Multimodal AI Based Facial and Acoustic Biomarkers of Negative Symptoms in Schizophrenia

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METHODOLOGICAL QUESTION

- Can negative symptoms in schizophrenia be meaningfully measured using an AI-enabled audiovisual dialog system? If reliability and validity are adequate, results can lead to contact-free, non-invasive, cost-effective assessment and monitoring of negative symptoms.
- Many individuals with schizophrenia present with negative symptoms including abnormalities in vocal expression, such as altered vocal production (i.e., alogia, reduced speech) and intonation/emphasis (i.e., blunted affect; affective lability). This is reflected in communication via coupled mechanisms: vocal articulation, facial gesturing and dialogue content.
- One barrier in understanding and measuring vocal abnormalities in negative symptoms is a reliance on clinician-based rating scales - these scales can be subjective, insensitive to change in treatment, require extensive training, lack regional and cultural adaptability, and have abstruse operational definitions.
- Speech behaviors and facial movements can inform clinicians about negative symptoms and include monotone and monosyllabic speech, few gestures, pausing, speech rates, and speed of movement of certain facial areas. Facial and speech changes in negative symptom patients are difficult to track and quantify with conventional techniques. A rising number of conversational agents (or chatbots) are equipped with artificial intelligence (AI) architecture which are non-invasive and can capture facial and speech movements efficiently.

AIMS

To investigate whether negative symptoms can be meaningfully measured using AI-enabled audiovisual dialog system called Neurological and Mental Health Screening Instrument (NEMSI assessment) by comparing speech metrics (e.g., prosody, rate, intelligibility, pausing duration etc.) and video metrics (e.g., specific facial and head movements) to clinician-rated psychometric assessments for negative symptoms.

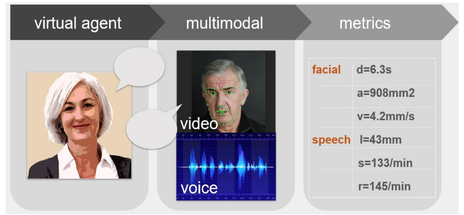
METHOD

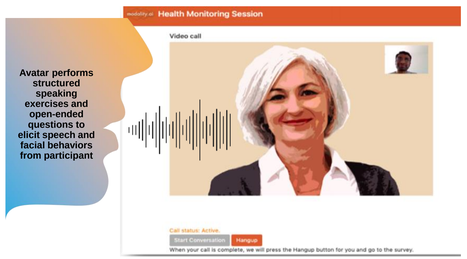
- Experimental Approach: At the first visit, the following instruments are administered: sociodemographic and clinical questionnaire, PANSS, BNSS, CDSS, CGI-S, AIMS, SAS, BARS and NEMSI assessment. The second visit occurs within a one-week period and is done by the same clinician to assess for test-retest reliability and intra-rater reliability. The second visit includes the same instruments in addition to the CGI-I (severity of illness, improvement, and degree of change). Healthy controls only performed the NEMSI assessment.
- Patient Eligibility: Inpatients with diagnosis of schizophrenia, age 18 - 60, English speaking, WRAT-IV Reading Score ≥ 8th grade, Negative symptoms as evidenced by score of ≥ 18 on PANSS Marder Negative Symptom Factor.
- Healthy Control Eligibility: Individuals with no prior history of mental illness, age 18 - 60, English speaking.
- Analysis: 1. Reliability (Intra Class Correlation Coefficient, ICC) 2. Validity: concurrent, convergent, divergent and discriminative using Pearson r correlation of NEMSI assessment speech and facial metrics to the BNSS, PANSS Marder Negative factor and the CDSS. 3. Internal Consistency of NEMSI using Cronbach Alpha α, 4. comparison of HC and schizophrenia using ANOVA and descriptive statistics

SPEECH, VOCAL AND FACIAL AI PROGRAM

Computer-based negative symptom measure: For NEMSI, participants interact with an avatar that provides a series of emotionally-ambiguous, valence-neutral tasks including a series of reading aloud tasks composed of sentences and a passage; an eyebrow raising task, an image description task, and a free speech task related to a topic of interest from the list provided.

The session takes 8–10 minutes to complete, during which the software produces facial and vocal metrics.



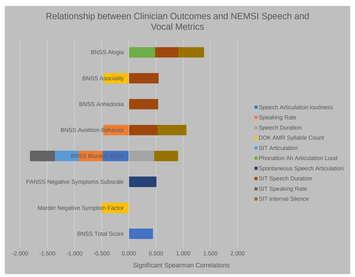


Speech and Facial Data from the program includes:

- Pitch (F0)
- Cepstral Peak Prominence (an acoustic measure of voice quality that is a robust acoustic measure of dysphonia severity)
- Speech Intelligibility (SIT), Duration, and Rate (with and without pauses)
- Articulation Rate and Loudness
- DDK - also known as syllable alternating motion rate (AMR), assesses repetitive movements of oral articulators
- Internal Silence (pauses)
- Syllable Rate and Count
- Lip Aperture
- Mouth Surface Area
- Jaw Velocity and acceleration
- Lower Lip Velocity and Acceleration
- Eye Opening and Eyebrow vertical position

RESULTS: SPEECH AND VOCAL METRICS

	BNSS Total Score	Marder Negative Symptom Factor	PANSS Negative Symptoms Subscale	BNSS Blunted Affect	BNSS Avolition Behavior	BNSS Anhedonia	BNSS Asociality	BNSS Alogia
	Spearman Rho correlations							
Articulation Loudness	0.445			-0.478				
Speaking Rate				-0.444	-0.466			
Speech Duration				0.467				
DDK AMR Syllable Count		-0.502					-0.463	
SIT Articulation				-0.437				
Phonation "Ah" Articulation Loudness								0.486
Spontaneous Speech Articulation			0.506					
SIT Speech Duration					0.530	0.540	0.548	0.431
SIT Speaking Rate				-0.459				
SIT Internal Silence				0.440	0.530			0.468



Spearman Correlations depicted between clinician outcomes and NEMSI assessment speech and vocal metrics. p < 0.05 significant; No statistical correction was performed.

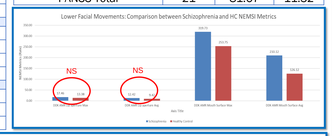
Relationships with AI Speech and Vocal Metrics and Clinician-Rated Assessments

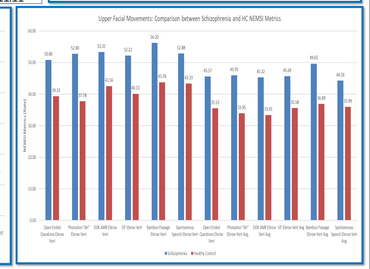
- Articulation is how clearly the speaker pronounces words. When some sounds are slurred together or dropped out of a word, the word may not be understood
  - The loudness of speech articulation was positively related to the BNSS Total Score
  - The phonation of articulation loudness was positively related to Alogia (poverty of speech)
  - Spontaneous Speech was positively related to the PANSS Negative Symptom Subscale
- Speech intelligibility (SIT) refers to how well someone can be understood when they're speaking
  - Speaking Rate was negatively correlated with Blunted Affect (better speaking rate, less blunted affect)
  - Speech Duration was positive correlated with Avolition, Anhedonia, Asociality and Alogia
  - Internal Silence was positive correlated with Blunted Affect, Avolition and Alogia

BASELINE DEMOGRAPHICS

Characteristic	Type	Schizophrenia Mean (n)	Schizophrenia SD (%)	Healthy Controls Mean (n)	Healthy Controls SD (%)
Age	Age (in years)	39.95	11.59	42.11	12.18
Gender	Male	16	76.19	3	33.33
	Female	5	23.81	6	67.67
Race	Black	14	66.67	6	67.67
	White	7	33.33	1	11.11
	Asian	0	0	0	0
	Other	0	0	2	22.22
Ethnicity	Hispanic	3	14.29	2	22.22
	Non-Hispanic	18	85.71	6	67.67
	Not reported	0	0	1	11.11

Baseline PANSS	n	Mean	SD
Positive Subscale	21	18.62	4.08
Negative Subscale	21	23.38	3.02
General Psychopathology	21	39.67	6.26
PANSS Total	21	81.67	11.32



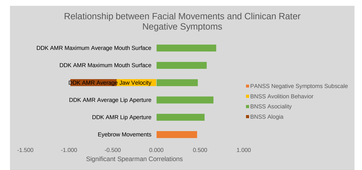


Schizophrenia compared to HC

ANOVA showed a significant difference ($p < 0.05$) between patients and HCs for most NEMSI speech and vocal metrics, all upper facial metrics, and some lower facial metrics; *NS = not significant*

RESULTS: FACIAL EXPRESSION AND GESTURES

	PANSS Negative Symptoms Subscale	BNSS Avolition Behavior	BNSS Asociality	BNSS Alogia
Eyebrow Movements	0.466			
DDK AMR Lip Aperture			0.552	
DDK AMR Average Lip Aperture			0.654	
DDK AMR Average Jaw Velocity		-0.456	0.474	-0.529
DDK AMR Maximum Mouth Surface			0.576	
DDK AMR Maximum Average Mouth Surface			0.686	



Relationships with AI Facial Metrics and Clinician-Rated Assessments

- Asociality or lack of motivation to engage in social interaction or activities was positively correlated to multiple facial metrics: lip aperture, jaw velocity and mouth surface
- Negative Symptom Subscale (PANSS) was positively correlated to Eyebrow movements

RESULTS: RELIABILITY AND VALIDITY

- Reliability NEMSI AI (Time 1 and Time 2): ICC = 0.982
- Reliability PANSS Marder Negative Symptoms (Time 1 and Time 2): ICC = 0.953
- Reliability BNSS Total Score (Time 1 and Time 2): ICC = 0.956
- Validity (Pearson r) of NEMSI with 1. BNSS Total Score = 0.801, 2. BNSS Alogia = 0.812, 3. BNSS Avolition = 0.844
- Internal Consistency (Cronbach α) NEMSI: 0.867 Test-Retest NEMSI: $p < 0.01$

CONCLUSIONS

- Speech and facial AI technology could aid in negative symptoms assessments
- NEMSI variables articulation rate and average mouth surface have strong correlations to negative symptoms
- The NEMSI assessment showed good to excellent reliability, validity, and internal consistency
- Additional testing on larger sample sizes, reproducibility, and generalizability of the software is warranted