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Bachelor Thesis

Speech Anomalies as a Symptom of Formal Thought Disorder in Schizophrenia: The Sensitivity of The Thought and Language Dysfunction Scale on Speech Related Items

Contents

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Abstract

Formal thought disorder (FTD) is a core symptom of schizophrenia and has been described as a set of language, thinking and communication deficits. The diagnosis of FTD takes place using a clinical rating scale that often encompasses speech related items. However, the relation between FTD and speech anomalies has yet to be explored. This study therefore investigated whether the speech related items of the Thought and Language Dysfunction Scale (TALD) corresponded with automatically measured features of the acoustic speech signal. Spontaneous speech of patients with schizophrenia (n=42) as well as healthy controls (n=42) was analysed using acoustic speech analysis software programs for 11 speech parameters. Results showed that, in comparison to healthy controls, patients with schizophrenia spoke softer, had a higher F1 frequency, made longer pauses, varied less in speech volume, had more shimmer, spoke a smaller percentage of the time and had a slower speech rate. However, no significant differences were found between patients with severe FTD and patients with less severe FTD. The sensitivity of the TALD was assessed by analysing the correlation between five speech related items on the scale and their associated speech parameters. Only two out of five items of the TALD correlated significantly with their associated speech parameter, suggesting the TALD is an inaccurate clinical tool with regards to speech related anomalies.

Key words: phonetic characteristics, voice analysis, language, schizophrenia, TALD, speech, formal thought disorder.

1 Introduction

Formal thought disorder (FTD) is a multifaceted set of symptoms, reflecting peculiarities in thinking, language, and communication (Hart and Lewine, 2017). It encompasses a diverse set of language and thought disturbances, including loose and indirect associations, illogicality, overly abstract or concrete responses, inappropriate intrusion of personal information and unusual word usage (Holzman et al., 1986). FTD occurs in patients with mania, organic diseases, depression and personality disorders but is most closely linked to schizophrenia (Kircher et al., 2014). FTD is a core symptom of schizophrenia, observed in approximately 50-80 % of the patients (Cavelti et al., 2018). However, insufficient understanding of the underlying mechanisms behind FTD

has limited the prospect of adequate patient recovery (Tan and Rossell, 2019). Getting to the core of FTD is hard, since the concept of thought is rather philosophical and drawing conclusions about the organisation, control or processing of thoughts through experimental research is therefore difficult. Andreasen (1979) argued that we can gain access to a person's thoughts through their speech. Since the disorganisation of language is an observable expression of FTD (Xu et al., 2014), the relation between language dysfunctions and schizophrenia has been studied on many levels. According to Kuperberg (2010), FTD could be defined as the set of severe language and communication deficits that occur in patients with schizophrenia.

1.1 Language deficits in FTD

Anomalies in language and communication are seen in most of the patients diagnosed with schizophrenia (Covington et al., 2005). However, only when these deficits occur in a severe form in a patient, it is classified as FTD (Kuperberg, 2010). Observable manifestations of FTD are mostly recognised in disorganised speech, comprising loose associations, derailment, tangentiality, or incoherence (Çokal et al., 2018). As argued by de Boer et al. (2020), the commonly used phrase 'disorganised speech' in relation to FTD patients could better be substituted for 'disturbed language', since the disorganisation does not occur at the level of sounds but is presented in semantic, pragmatic and syntactic dysfunction. For instance, Çokal et al. (2018) found that patients with FTD produce more referential anomalies, fewer definite noun phrases and less complex syntactic structures than people without schizophrenia. Access to the mental lexicon is impaired in many patients, resulting in stilted speech, word approximation and neologisms (Covington et al., 2005). Importantly, FTD can be sub-categorised into positive FTD (PosFTD) and negative FTD (NegFTD) and both these subcategories are related to different language anomalies. Symptoms associated with schizophrenia are often classified in either positive or negative symptoms, with the former being characterised as the appearance of experiences that would normally be absent (e.g. delusions and hallucinations) and the latter as a decrease of what would normally be present, encompassing alogia, affective flattening, avolition, apathy, anhedonia, anergia, inattentiveness and poverty of speech. (Sass, 2003). PosFTD is clinically characterised by incoherence in language, inattentiveness, and the use of idiosyncratic words, NegFTD is characterised by a reduction in the amount of meaningful speech (Kircher et al., 2001). Deficits in semantic processing and syntactic comprehension are mostly observed in PosFTD, while NegFTD seems to be mostly associated with semantic comprehension (Nagels et al., 2016). It has been established that patients with schizophrenia more frequently have NegFTD compared to, for example, patients with mania, who more often have PosFTD (Andreasen and Grove, 1986).

1.2 Speech anomalies in schizophrenia

The different study results discussed in section 1.1 indicate that language abilities are impaired in FTD patients. However, the amount of research on this subject is limited and, more importantly, no research has yet been done on the characteristics of speech in FTD patients, even though speech in patients with schizophrenia is known to be aberrant (Cavelti et al., 2018; Kircher et al., 2018; Parola et al., 2019; Çokal et al., 2019). A recent meta-analysis of Parola et al. (2019) investigated voice patterns of patients with schizophrenia by analysing different possible speech aberrations. The comparison of study results showed significant differences between the speech of patients with schizophrenia and healthy controls, mainly on temporal speech measurements. The proportion of spoken time, pause duration, pitch variability and speech rate differed significantly between groups. The most significant effect was found for pause duration, which was especially related to negative symptoms in schizophrenia. Other studies showed that not only the duration

of pauses is longer in patients with schizophrenia, but the number of pauses is significantly higher as well (Rapcan et al., 2010; Martínez-Sánchez et al., 2015). Clinical symptoms of schizophrenia that can be related to specific voice characteristics yield stronger results. For instance, *flat affect* is associated with pitch variability and the proportion of spoken time, and *alogia* can be related to the proportion of spoken time as well. An important remark Parola et al. (2019) make concerns the cognitive load of experimental tasks in studies. Tasks with higher cognitive load and tasks that require more social competences appear to result in larger effect sizes for speech anomalies, both in the comparison between people with and without schizophrenia and in the assessment of symptoms. The smallest effect sizes are seen in tasks in which patients can speak freely (Parola et al., 2019). Research on language in schizophrenia, or specifically on FTD, should therefore focus on the analysis of spontaneous speech and language aspects that require a low cognitive load, in order to prevent measuring cognitive deficits more than language deficits.

1.3 Phonetic speech characteristics

Characteristics of speech that are not related to cognition can be found at the level of phonetics. To the best of our knowledge, no work has been done on phonetic speech characteristics in patients with FTD. However, patients with schizophrenia are for instance known to have a lower mean fundamental frequency (f0) and reduced variability (Bernardini et al., 2016), a lower standard deviation of the second formant (Compton et al., 2018), a lower voice intensity (Martínez-Sánchez et al., 2015) and less variation in loudness (Compton et al., 2018). The lower mean fundamental frequency (f0) and reduced variability is often related to the negative symptom *flat effect* seen in patients with schizophrenia.

The fundamental frequency is defined as the amount of repetitions of a sound wave that is being produced by the vocal cords during a certain period of time, which is equivalent to the number of cycles of opening and closure of the glottis (Teixeira et al., 2013). Disturbances of the f0, jitter and shimmer, are shown to increase in laryngeal pathology and can therefore indicate voice disorders (Brockmann et al., 2011; Teixeira et al., 2013). Jitter is determined by frequency variation from cycle to cycle (Zwetsch et al., 2006) and is caused by a lack of control over the vibration of the vocal cords (Teixeira et al., 2013). Shimmer refers to the amplitude of the sound wave and is related to glottal resistance and mass lesions on the vocal cords (Teixeira et al., 2013; Covington et al., 2012). Articulatory movements involved in speech production can be measured phonetically through spectral analyses (Zhang, 2016) and have shown to be adequate measurements for the recognition of (motor) speech disorders (Sapir et al., 2010). A formant is a spectral shaping caused by acoustic resonance of the vocal tract (Zhang, 2016) and enables people to differentiate speech sounds, in particularly vowels. The first two formants are sufficient markers for identification of normal and pathological voices (Srinivasan et al., 2012). The first formant 1 (F1) is related to the jaw or mouth opening and, consequently, tongue height, and the second formant (F2) is determined by the front or back position of the tongue or the rounding of the lips (Compton et al., 2018). To summarise, these different speech characteristics all form possible causes of what can be perceived as aberrant speech in general. Due to the association of these speech parameters with either schizophrenia or pathological voices in general, it can be hypothesised that these speech anomalies occur in patients with FTD as well.

1.4 FTD assessment

The diagnosis of FTD takes place through assessment by a clinician that uses a recognised clinical rating tool. Different rating tools have been developed over the years, focusing on a diverse range of phenomena and encompassing different items and rating criteria. The most recently developed

and recognised rating tool is the Thought and Language Dysnfunction Scale (TALD) (Kircher et al., 2014). The TALD distinguishes itself from other rating scales for FTD by not only using objective assessment, but also including a subjective component where the patient can report on certain phenomena itself. The TALD includes all reported FTD symptoms from the early 20th century onwards (Kircher et al., 2014) and is a comprehensive and convenient measure with good psychometric qualities (Kircher et al., 2018; Mutlu et al., 2019). Patients receive a score on thirty different items which are assessed during a clinical interview performed by a clinician. Out of the thirty phenomena that the scale contains, the TALD seems to measure the speech of the patients on at least five items. These selected items, which are expected to be directly related to or expressed by speech, are listed in table 5 in the Appendix. Subjective TALD-scores were eliminated from the analysis to prevent possible validity violations due to the subjective nature of these values. Interestingly, despite the fact that there seems to be no research on speech characteristics in patients with FTD, the TALD diagnoses FTD on the basis of at least several speech related items. On top of that, the anomalies in speech are assessed by the personal and therefore subjective judgement of a clinical rater. The assessment of FTD by making use of the TALD therefore raises the question of how the speech related items on this clinical rating scale are represented in the speech of patients with FTD.

1.5 The current study

This study investigates whether the current subjective identification of abnormal speech in FTD corresponds to what can be objectively measured in speech. Severity of speech anomalies in patients with schizophrenia is often used as one of the clinical markers of FTD, with speech related items being part of clinical rating tools such as the TALD. However, symptoms like *poverty of speech, logorrhoea or pressured speech* seem diagnostically unspecific and possibly rater dependent. The current study therefore aims to verify the convergent validity of the TALD on certain speech related rating components by comparing these TALD scores with extracted features of the acoustic speech signals. We hypothesise that the TALD-phenomenon *Rupture of Thought* should be represented by the number of pauses, the TALD-phenomenon *Pressured Speech* by the speech rate, the TALD-phenomenon *Slowed Thinking* by the duration of pauses and the speech rate, the TALD-phenomenon *Logorrhoea* by the proportion of spoken time and the TALD-phenomenon *Poverty of Speech* by the proportion of spoken time. A discrepancy between the mentioned TALD-phenomena and their related speech parameters would underline the need for objective measurements of FTD symptoms.

We further hypothesise that anomalies in phonetic and temporal speech properties are most strongly correlated to NegFTD, since deficits in speech fluency are reported to be related to NegFTD more than to PosFTD (Rapcan et al., 2010; Bora et al., 2019). The correlation of these speech anomalies with FTD could provide an insight in the possible linguistic foundation of FTD severity in schizophrenia.

2 Method

2.1 Participants

This study included a total of 42 patients that participated in a randomised controlled medication trial (RAPSODI (ClinicalTrials.gov, 2017)) at the psychiatry department of the University Medical Centre Utrecht. All patients were diagnosed according to the DSM-IV classification (Sheehan et al., 1998) and either had a diagnosis of 295.x or 298.9. The duration of disease, the

PANNS scores and the TALD scores were also reported to give an overview of the patient group. In addition, 42 healthy participants (age, gender and parental education matched) were used as a control group. All participant in this study were over eighteen years old, native speakers of Dutch and did not have an uncorrected hearing impairment or a language or speech disorder.

Patients were recruited in both in- and outpatient facilities throughout the Netherlands. All participants participated voluntarily and gave written informed consent prior to participation. They received a gift card for their participation. The RAPSODI study was approved by the research and ethics committee of the University Medical Center Utrecht and was performed in accordance with the Declaration of Helsinki.

2.2 Acquisition of speech samples

A semi-structured interview was conducted by trained interviewers in order to elicit spontaneous speech from all participants. The interview consisted of open-ended informal questions concerning daily life topics. To strengthen ecological validity, participants were not informed about the linguistic focus of the study until after the interview. If a participant did not want to answer a question the interviewer continued to the next question. The interview was recorded for fifteen minutes using headsets with microphones and a TASCAM DR-40 V2 4-channel digital audio recorder.

2.3 Measures

2.3.1 FTD assessment

All patients were screened for presence of formal thought disorder using the TALD, developed by Kircher et al. (2014). The scale consists of 30 items encompassing four FTD factors: Objective Positive (ObjPos), Subjective Negative (SubNeg), Objective Negative (ObjNeg) and Subjective Positive (SubPos). The objectively observable and subjectively reported symptoms are evaluated in a semi-structured clinical interview of fifty-minutes. The assessment of the objective symptoms (ObjPos and ObjNeg) takes place during the interview and the assessment of subjective items (SubPos and SubNeg) takes place shortly after the interview. The subjective symptoms are phenomena that have been directly asked about by the rater and thus reported by the patients themselves.

Each item can be scored on a likert-scale from 0 to 4. The severity of the phenomena is established based on the score options represented in Table 1.

Table 1: Severity Assessment of Items on the TALD

Score	Graduation
0	Not present
1	Doubtful (not clearly pathological, may also occur in healthy individuals)
2	Mild
3	Moderate
4	Severe

The TALD was assessed by consensus rating of two trained researchers. Since some of the phenomena only occur under stressful circumstances (delusions, hallucinations, emotional life events, etc.) the interviewers addressed emotional topics as well.

The patients were split into a group that displayed substantial FTD symptoms and a group that displayed little or less FTD symptoms using a median split. These groups were being categorised respectively as *high FTD* and *low FTD*.

2.3.2 Phonetic assessment

The phonetic characteristics of the speech of the participants were measured using openSMILE and PRAAT. OpenSMILE is an open-source analysis tool that enables feature extraction and audio analysis of speech signals by applying machines learning methods to classify and analyse data (Eyben et al., 2010). Pitch variability, loudness, variation in loudness, jitter, shimmer, F1 frequency and F2 frequency were established by making use of the The Geneva Minimalistic Acoustic Parameter Set (GeMAPS) for Voice Research and Affective Computing (Eyben et al., 2010).

PRAAT is a free software package for the analysis of acoustic speech signals (Boersma and Weenink, 2009) and is used to measure the number of pauses, the speech rate and the proportion of spoken time of each participant. In addition, the average duration of pauses was investigated for this study as well. The duration of pauses was calculated by subtracting the phonation time from the participant's total speaking time and subsequently dividing this result by the number of pauses. The *number of pauses* variable includes the number of times a participant paused for a minimum of 0.3 seconds. The pause duration is measured in minutes rounded to two decimal places and the proportion of spoken time is expressed as a percentage of the total duration of the interview.

The measurement of the speech parameters is performed using different statistics, particularly based on influences of sex. Since several speech parameters are strongly influenced by sex (Biemans, 2000; Iseli et al., 2007), the standard deviation of these parameters (pitch, jitter and shimmer) was used instead of the mean. For the F1 and F2 frequency the standard deviation has been used as well, in pursuance of previous studies on this topic (Bernardini et al., 2016; Compton et al., 2018).

2.4 Statistical analyses

Two multivariate analyses of covariance (MANCOVA) were performed to examine whether the covariant matrix of the speech parameters differed significantly between groups (patients versus controls, and *high FTD* versus *low FTD*). Covariates were age, sex and parental education. Post-hoc independent samples t-tests were performed to assess differences for each variable independently.

Pearson's correlations were calculated between the objective TALD-subscores and the speech variables, as well as between ObNeg and speech variables specifically. Furthermore, the five TALD phenomena (Rupture of Thought, Pressured Speech, Slowed Thinking, Logorrhoea and Poverty of Speech) were tested by conducting Pearson's correlations between these selected items and their associated speech parameters.

3 Results

3.1 Sociodemographic and clinical characteristics

Table 2 shows the demographic and clinical characteristics of the patient group as a whole, the subgroups *high FTD* and *low FTD* and the healthy control group. Patients with a schizophrenia-

Table 2: Demographic and Clinical Characteristics of Healthy Controls (HC), Schizophrenia Patients and Low and High FTD subgroups

	HC	Schizophrenia	Low FTD	High FTD
Sample size, n	42	42	21	21
Male gender, n (%)	31 (73.8)	31 (73.8)	12 (57.1)	19 (90.5)
Age, mean (SD)	42.6 (11.63)	43.3 (11.18)	44.6 (11.78)	42.2 (10.71)
Years of education, mean (SD)	15.1 (1.58)	13.2 (1.96)	13.3 (1.80)	13.1 (2.15)
Years of education parents, mean (SD)	11.8 (2.89)	11.8 (2.87	11.3 (2.79)	12.3 (2.94)
Duration disease years, mean (SD)	-	17.2 (11.78)	17.4 (13.32)	17.0 (10.34)
\textbf{DSM diagnosis, n (%)}				
Schizophrenia	-	30 (71.4)	15 (71.4)	15 (71.4)
Schizoaffective disorder	-	10 (23.8)	5 (23.8)	5 (23.8)
Psychosis NOS	-	2 (4.8)	1 (4.8)	1 (4.8)
\textbf{PANSS, mean (SD)}				
Total	-	51.5 (13.01)	44.6 (11.78)	58.1 (13.36)
Positive	-	13.2 (5.04)	11.1 (4.58)	15.2 (4.73)
Negative	-	11.8 (4.15)	10.5 (3.34)	13.0 (4.57)
General	-	26.5 (7.03)	23.1 (4.15)	29.9 (7.77)
\textbf{TALD, mean (SD)}				
Total	-	18.0 (8.87)	10.9 (5.35)	25.1 (5.12)
ObjPos	-	4.6 (5.37)	1.7 (2.22)	7.6 (5.97)
ObjNeg	-	1.4 (1.53)	1.1 (1.42)	1.7 (1.62)
SubPos	-	3.1 (2.38)	1.9 (2.10)	4.3 (1.98)
SubNeg	-	8.9 (4.92)	6.2 (4.04)	11.5 (4.36)

spectrum disorder and healthy controls on average did not differ in age, gender distribution, level of education and parental level of education.

3.2 Group comparisons

The first MANCOVA showed there was a statistically significant difference between the patient group and the control group on the combined dependent variables after controlling for age, sex and parental level of education, $F(11, 69) = 9.50$, $p < .001$, Wilks' $\Lambda = .40$, partial $\eta 2 = .60$. Means, standard deviations and level of significance of each speech parameter are listed for both groups in Table 3. Post-hoc independent samples t-tests showed significant differences on individual dependent variables. The patient group spoke softer, had a higher F1 frequency, made longer pauses, varied less in speech volume, had more shimmer, spoke a smaller percentage of the time and had a slower speech rate. There were no significant differences between the patient group and the control group on pitch variability, jitter, shimmer, F2 frequency and the amount of pauses.

The second MANCOVA exhibited no statistically significant difference between the *High FTD* group and the *Low FTD* group on the combined dependent variables after controlling for age, sex and parental level of education $F(11, 27) = 5.60$, $p = .82$, Wilks' $\Lambda = .81$, partial $\eta 2 = .195$.

Table 3: Means and Standard Deviations and Significance Levels of the Speech Parameters per Group

	HC		Schizophrenia				
	M	SD	M	SD	t	df	p
Pitch variability	.20	.03	.19	.04	-.69	82	.49
Loudness	.46	.16	.39	.13	2.23	82	.03
Variation in Loudness	.96	.12	1.08	.13	4.16	82	<.001
Jitter	1.82	.17	1.85	.23	.71	82	.71
Shimmer	.99	.08	1.01	.10	.66	82	<.001
F1 frequency	.36	.03	.38	.04	2.67	82	.01
F2 frequency	.18	.01	.18	.00	.06	82	.95
Number of pauses	259	47	264	137	.22	50	.826
Pause duration (sec.)	1.12	.24	1.49	.37	-5.50	82	<.001
Speech rate	2.90	.47	2.34	.50	-5.31	82	<.001
Proportion of spoken time	87.5	4.69	79.67	8.69	-5.15	63	<.001

Note. M = mean. SD = standard deviation. t = t-test values. df = degrees of freedom. p = significance.

3.3 Correlation analysis

Results of the correlation analyses for the speech parameters and the objective TALD-scores are listed in Table 4. Variation in speech volume and the subscore *objective negative* of the TALD were found to be moderately negatively correlated. No other subscores correlated significantly with the speech parameters.

The individual correlation analyses revealed a significant correlation between the TALD phenomenon Slowed Thinking and pause duration (r(41) = .31s, p = .004), and a significant correlation between the TALD phenomenon Poverty of Speech and the proportion of spoken time (r(41) = .49, p = < .001). No significant correlations were found between the TALD phenomenon Rupture of Thought and the amount of speech pauses (r(41) = .18, p = .261), the TALD phenomenon Pressured Speech and the speech rate (r(41) = .03, p = .846), the TALD phenomenon Logorrhoea and the proportion of spoken time (r(41) = -.10, p = .526) and the TALD phenomenon slowed Thinking and the speech rate (r(41) = -.10, p = .532).

Table 4: Pearson Correlation Coefficients between Speech Parameters and the Objective TALD-(sub)scores

Variable	TALD ObPos	TALD ObNeg
Pitch variability	0.037	-0.025
Loudness	-0.056	-0.027
Variation in Loudness	0.081	-.418**
Jitter	-0.092	-0.081
Shimmer	-0.142	-0.123
Formant 1 frequency	0.263	0.023
Formant 2 frequency	0.159	-0.187
Number of pauses	-0.049	0.157
Duration of pauses	-0.022	0.025
Speech rate	-0.032	0.108
Proportion of spoken time	-0.118	-0.065

*Note. M = mean. SD = standard deviation. * indicates p <.05. ** indicates p < .01.*

4 Discussion

This study examined whether the subjectively scored speech-related components of the clinical rating tool the TALD matched the objectively measured speech characteristics in the patients their acoustic speech signal. A computational automatic analysis of the recorded spontaneous speech extracted the acoustic measures, which yielded significant differences for different phonetic and temporal speech characteristics as distinctive for patients with schizophrenia in comparison to healthy controls. The patients group spoke softer, had a higher F1 frequency, made longer pauses, varied less in speech volume, had more shimmer, spoke a smaller percentage of the time and had a slower speech rate. However, no significant correlations were found between the measured speech parameters and FTD symptom severity. This finding suggests a possible shortcoming of the TALD as a sensitive, constructively valid rating tool of FTD. The results show that the scores on the TALD corresponded on only two out of the five selected speech related phenomena to the acoustic features. The scores on the item *Slowed Thinking* were significantly correlated with the duration of pauses and the item *Poverty of Speech* was found to be significantly correlated with the percentage of time a participant was speaking. However, there is insufficient data to accept the hypothesis that *Rupture of Thought* relates to the number of speech pauses, that *Pressured Speech* relates to speech rate, that *Logorrhoea* relates to the proportion of spoken time and that *Slowed Thinking* relates to the speech rate. Hence, the construct validity of the TALD on these speech-related components can be questioned. Since the results of the computational speech analysis method actually yielded significant differences between patients and controls on phonetic and temporal measures, it seems more plausible to assume that the reliability violation is caused by the subjective judgement of the assessor.

Furthermore, it was hypothesised that anomalies in speech would be most strongly associated with NegFTD. Results of the correlation analysis show that only one of the speech parameters is significantly correlated with negative FTD. A significant negative correlation has been found between the speech parameter *variation in loudness* and the ObjNeg subscore of the TALD. This is a very interesting and unexpected result, which we will discuss further. The ObjNeg subscore includes the FTD symptoms *Slowed Thinking, Poverty of Speech* and *Concretism*. None of these phenomena are described to be related to the variety in speech volume of the patient and are therefore not expected to be associated with loudness in any way. The relation found in this study therefore indicates a false judgement of flat affect in the voice of a patient as an indication of slowed thinking, poverty of speech or concretism. This misjudgement demonstrates the unreliability of personal perception and it can therefore be suggested that the TALD does not meet the requirements of a clinically reliable rating scale for these specific speech phenomena.

The results of this study should be carefully interpreted in the light of several considerations. First of all, the total TALD-scores in this study sample are quite low. This might indicate that for most of the participants included in this study, FTD manifestations only occur mildly. The lower overall FTD levels in the patient group may have contributed to the absence of significant results on distinctive deviations in their speech. On top of that, the range (0-37) of the total scores indicates limited variety in FTD. A lower variety among patients regarding the severity of their FTD symptoms makes it difficult to distinguish patients with FTD from patients without FTD based on their speech. In accordance with this comment, the second limitation therefore relates to the group size of the study. A bigger study sample would have improved variety in FTD symptom severity and enhanced the statistical validity. Third, influences from factors such as medication use, duration of disease and co-morbidity with other conditions may have affected speech characteristics of the patients. All patients included in this study were treated with antipsychotic medication at the moment their spontaneous speech was recorded. Research on the influences of antipsychotic medication suggests certain antipsychotic medication to cause a lower speech

rate (de Boer, 2017). Besides, the split FTD groups were not evenly distributed in terms of sex. The *high FTD* group contained significantly more men than the *low FTD* group. Although we corrected for sex influences by taking the standard deviation of the speech parameters that were expected to be sensitive for sex, it should still be taken into consideration that the uneven distribution of sex in the two groups may have had an influence on the measured speech parameters. In addition, a small number of patients were known to have depressive symptoms, which may have influenced speech parameters such as pitch variability, pause duration and speech rate, which are known to be aberrant in patients with depression (Cannizzaro et al., 2004).

To summarise, this study investigated speech anomalies as a symptom of FTD in patients with schizophrenia by analysing the sensitivity of speech related items on the TALD. Anomalies in phonetic and temporal speech characteristics appeared to be distinctive for patients with schizophrenia in comparison to healthy controls, but were not significantly correlated with FTD symptom severity or NegFTD in particular. More importantly, the results showed a discrepancy between the subjectively rated speech anomalies in the TALD and the objectively measured speech anomalies by computational software. Future research should unveil what it specifically encompasses in the speech of patients that is currently perceived as aberrant by clinicians.

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5 Appendix

Table 5: Items of the Thought and Language Dysfunction Scale (TALD) with Corresponding Descriptions

Item	Description
Circumstantiality	Thinking is circuitous; minor matters cannot be separated from essential matters. The main point gets lost in the description of details, without losing the intentional goal completely (long-winded speech).
Derailment	A pattern of spontaneous speech in which ideas slip "off the track" onto other thoughts which are clearly but obliquely related. Things may be said in juxtaposition which lack a meaningful relationship, or the patient may shift idiosyncratically from one frame of reference to another. At times there may be vague connections between the ideas. The objective characteristic of Derailment should be coded as if the interviewer were talking to the patient for the first time (unaware of potential personal associative connections between the thoughts). One manifestation of this disorder is a slow steady slippage, with no single Derailment being particularly severe, so that the speaker gets farther and farther off the track with each Derailment without any awareness that his reply no longer has any connection to the question being asked.
Tangentiality	Ideas do not follow a straight path. Within longer speech passages, content slowly drifts away from where it originally started. The patient does not return to the initial topic.
Dissociation of Thinking	The content of a phrase, sentence or thought has no reference to what has been said before. In contrast to Derailment (Item 2) where associative bridges are still recognizable, Dissociation of Thinking refers to the state in which words, sentences and thoughts have no relation to each other. In less severe occurrences, single sentences may still make sense; however, coherence between sentences is absent. In the severest occurrences, coherence within a sentence or even within individual words is absent (scattered speech).
Crosstalk	The response of the patient misses the point at hand, although he has understood the question. The evaluation of this item does not depend on whether the answer to the question is wrong or not (like a wrong answer in an examination), but that the patient is talking past the question. If the interviewer has any kind of suspicion with regard to the presence of Crosstalk, it must be verified that the patient has understood the question correctly. Therefore, the patient should be asked to repeat the question. Intentional ignoring of the question ("beating around the bush") should not be considered.
Perseveration	Adherence to previously mentioned ideas and topics that no longer fit the current context.
Verbigeration	Unnecessary repetition of a single word
Rupture of Thought	Objectively observed sudden interruption of a previously fluid line of thought. The phenomenon may occur in the middle of a sentence and for no apparent reason

Item	Description
Pressured Speech	The speed of speech production is increased
Logorrhoea	An excessively strong urge to speak. Logorrhoeic speech itself may be coherent and logical. Accelerated speech production need not be present. Communication with the patient is hindered. The patient is either not able to recognize when he is being interrupted or simply ignores such interruptions.
Manneristic Speech	For the observer, speech (word selection, sentence structure, articulation or prosody) seems affected and ornate, eccentric, unnatural, pompous, overblown, fancy, stylised or flowery.
Semantic Paraphasia	Substitution of an inappropriate word (the word is semantically related to the appropriate word). The speaker may or may not recognize his error and attempt to correct it.
Phonemic Paraphasia	Mispronunciation (with regard to phonetic articulation) of a word. Milder forms may occur as "slips of the tongue" in everyday speech. The speaker usually recognizes his error and may attempt to correct it.
Neologisms	New word formations, which do not correspond to lexical conventions. Most Neologisms are not directly intelligible. In extreme cases a new artificial language can be formed or used by the patient.
Clanging	A pattern of speech in which sounds, rather than meaningful relationships, appear to govern word choice, so that the intelligibility of the speech is impaired and redundant words are introduced. In addition to rhyming relationships, this pattern of speech may also include punning associations, so that a word similar in sound (polysemy/homophony) brings in a new thought.
Echololia	Senseless repetitions of words and sentences with no regard to their meanings and semantic functions. The patient echoes the words or sentences of the interviewer.
Poverty of Content Speech	Although replies are long enough that speech is adequate in amount, it conveys little information. Language tends to be vague, often overly abstract or overly concrete, repetitive, and stereotyped. The interviewer may recognize this finding by observing that the patient has spoken at some length but has not given adequate information to answer the question. Alternatively, the patient may provide enough information, but require many words to do so, so that a lengthy reply can be summarized in a sentence or two.

Item	Description
Restricted Thinking	Restriction in the range of content, adherence to one topic or a few topics, or fixation on a few key ideas. During the conversation, the patient experiences difficulties in switching from one topic to another, or constantly returns to the initial topic. For a successful exploration, it is necessary that the examiner offers the patient a variety of topics. This is important since the topic of illness always forms part of a psychiatric exploration, but this should not automatically be treated as resulting from Restricted Thinking. When exploring the topic of illness, it is only possible to refer to Restricted Thinking when the patient is fixed on single aspects of his illness, and when he is not able to detach from these aspects despite being offered other topics of discussion (e.g. a depressive patient who is preoccupied with his indigestion).
Slowed Thinking	From the observer's perspective, the patients' thought process seems to be slowed down (objective). As a result of this sluggish thinking process, the conversation is languid and torpid.
Poverty of Speech	Restriction in the amount of spontaneous speech, so that answers to given questions tend to be brief, concrete and unelaborated. Unprompted additional information is rarely provided. Replies may be monosyllabic, and some questions may be left unanswered altogether. When confronted with this speech pattern, the interviewer may find himself frequently prompting the patient in order to encourage elaboration of replies. To elicit this finding, the examiner must allow the patient adequate time to answer and to elaborate his answer.
Concretism	Concretism refers to difficulty in the comprehension of abstract (figurative) sentences or phrases (e.g. the understanding/interpretation of proverbs, metaphors, jokes). The patient adheres to the concrete meaning of the words/utterances

Note. Bold items are the selected phenomena paired with speech parameters