 1994. The omnipotence of voices: a cognitive approach to auditory hallucinations. *Br. J. Psychiatry* 164, 190–201.
- Chang, J.S., Kim, Y., Kim, S.H., Hwang, S., Kim, J., Chung, I.-W., Kim, Y.S., Jung, H.-Y., 2015. Differences in the internal structure of hallucinatory experiences between clinical and nonclinical populations. *Psychiatry Res.* 226, 204–210.
- Chang, J.S., Yi, J.S., Ahn, Y.M., Kim, J.H., Kim, Y.S., 2009. Stabilization of the internal structure of persistent auditory verbal hallucinations in schizophrenia. *Aust. N. Z. J. Psychiatry* 43, 244–251.
- Charrad, M., Ghazzali, N., Boiteau, V., Niknafs, A., 2014. NbClust: an R package for determining the relevant number of clusters in a data set. *J. Stat. Softw.* 61, 1–36.
- Clark, H.H., 2004. Pragmatics of language performance. In: Horn, L.R., Ward, G. (Eds.), *The Handbook of Pragmatics*. Blackwell, Malden, Massachusetts, pp. 365–382.
- Çokal, D., Sevilla, G., Jones, W.S., Zimmerer, V., Deamer, F., Douglas, M., Spencer, H., Turkington, D., Ferrier, N., Varley, R., Watson, S., Hinzen, W., 2018. The language profile of formal thought disorder. *NPJ Schizophr.* 4, 1–8.
- Corstens, D., Longden, E., May, R., 2012. Talking with voices: exploring what is expressed by the voices people hear. *Psychos. Psychol. Soc. Integr. Approaches* 4, 95–104.
- Covington, M.A., McFall, J.D., 2010. Cutting the Gordian knot: the moving-average type-token ratio (MATTR). *J. Quant. Linguist.* 17, 94–100.

- Daalman, K., Boks, M.P.M., Dieren, K.M., de Weijer, A.D., Blom, J.D., Kahn, R.S., Sommer, I.E.C., 2011. The same or different? A phenomenological comparison of auditory verbal hallucinations in healthy and psychotic individuals. *J. Clin. Psychiatry* 72, 320–325.
- David, A.S., 2010. Why we need more debate on whether psychotic symptoms lie on a continuum with normality. *Psychol. Med.* 40, 1935–1942.
- de Boer, J.N., Heringa, S.M., van Dellen, E., Wijnen, F.N.K., Sommer, I.E.C., 2016. 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. *Brain Lang.* 162, 10–18.
- de Boer, J.N., Voppel, A.E., Brederoo, S.G., Wijnen, F.N.K., Sommer, I.E.C., 2020. Language disturbances in schizophrenia: the relation with antipsychotic medication. *NPJ Schizophr.* 6, 1–9.
- Dragojevic, M., Fasoli, F., Cramer, J., Rakić, T., 2020. Toward a century of language attitudes research: looking back and moving forward. *J. Lang. Soc. Psychol.* 1–20.
- Dryer, M.S., 2013a. Order of adposition and noun phrase. In: Dryer, M.S., Haspelmath, M. (Eds.), *The World Atlas of Language Structures Online*. Max Planck Institute for Evolutionary Anthropology, Leipzig.
- Dryer, M.S., 2013b. Definite articles. In: Dryer, M.S., Haspelmath, M. (Eds.), *The World Atlas of Language Structures Online*. Max Planck Institute for Evolutionary Anthropology, Leipzig.
- Fernyhough, C., 2004. Alien voices and inner dialogue: towards a developmental account of auditory verbal hallucinations. *New Ideas Psychol.* 22, 49–68.
- First, M.B., Spitzer, R.L., Gibbon, M., Williams, J.B.W., 1995. The structured clinical interview for DSM-III-R personality disorders (SCID-II). Part I: description. *J. Personal. Disord.* 9, 83–91.
- Frank, S.M., Rendon, M.I., Siomopoulos, G., 1980. Language in hallucinations of adolescent schizophrenics. In: Rieber, R.W. (Ed.), *Applied Psycholinguistics And Mental Health*. Springer, Boston, MA, pp. 115–126.
- Frith, C.D., Done, D.J., 1988. Towards a neuropsychology of schizophrenia. *Br. J. Psychiatry* 153, 437–443.
- Fuentes-Claramonte, P., Soler, J., Hinzen, W., Ramiro-Sousa, N., Rodríguez-Martínez, A., Sarri-Closa, C., Sarró, S., Larrubia, J., Padilla, P.P., McKenna, P.J., Pomarol-Clotet, E., 2019. The interfering effects of frequent auditory verbal hallucinations on shadowing performance in schizophrenia. *Schizophr. Res.* 208, 488–489.
- Giacalone Ramat, A., Andorno, C.M., 2006. Referential relations in spoken discourse. In: Brown, K., Anderson, A.H., Bauer, L., Berns, M., Hirst, G., Miller, J. (Eds.), *The Encyclopedia of Language & Linguistics*. Elsevier Publishing, pp. 450–457.
- Gombert, J.E., 1993. Metacognition, metalanguage and metapragmatics. *Int. J. Psychol.* 28, 571–580.
- Grice, H.P., 1975. Logic and conversation. In: Cole, P., Morgan, J.L. (Eds.), *Syntax And Semantics 3: Speech Acts*. Academic Press, New York, NY, pp. 41–58.
- Grieve, J., Ruetten, T., Speelman, D., Geeraerts, D., 2017. Social functional linguistic variation in conversational Dutch. In: Fringali, E. (Ed.), *Studies in Corpus-based Sociolinguistics*. Routledge, New York, NY, pp. 253–272.
- Haddock, G., McCarron, J., Tarrier, N., Faragher, E.B., 1999. Scales to measure dimensions of hallucinations and delusions: the psychotic symptom rating scales (PSYRATS). *Psychol. Med.* 29, 879–889.
- Hanks, P., 2006. Proper names: linguistic status. In: Brown, K., Anderson, A.H., Bauer, L., Berns, M., Hirst, G., Miller, J. (Eds.), *The Encyclopedia of Language & Linguistics*. Elsevier Publishing, pp. 134–137.
- Hoffman, R.E., Oates, E., Hafner, J., Hustig, H.H., McGlashan, T.H., 1994. Semantic organization of hallucinated “voices” in schizophrenia. *Am. J. Psychiatry* 151, 1229–1230.
- Hugdahl, K., Sommer, I.E.C., 2018. Auditory verbal hallucinations in schizophrenia from a levels of explanation perspective. *Schizophr. Bull.* 44, 234–241.
- Jones, S.R., 2010. Do we need multiple models of auditory verbal hallucinations? Examining the phenomenological fit of cognitive and neurological models. *Schizophr. Bull.* 36, 566–575.
- Jones, S.R., Fernyhough, C., 2007. Thought as action: inner speech, self-monitoring, and auditory verbal hallucinations. *Conscious. Cogn.* 16, 391–399.
- Juvonen, P., 2006. Articles, definite and indefinite. In: Brown, K., Anderson, A.H., Bauer, L., Berns, M., Hirst, G., Miller, J. (Eds.), *The Encyclopedia of Language & Linguistics*. Elsevier Publishing, pp. 484–487.
- Klein, H., 1998. Adverbs of Degree in Dutch And Related Languages. John Benjamins Publishing Company, Amsterdam, The Netherlands.
- Kurzon, D., 2006. Adpositions. In: Brown, K., Anderson, A.H., Bauer, L., Berns, M., Hirst, G., Miller, J. (Eds.), *The Encyclopedia of Language & Linguistics*. Elsevier Publishing, pp. 63–66.
- Larøi, F., Sommer, I.E.C., Blom, J.D., Fernyhough, C., Ffytche, D.H., Hugdahl, K., Johns, L. C., McCarthy-Jones, S., Preti, A., Raballo, A., Slotema, C.W., Stephane, M., Waters, F., 2012. The characteristic features of auditory verbal hallucinations in clinical and nonclinical groups: state-of-the-art overview and future directions. *Schizophr. Bull.* 38, 724–733.
- Larøi, F., Thomas, N., Aleman, A., Fernyhough, C., Wilkinson, S., Deamer, F., McCarthy-Jones, S., 2019. The ice in voices: understanding negative content in auditory-verbal hallucinations. *Clin. Psychol. Rev.* 67, 1–10.
- Lin, X., Zhuo, C., Li, G., Li, J., Gao, X., Chen, C., Jiang, D., 2020. Functional brain alterations in auditory hallucination subtypes in individuals with auditory hallucinations without the diagnosis of specific neurological diseases and mental disorders at the current stage. *Brain Behav.* 10, 1–12.
- Maijer, K., Begemann, M.J.H., Palmen, S.J.M.C., Leucht, S., Sommer, I.E.C., 2018. Auditory hallucinations across the lifespan: a systematic review and meta-analysis. *Psychol. Med.* 48, 879–888.
- McCarthy-Jones, S., Thomas, N., Strauss, C., Dodgson, G., Jones, N., Woods, A., Brewin, C.R., Hayward, M., Stephane, M., Barton, J., Kingdon, D., Sommer, I.E.C., 2014a. Better than mermaids and stray dogs? Subtyping auditory verbal hallucinations and its implications for research and practice. *Schizophr. Bull.* 40, S275–S284.
- McCarthy-Jones, S., Trauer, T., Mackinnon, A., Sims, E., Thomas, N., Copolov, D.L., 2014b. A new phenomenological survey of auditory hallucinations: evidence for subtypes and implications for theory and practice. *Schizophr. Bull.* 40, 231–235.
- McGuire, P.K., David, A.S., Murray, R.M., Frackowiak, R.S.J., Frith, C.D., Wright, I., Silbersweig, D.A., 1995. Abnormal monitoring of inner speech: a physiological basis for auditory hallucinations. *Lancet* 346, 596–600.
- Menyhart, O., Weltz, B., Györfy, B., 2021. MultipleTesting.com: a tool for life science researchers for multiple hypothesis testing correction. *PLOS ONE* 16, e0245824. <https://doi.org/10.1371/journal.pone.0245824>.
- Moors, A., De Houwer, J., Hermans, D., Wanmaker, S., van Schie, K., Van Harmelen, A.-L., De Schryver, M., De Winne, J., Brysbaert, M., 2013. Norms of valence, arousal, dominance, and age of acquisition for 4,300 Dutch words. *Behav. Res. Methods* 45, 169–177.
- Nayani, T.H., David, A.S., 1996. The auditory hallucination: a phenomenological survey. *Psychol. Med.* 26, 177–189.
- Oosterhoff, J., 2015. *Modern Dutch Grammar: A Practical Guide*. Routledge, New York, NY.
- Platt, J.C., 1999. Fast training of support vector machines using sequential minimal optimization. In: Schölkopf, B., Burges, C.J.C., Smola, A.J. (Eds.), *Advances in Kernel Methods: Support Vector Learning*. MIT Press, Cambridge, Mass, pp. 185–208.
- R Core Team, 2020. R: A Language And Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.
- Richards, B., 1987. Type/token ratios: what do they really tell us? *J. Child Lang.* 14, 201–209.
- Rollins, C.P.E., Garrison, J.R., Simons, J.S., Rowe, J.B., O’Callaghan, C., Murray, G.K., Suckling, J., 2019. Meta-analytic evidence for the plurality of mechanisms in transdiagnostic structural MRI studies of hallucination status. *EClinicalMedicine* 8, 57–71.
- RStudio Team, 2019. RStudio: Integrated Development Environment for R. RStudio Inc, Boston, MA.
- Salomé, F., Boyer, P., Fayol, M., 2000. The effects of psychoactive drugs and neuroleptics on language in normal subjects and schizophrenic patients: a review. *Eur. Psychiatry* 15, 461–469.
- Sevilla, G., Rosselló, J., Salvador, R., Sarró, S., López-Araquistain, L., Pomarol-Clotet, E., Hinzen, W., 2018. Deficits in nominal reference identify thought disordered speech in a narrative production task. *PLOS ONE* 13, e0201545.
- Sommer, I.E.C., Dieren, K.M., 2009. Language production in the non-dominant hemisphere as a potential source of auditory verbal hallucinations. *Brain* 132, e124.
- Sommer, I.E.C., Kleijer, H., Hugdahl, K., 2018. Toward personalized treatment of hallucinations. *Curr. Opin. Psychiatry* 31, 237–245.
- Stephane, M., Thuras, P., Nasrallah, H., Georgopoulos, A.P., 2003. The internal structure of the phenomenology of auditory verbal hallucinations. *Schizophr. Res.* 61, 185–193.
- Stone, H., Stone, S., 1989. *Embracing Our Selves: The Voice Dialogue Training Manual*. Nataraj Publishing, Novato, California.
- Svenonius, P., 2007. Adpositions, particles and the arguments they introduce. In: Reuland, E.J., Bhattacharya, T., Spathas, G. (Eds.), *Argument Structure*. John Benjamins, Amsterdam, The Netherlands, pp. 63–103.
- Talmy, L., 2000. *Toward a Cognitive Semantics*. The MIT press, Cambridge, Mass.
- Tovar, A., Fuentes-Claramonte, P., Soler-Vidal, J., Ramiro-Sousa, N., Rodríguez-Martínez, A., Sarri-Closa, C., Sarró, S., Larrubia, J., Andrés-Bergareche, H., Miguel-Cesma, M.C., Padilla, P.P., Salvador, R., Pomarol-Clotet, E., Hinzen, W., 2019. The linguistic signature of hallucinated voice talk in schizophrenia. *Schizophr. Res.* 206, 111–117.
- Turkington, G.D., Lawrence, T., Stuart, W., 2019. Linguistic analysis of the valence, arousal and dominance of auditory hallucinations and internal thoughts in schizophrenia: implications for psychoeducation and CBT. *Cogent Psychol.* 6, 1–5.
- van Schuppen, L., van Krieken, K., Sanders, J., 2019. Deictic navigation network: linguistic viewpoint disturbances in schizophrenia. *Front. Psychol.* 10, 1–8.
- Waters, F., Badcock, J., Michie, P., Maybery, M., 2006. Auditory hallucinations in schizophrenia: intrusive thoughts and forgotten memories. *Cognit. Neuropsychiatry* 11, 65–83.
- Waters, F., Fernyhough, C., 2017. Hallucinations: a systematic review of points of similarity and difference across diagnostic classes. *Schizophr. Bull.* 43, 32–43.
- Witten, I.H., Frank, E., Hall, M.A., Pal, C.J., 2016. *The WEKA workbench*. In: *Data Mining: Practical Machine Learning Tools And Techniques*. Morgan Kaufmann, Cambridge, Mass, pp. 553–571.
- Woods, A., Jones, N., Alderson-Day, B., Callard, F., Fernyhough, C., 2015. Experiences of hearing voices: analysis of a novel phenomenological survey. *Lancet Psychiatry* 2, 323–331.
- Yule, G., 1996. *Pragmatics*. Oxford University Press, New York, NY.
- Zimmerer, V.C., Watson, S., Turkington, D., Ferrier, I.N., Hinzen, W., 2017. Deictic and propositional meaning-new perspectives on language in schizophrenia. *Front. Psychiatry* 8, 1–17.
- Zmigrod, L., Garrison, J.R., Carr, J., Simons, J.S., 2016. The neural mechanisms of hallucinations: a quantitative meta-analysis of neuroimaging studies. *Neurosci. Biobehav. Rev.* 69, 113–123.