



Published in final edited form as:

Early Interv Psychiatry. 2025 January ; 19(1): e13628. doi:10.1111/eip.13628.

Evolution of linguistic markers of agency, centrality and content during metacognitive therapy for psychosis: a pilot exploratory study

Amir H. Nikzad, M.D.^{1,*}, Paul H. Lysaker, Ph.D.^{2,3}, Kyle S. Minor, Ph.D.⁴, Bethany Leonhardt, Psy.D.^{3,5}, Mark Y. Liberman, Ph.D.⁶, Jenifer Vohs, Ph.D.^{3,5}, Courtney N. Wiesepepe, Psy.D.⁷, Sunny X. Tang, M.D.¹

¹ Institute of Behavioral Science, Feinstein Institutes for Medical Research, Northwell Health

² Department of Psychiatry, Richard L. Roudebush VA Medical Center

³ Department of Psychiatry, Indiana University School of Medicine

⁴ Department of Psychology, Indiana University – Purdue University Indianapolis

⁵ Prevention and Recovery Center for Early Psychosis, Sandra Eskenazi Mental Health Center

⁶ Linguistic Data Consortium, University of Pennsylvania

⁷ Department of Psychology, Austin VA Outpatient Clinic, Central Texas VA Health Care System

Abstract

Aim: Metacognitive Reflection and Insight Therapy (MERIT) is a form of person-centred psychotherapy that promotes recovery-oriented outcomes by targeting metacognitive capacity. Previous research has shown the feasibility and clinical benefits of MERIT. However, it is not clear whether and how the specific processes targeted by MERIT (e.g., improved sense of agency, self-reflectivity, awareness of others, etc.) are manifested in the patient-therapist communications. In this study, we used natural language processing (NLP) to explore objective linguistic markers of change during MERIT for early psychosis.

Methods: Five patients underwent 24 sessions each of MERIT, which were recorded and transcribed verbatim. The transcripts underwent NLP to determine the patterns of pronoun use and the frequency of semantic categories related to temporality and mental processing. Mixed linear regressions were used to examine how NLP features evolve over the course of psychotherapeutic sessions.

Results: Analyses detected shifts in specific language signals over time including: 1) changes in patterns of pronoun usage with more active and central first-person plural pronoun (We); 2) transition in temporal focus of speech from past-focus towards present- and future-focus; and 3) increased words representing perceptual and cognitive processes.

* Corresponding Author: ANikzad@Northwell.edu.

Conflict of Interest

SXT receives research funding from Winterlight Labs and holds equity with North Shore Therapeutics. She is also a consultant for both entities. SXT received funding support from the Brain and Behavior Research Foundation (BBRF) Young Investigator Award and NIH K23 MH130750-01. The other authors have nothing to disclose.

Conclusion: Our findings suggest NLP can objectively quantify meaningful signals consistent with expected subjective changes in MERIT and potentially other psychotherapeutic interventions.

Keywords

Metacognitive Reflection and Insight Therapy (MERIT); Natural Language Processing (NLP); Semantic Role Labelling; Semantic Speech Graph; Computational Psychiatry

Introduction

To date, the mainstay of treatment for psychosis are pharmacological interventions that target neurochemical abnormalities presumed to underlie symptoms (Kane, 2013; Kane & McGlashan, 1995). However, evolving research has suggested that recovery from psychosis and reintegration with the community is a complex matter that goes beyond symptom reduction (Korsbek, 2013; Leonhardt et al., 2017; Owen et al., 2016; Vita & Barlati, 2018). Recovery involves a range of deeply subjective and personal outcomes (Lysaker, Kukla, et al., 2020), which includes, for example, developing feelings of mastery, control, and self-worth. Overarchingly, recovery may further require the development of a cohesive understanding of one's psychiatric and social challenges and the possibilities needed to decide how to actively manage and respond to them (Müller et al., 2014). This study explores select language-based markers that could potentially quantify and track the trajectories of therapeutic targets over the course of recovery-oriented psychotherapy for psychosis.

Person-centred psychotherapy has been developed and implemented in response to the need to promote self-management and recovery in psychosis. One approach in particular, Metacognitive Reflection and Insight Therapy (MERIT), has suggested that psychotherapy may promote these more subjective forms of outcome by enhancing metacognitive capacity. Within MERIT, metacognition is defined as a spectrum of activities that enable persons to monitor and regulate cognition and behavior (Flavell, 1979; Moritz & Lysaker, 2018). Metacognition, therefore, involves the ability to notice and reflect upon discrete emotional, cognitive and embodied experiences as well as form a larger sense of one's and others' purposes, possibilities, and relative places in the world. With intact metacognitive capacity, persons are able to form an integrated as opposed to fragmented sense of themselves and the course of their lives. People with psychosis, on the contrary, demonstrate significant metacognitive impairments relative to healthy control participants as well as others with less severe forms of mental illness or those facing similar levels of adversity, such as individuals diagnosed with HIV (Lysaker et al., 2012, 2014; Lysaker, Vohs, et al., 2015). Such deficits are central to the psychosis phenotype and contribute to difficulties forming a coherent sense of self, others, and life (Lysaker et al., 2019), and are also related to canonical psychosis symptom dimensions and poor outcomes (Arnon-Ribenfeld et al., 2017; Tang et al., 2022). Metacognition has also been proposed as a potential mediator between neurobiological changes and psychosis symptoms (Bob et al., 2016).

MERIT aims to enhance metacognitive capacity as its primary target by promoting a sense of mastery and agency in the patient, enhancing self-reflectivity and insight,

improving mentalizing capacity, and establishing a de-centralized perspective regarding one's relationship with their community (Figure 1). Over the course of treatment, individuals are encouraged to produce narrations about themselves and others, and form a more integrated sense of themselves and others (Lysaker et al., 2018, 2021; Lysaker, Gagen, et al., 2020). Attention is paid to the content of therapeutic exchanges, including goals, life story, thoughts, and challenges, as well as to the therapeutic relationship and its impacts on the participant's experiences. Altogether, the purpose of MERIT is to collaborate with participants to develop an integrated sense of agency, reconstruct their relationships to others, and realign with their prospective goals. To date, research has found MERIT can be feasibly delivered within outpatient settings and accepted by those with psychosis (Minor et al., 2022). It has been linked with significant improvements in metacognitive capacity as well as improvements in insight into the nature of their disorder (Leonhardt et al., n.d.; Vohs et al., 2018). Qualitative studies have also reported improvements in the subjective experience of agency and self-direction (de Jong et al., 2020; Lysaker, Kukla, et al., 2015) while case studies have revealed MERIT can be flexibly applied to those with differing clinical presentations (Lysaker, Gagen, et al., 2020).

One limitation in research on MERIT and recovery-oriented psychotherapies in general is the lack of objective markers which identify and quantify psychotherapeutic processes. Actual exchanges in psychotherapy sessions remain mostly unexplored and direct assessment using traditional approaches such as behavioral coding is time-consuming and depended on human judgement (Imel et al., 2015). Because metacognition is a description of complex and wide-ranging internal processes and experiences, attempts to quantify this domain are necessarily limited by being indirect and incomplete. For example, psychometric scales to assess insight were previously used to demonstrate changes promoted by MERIT, but are limited in their scope and are less informative about other components of metacognition such as agency and mentalizing (Figure 1). One possible way to quantify additional dimensions of metacognitive changes associated with MERIT is through natural language processing (NLP). NLP is an emerging approach in psychotherapy research which can objectively quantify elements such as quality and progress of treatment (Goldberg et al., 2020). Clinical applications of NLP include identification of successful conversational strategies, evaluation and improvement of therapeutic skills of psychotherapists, and better detection of high-risk clinical conditions such as suicidality (Althoff et al., 2016; Flemotomos et al., 2022; Levis et al., 2021). Moreover, emotional and metacognitive conversational dynamics such as humorous or emotional exchanges were shown to be detectable using NLP models (Ramakrishna et al., 2018; Tanana et al., 2021).

Specifically, two NLP approaches appear to be particularly informative about the kinds of conversational dynamics expected in the course of metacognitive therapy. First, semantic role labelling is able to identify and quantify agency in terms of active or passive linguistic relations (Nikzad et al., 2022). For example, while "*Good things always happen to us*" and "*We bring joy to our lives*" both have positive connotations, the latter utterance is associated with more sense of agency as reflected in the active role acquired by the first-person pronoun. An increase in the use of active roles for the first-person pronoun during therapy sessions has been shown to be associated with good psychotherapy outcomes (Van Staden & Fulford, 2004a). Second, Linguistic Inquiry and Word Count Program (LIWC) is capable

of quantifying semantic content of speech in terms of frequencies of words belonging to various semantic domains, such as time orientation, informal language, and affective, social and cognitive processes. LIWC profiles were found to be informative for the mental health of speakers, with positive and negative emotive words indicating well-being and psychological distress, respectively (Vine et al., 2020). Notably, some particular domains of LIWC (e.g., emotion-related word categories) were found to be related to the core concepts of metacognitive therapy such as hope (Bonfils et al., 2016).

Here, we utilize computational semantic analysis to explore linguistic markers that could potentially be informative about metacognitive changes associated with MERIT for early psychosis (MERIT-EP) (Vohs et al., 2018) to supplement information collected via standard clinical scales (Figure 1). Because the psychotherapeutic process involves a cooperative exchange between the participant and the therapist, we hypothesize that linguistic signals reflecting metacognitive changes will be detectable in the speech of participants as well as therapists over the course of treatment. We will examine: 1) changes in centrality and agency of self- and others-representations reflected in patterns of pronoun usages; and 2) sense of purpose and metacognitive capacities reflected in temporal focus and semantic themes related to mental processes. We will also explore the trajectories of such changes in different participants in the context of their individual clinical outcomes. Since the therapeutic process for MERIT is carried out by means of conversational exchanges (i.e., a linguistic process), our findings may also have implications for understanding the role of language in execution and modulation of metacognitive self-regulation in psychosis.

Methods

Intervention

Five participants diagnosed with early phase psychosis were recruited from community services and provided informed consent. Participants each underwent 24 sessions of MERIT for early psychosis, adjunctive to their antipsychotic medical treatment, delivered by two psychotherapists with expertise in this modality (therapist 1 – 4 participants, therapist 2 – 1 participant, Table 1S). One therapist was a post-doctoral fellow with 3 years of training in MERIT and the other therapist was a pre-doctoral intern with one year of training in MERIT. Both therapists were Caucasian women in their mid-twenties. Sessions were audio-recorded and supervised by two MERIT experts, utilizing the MERIT Therapist Adherence Scale (MERIT-TAS) (Lysaker & Klion, 2017) to assess for fidelity to the MERIT model. Disease severity and illness awareness were measured using the Positive and Negative Syndrome Scale (PANSS) (Kay et al., 1987) and the Scale to Assess Unawareness of Mental Disorder (SUMD) (Amador et al., 1994), respectively, at pre- and post-intervention time points (Table 1S).

MERIT psychotherapy sessions include therapist adherence to eight elements: attending to the patient's agenda, insertion of the therapist's mind, production of narratives, reflection on a psychological problem, attending to the therapeutic relationship, discussion of progress of the therapy, intervening at the appropriate level of self-reflectivity/reflection about others, and intervening at the appropriate level of psychological mastery. Further information about

the protocol for the intervention has been previously described (Vohs et al., 2018) and all procedures were approved by the Indiana University Institutional Review Board.

Language Samples

All sessions were recorded and transcribed verbatim (n=120 transcripts). Personal identifiers were removed from transcripts prior to automated linguistic analyses. The first and the final MERIT sessions for each participant were excluded from further analysis due to their different therapeutic structures (introductory and concluding sessions), resulting in 110 therapy sessions across the five participants. The transcript for each session was then separated into the participant and therapist portions for the final analysis (220 total samples).

Experiment 1. Frequency, Activity/Passivity, and Centrality of Pronoun Categories

For each sample, utterances were tokenized using SpaCy word-tokenizer (Montani et al., 2022), and the frequency of different categories of pronouns were then counted. We categorized pronouns into four distinct groups: those that represent the speaker (*I*- including I, me, my, etc.), the interlocutor (*You*- including you, yours, yourself, etc.), both speech participants (*We*- including, we, us, ours, etc.), and others (*They*- including she, he, they, hers, his, their, etc.).

Next, we generated semantic graph models to determine the activity/passivity, and centrality of the pronoun categories (Nikzad et al., 2022). All features are enlisted in Table 1. Speech graph methodology is illustrated in Figure 2. First, samples were parsed into its constitutive utterances based on grammatical completeness and the presence of pauses. Each utterance underwent semantic role labelling (SRL) using RESTful API available at [VerbAtlas.org](https://verbAtlas.org) (Conia et al., 2021). Based on the English Propositional Bank formalism, active (A0) and passive (A1 and A2) arguments and verb-predicates were extracted per each utterance (Palmer et al., 2005). For example, by processing “*She brings joy to my life*”, ‘*she*’ was identified as the active argument, ‘*joy*’ and ‘*to my life*’ as the first and second passive arguments, and ‘*brings*’ as the verb-predicate. Within each set (A0: ‘*she*’, A1: ‘*joy*’, A2: ‘*to my life*’, Predicate: ‘*bring*’), pronouns were replaced with their prototypical forms: *I*, *You*, *We* and *They*. In the example above, ‘*she*’ is replaced with ‘*they*’ and ‘*my*’ is replaced with ‘*I*’. Non-content words such as prepositions and articles were excluded (e.g., ‘*to*’ was removed), and content words were replaced with their lemmatized form using SpaCy modules (‘*brings*’ was replaced with ‘*bring*’) (Montani et al., 2022). The final sets of active-argument, passive-argument and verb-predicate were then used to create semantic graph representations of speech using networkx library (A0: ‘*they*’, A1: ‘*joy*’, A2: ‘*I life*’, Predicate: ‘*bring*’) (Hagberg hagberg et al., 2008). Action graphs were generated by connecting the active-argument (A0) to the passive-arguments (A1 and A2) in each predicative block in a directed way (‘*they*→‘*joy*’ and ‘*they*→‘*I life*’). Activity and passivity of four pronoun categories of *I*, *You*, *We*, and *They* were quantified by measuring the out-degree and in-degree of their respective nodes to quantify their frequency in active and passive roles, respectively. To normalize for the effect of verbosity, we used dynamic measurements with a moving window of thirty predicative blocks and forward-moving steps of one predicate (Nikzad et al., 2022). Action-predication graphs were generated by connecting predicates to all arguments (A0, A1, and A2), and active arguments (A0) to

passive arguments (A1 and A2) in each predicative block in an undirected fashion to allow centrality computation (e.g., ‘bring’–‘they’, ‘bring’–‘joy’, ‘bring’–‘I life’, ‘they’–‘joy’ and ‘they’–‘I life’). Based on this graph model, we then computed betweenness centralities of nodes, i.e., how often a particular node mediates the shortest path between other nodes (Brandes, 2010). The betweenness centrality values for each pronoun category were then captured as the measure of the centrality of self- and others- mental representations. This measurement was not normalized for verbosity due to its fractional nature.

Experiment 2. Word-Frequencies per Semantic Categories

Samples were also fed to LIWC-2015 program in order to obtain the normalized frequencies of semantic categories (number of words belonging to each category per 100 total words) related to temporal focus (past, present, and future) and different domains of mental processes (cognitive, perceptual, biological, affective, and social) for each speaker at each session (Pennebaker et al., 2015). These categories were extracted because we hypothesized that gaining insight during the course of MERIT would affect the pattern of word usage related to temporality and cognition. Table 1 defines and exemplifies these categories. More details regarding LIWC analysis is presented in Table 2S for select samples.

Statistical analysis

We used mixed linear regressions to examine how participant and therapist speech evolve over the course of psychotherapeutic sessions, with a fixed effect of sessional progression (indexed as 2–23), a random effect of participant, and linguistic features as predictive targets. Bonferroni correction was used to account for multiple comparisons as follows: Experiment 1. 4 comparisons for pronoun frequencies (corrected $\alpha = 0.0125$), and 12 comparisons for graph features (corrected $\alpha = 0.004$); and Experiment 2. 3 comparisons for temporal focus (corrected $\alpha = 0.0167$), and 5 comparisons for mental processes (corrected $\alpha = 0.01$). Therapist was included as a covariate to account for the delivery of MERIT by two different psychotherapists.

Results

Pre- and Post-Intervention Clinical Measures

Individual indices of disease severity (PANSS total) and illness awareness (SUMD and insight sub-scale of PANSS) at pre- and post-intervention time points are presented in the supplements (Table 1S). Participants differed in disease severity prior to the intervention, with PANSS total scores ranging from 44 to 81 (mean 57, standard deviation 15). Two participants experienced more severe symptoms after the intervention (Participants 3 and 4); however, all participants showed improved insight into their clinical condition, which was the primary endpoint for the intervention.

Experiment 1. Frequency, Activity/Passivity, and Centrality of Pronoun Categories

We explored the longitudinal change in the pattern of pronoun usages in terms of the frequency, activity/passivity, and centrality of four categories of pronouns pertaining to the speaker – *I*, interlocutor – *You*, speech participants – *We*, and the others – *They*. There was an increasing trend in overall pronoun usage for participants and therapists, the latter of

which was statistically significant ($\beta = 0.17, p < 0.05$). For individual pronoun categories, participants and therapists demonstrated inverse patterns. Participants used more *You*, and less *We* and *They* categories over time, whereas therapists used more *I* and *We*, and less *You* and *They* (Table 2). Only the increasing usage of *We* in therapists' speech remained significant when corrected for multiple comparisons ($\beta = 0.38, \text{corrected } p < 0.001$).

Semantic graph analysis of action relations showed decreased passive use of *We* in the participants' speech as reflected in a significant decline in in-degree of its representative node over the course of the treatment sessions ($\beta = -0.29, p < 0.01$). Conversely, the same pronoun category showed an increasing pattern of activity in the speech of therapists as reflected in the increasing out-degree of the *We* node ($\beta = 0.27, p < 0.01$). Both changes survived Bonferroni correction for multiple comparisons. Therapist speech also showed increased activity of *I* and decreased activity of *You* per sessional progression (Table 2).

There was no significant change in the centrality of pronoun categories in the speech of participants. However, the centrality of *I* ($\beta = 0.25, p < 0.01$) and *We* ($\beta = 0.35, p < 0.01$) increased significantly in therapist discourse, the latter of which survived Bonferroni correction (Table 2). A trend toward decreasing centrality of *You* in therapist speech was also detected ($\beta = -0.13, p = 0.12$).

All Bonferroni survived relations were subsequently re-examined with mixed linear models including therapist as a covariate to account for the delivery of MERIT by two different therapists. All relations maintained their significance in the reassessment.

Experiment 2. Word-Frequencies per Semantic Categories

The distribution of semantic categories in participant and therapist speech is presented in Table 3. The temporal focus of therapeutic exchanges showed a gradual shift with decreasing past-orientation ($\beta = -0.31$ and -0.24 for participant and therapist respectively) and increasing present- ($\beta = 0.38$ and 0.34 , same order) and future-orientation ($\beta = 0.19$ for both). Each of these relationships remained statistically significant when correcting for multiple comparisons (p -values < 0.01), except for the increase in future orientation for therapists which became trend-level (p -value = 0.02).

When examining changes over time for the five domains of mental processes, we found significant increase of using words that signify perceptual processes in participants ($\beta = 0.20, p = 0.01$) and therapists ($\beta = 0.19, p = 0.01$). There was also an increase in the usage of cognitive process category ($\beta = 0.28, p < 0.01$) and decreasing pattern in that of affective and social categories for therapists ($\beta = -0.20$ and -0.17 respectively). When correcting for multiple comparisons, only the increasing usage of words related to cognitive category by the therapists remained significant.

Here too, all Bonferroni survived relations were re-examined with mixed linear models including therapist as a covariate to account for the effect of multiple therapists delivering MERIT. All relations remained significant in the reassessment.

Individual Trajectories of Computational Linguistic Features

Eleven linguistic features showed significant correlations with sessional progression when accounting for multiple comparisons. These include normalized frequency and in-degree of *We* category, and past, present and future temporal focus in participant speech, and normalized frequency, out-degree and centrality of *We* category, past and present temporal focus, and cognitive mental processes in therapist speech. Figure 3 illustrates individual differences in the trajectories of these linguistic features during the course of therapy. Although the sample size is not sufficient for conclusive inter-individual comparisons, we explored variations in trajectories for the computational linguistic features in individual participants. We found that the participants with highest insight gain also appears to demonstrate large magnitudes of change in multiple linguistic markers (Participant 1 with SUMD change = 7, mean SUMD change for all participants = 3, more details in Table 1S). This effect is observable in both participants and therapist transcripts.

Discussion

In this study, we used automated semantic analysis to identify longitudinal linguistic changes in transcripts of individuals with psychosis receiving MERIT. Following our initial hypotheses, we were able to detect meaningful speech signals over the course of the psychotherapy. First, we observed significant changes in the frequency and nature of pronoun use toward more active tone which may reflect growing sense of agency. Second, we detected a shift in themes related to temporality, cognitive and perceptual processes in favor of improved sense of purpose.

Consistent with our first hypothesis, during the course of therapy, an increasingly more active and central representation of a shared identity emerged in the speech of participant and therapist, hypothesized to reflect agentive aspect of metacognition. This emergence was captured in person pronoun categories with non-identical but complementary patterns for therapist and participant. On the participant's side, the frequency of *You* – referring to the therapist – was increased and the frequency and passivity of *We* were decreased. In a complementary fashion, the frequency, centrality and activity of *We* and *I* increased in the speech of therapist, whereas the frequency and activity of *You* – referring to the participant – were decreased. Altogether, these changes are consistent with a directed conversational relationship, through which a collaborative and active mutual identity is produced by the leading role of therapist, reflected in her active linguistic representation (e.g., 'we would talk about your plans after you leave here'; 'we can try to figure things out'; 'I remember when we first started and you had that concern', etc.). Our results resonate with previous findings indicating more active first-person pronoun usages in successful psychotherapies (Van Staden & Fulford, 2004b).

The findings also supported our second hypothesis: over time, the psychotherapeutic exchanges became more directed toward present and future temporal foci, and less towards the past, suggestive of more projective and goal-oriented discussions (de-centration & perspective). Here, too, an increase in the usage of words related to the cognitive processes in therapist speech indicates a directed therapeutic relationship which is scaffolded by the therapist. This adds another perspective to the study of language behavior in psychosis

during therapy sessions. Psychotherapy is permitted through an implicit agreement to cooperate by means of language. It has also been suggested that explicit activation of cooperation in the course of therapy may increase metacognitive abilities, hence improved outcomes (Monticelli et al., 2018). However, the non-identical but complementary patterns of change associated with both experiments in our study implies the guiding role of the therapist throughout this cooperative relationship. Here, the communicative cooperation is based on a process of joint reflection, in which therapists may scaffold increasingly integrated ideas about participants and their actions in the world.

Our results offer possible quantitative correlates for psychotherapeutic processes, but do not directly demonstrate or prove the mechanisms at work. However, they are consistent with active inference models of psychosis and psychotherapy. As active inference model of psychosis suggests formal thought disorders (FTD) can be conceptualized as underlying imprecise predictions (or priors) about different hierarchical levels of interlocutor's discourse (e.g. intentions, narrations, sentences, and lexicon), which are then manifested as failures to commit to conversational goals or distortions in the structure of speech (Limongi et al., 2023; Palaniyappan & Venkatasubramanian, 2022). Following the similar logic, active inference model of psychotherapy conceptualizes the therapeutic interventions as attempts to modify maladaptive priors (Chamberlin, 2023; Krupnik, 2019). Previous studies on MERIT have indicated that the therapeutic effects of MERIT may go beyond the development of clinical insight and include reduction in disorganized FTD symptoms (Minor et al., 2022). Therefore, it may be argued that the therapeutic effects of MERIT may unfold through modulation of the underlying hierarchy of predictive processing by integrating pertinent metacognitive information and allowing for more accurate updating of the priors.

The effect of communication on metacognition as the primary target of MERIT may further be explained through the framework of Vygotsky's theories on psycholinguistics. In this framework, language is conceptualized as having two primary functions: communication and self-regulation (Rieber & Carton, n.d.). While the communicative function of language facilitates social exchanges between individuals, its self-regulatory function in the form of egocentric speech or inner speech serves as a means of mental and behavioral regulations. Some psychosis symptoms, such as self-talking and auditory verbal hallucination, can be considered as disturbances of the self-regulatory function of language where normal self-regulatory language is instead perceived as being external in origin (Alderson-Day & Fernyhough, 2015). Moreover, inner speech as the primary form of self-regulatory function of language in adults is thought to be central to metacognition (Morin, 2005). Following the same logic, metacognitive psychotherapy of psychosis can be conceptualized as a process through which self-regulatory functions are restored by the influence of communicative function of language (Figure 1S). Thus, language serves not as a mere reflection of inner processes, but as both the substrate and the tool for the therapeutic mechanism. This is consistent with previous assertions that the capacity for intersubjectivity and metacognition may grow together and as a deeper sense of a shared connection with others emerges what one wants the others to know may become clearer and more nuanced (Hasson-Ohayon et al., 2020).

As it is presented in the Figure 1, MERIT defines metacognition as a complex and multi-faceted psychological construct. While building blocks of metacognitive capacity are not reducible to language behavior in general or to NLP features in particular, we observed linguistic changes that are consistent with hypothetical expectations related to metacognitive improvement. Based on the current findings, linguistic markers could be best interpreted as objective and measurable linguistic markers of the progression of MERIT. This is a preliminary conclusion and needs to be replicated in larger and independent cohorts and shown to be specific to MERIT. Future studies are also needed to explore the nature (causal vs correlate) or direction of relationship between metacognition and its components as psychological constructs on one hand, and language behavior and its computational features on the other. In addition, future studies should investigate the specificity of current findings to metacognition in contrast with other potential driving elements such as therapeutic alliance (Ryu et al., 2023).

There are further limitations. The current study is limited due to its sample size, and we lack a control group. Participants were also heterogeneous and demonstrated different psychosis severity and disease trajectories. They did not uniformly improve in their clinical rating during the course of the intervention. However, as presented in Table 1S, all participants showed enhanced insight in at least one of the scoring scales following the course of MERIT treatment. Another limitation comes from the nature of our speech data which was confined to in-session verbal exchanges. Samples were not assessed with benchmark clinical scales such as thought, language and communication (TLC) or thought and language index (TLI). Although we found meaningful longitudinal patterns of change during therapy, it is yet unclear whether and how these changes relate to clinical scales and further translate to real-life conversational behavior and sustained social relationships. Future studies may incorporate clinical scales and also try to detect similar linguistic effects, i.e. increased agency and goal-directedness, from speech samples collected in everyday life setting. Objective measurement of change in language behavior during psychotherapy sessions and further validation of transmission of altered language behavior to other social settings may contribute to better understanding of psychotherapeutic processes. This may also help to evaluate and improve therapeutic efficacy of distinct approaches and therapeutic skills of individual therapists based on scalable and objective criteria. To further validate the relevance of linguistic signals to in-session conversational purposes, future studies may target linguistic markers specific to distinct elements of MERIT. Finally, NLP features were extracted here in a hypothesis-driven and selective manner. Future studies with larger cohorts are necessary to incorporate more NLP features (such as comparing semantic similarity of the content of therapeutic exchanges to metacognitive concepts) and adopt a data-driven approach to minimize feature selection biases.

Conclusion

Our findings suggest that automated semantic analysis can objectively quantify meaningful signals consistent with deeply subjective changes related to recovery from psychosis during psychotherapeutic interventions. The changes in the language found across psychotherapy transcripts are consistent with first-person accounts of the experience of self-directed recovery and the theorized mechanisms of MERIT. In this framework, firstly, participants

experience themselves as increasingly able to think about themselves in the moment and form ideas of challenges they face in ways that others could relate to and understand, and secondly, this sense-making occurred in the context of action in the world as participants were increasingly able to experience themselves as making sense of how they want to and have been responding to those challenges. These findings also potentially reflect increased sense of agency and more collaborative mode of thinking—additional intended effects from MERIT-EP. In general, lexical and semantic analyses may reveal deeper changes in how individuals with psychosis make sense of and respond to the world as they move towards recovery. Moreover, semantic analysis of conversational dynamics during therapy sessions, in which metacognitive impairments are targeted by language interventions, may expand the applicability of NLP in psychosis beyond the bio-marker paradigm. In other words, language be conceptualized not only as a domain where psychosis disease processes are reflected, but also as a channel to deliver adequate compensatory interventions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

- Alderson-Day B, & Fernyhough C (2015). Inner Speech: Development, Cognitive Functions, Phenomenology, and Neurobiology. *Psychological Bulletin*, 141(5), 931–965. 10.1037/BUL0000021 [PubMed: 26011789]
- Althoff T, Clark K, & Leskovec J (2016). Large-scale Analysis of Counseling Conversations: An Application of Natural Language Processing to Mental Health. *Transactions of the Association for Computational Linguistics*, 4, 463–476. 10.1162/TACL_A_00111 [PubMed: 28344978]
- Amador XF, Flaum M, Andreasen NC, Strauss DH, Yale SA, Clark SC, & Gorman JM (1994). Awareness of Illness in Schizophrenia and Schizoaffective and Mood Disorders. *Archives of General Psychiatry*, 51(10), 826–836. 10.1001/ARCHPSYC.1994.03950100074007 [PubMed: 7944872]
- Arnon-Ribenfeld N, Hasson-Ohayon I, Lavidor M, Atzil-Slonim D, & Lysaker PH (2017). The association between metacognitive abilities and outcome measures among people with schizophrenia: A meta-analysis. *European Psychiatry: The Journal of the Association of European Psychiatrists*, 46, 33–41. 10.1016/J.EURPSY.2017.08.002 [PubMed: 28992534]
- Bob P, Pec O, Mishara AL, Touskova T, & Lysaker PH (2016). Conscious brain, metacognition and schizophrenia. *International Journal of Psychophysiology: Official Journal of the International Organization of Psychophysiology*, 105, 1–8. 10.1016/J.IJPSYCHO.2016.05.003 [PubMed: 27178724]
- Bonfils KA, Luther L, Firmin RL, Lysaker PH, Minor KS, & Salyers MP (2016). Language and hope in schizophrenia-spectrum disorders. *Psychiatry Research*, 245, 8–14. 10.1016/J.PSYCHRES.2016.08.013 [PubMed: 27526311]
- Brandes U (2010). A faster algorithm for betweenness centrality*. <https://doi.org/10.1080/0022250X.2001.9990249>, 25(2), 163–177. 10.1080/0022250X.2001.9990249
- Chamberlin DE (2023). The Active Inference Model of Coherence Therapy. *Frontiers in Human Neuroscience*, 16, 874. 10.3389/FNHUM.2022.955558

- Conia S, Orlando R, Brignone F, Cecconi F, & Navigli R (2021). InVeRo-XL: Making Cross-Lingual Semantic Role Labeling Accessible with Intelligible Verbs and Roles. EMNLP 2021 – 2021 Conference on Empirical Methods in Natural Language Processing: System Demonstrations, 319–328. 10.18653/V1/2021.EMNLP-DEMO.36
- de Jong S, Hasson-Ohayon I, van Donkersgoed R, Aleman A, & Pijnenborg GHM (2020). A qualitative evaluation of the effects of Metacognitive Reflection and Insight Therapy: “Living more consciously.” *Psychology and Psychotherapy*, 93(2), 223–240. 10.1111/PAPT.12212 [PubMed: 30548375]
- Flavell JH (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist*, 34(10), 906–911. 10.1037/0003-066X.34.10.906
- Flemotomos N, Martinez VR, Chen Z, Singla K, Ardulov V, Peri R, Caperton DD, Gibson J, Tanana MJ, Georgiou P, Van Epps J, Lord SP, Hirsch T, Imel ZE, Atkins DC, & Narayanan S (2022). Automated evaluation of psychotherapy skills using speech and language technologies. *Behavior Research Methods*, 54(2), 690–711. 10.3758/S13428-021-01623-4/FIGURES/4 [PubMed: 34346043]
- Goldberg SB, Flemotomos N, Martinez VR, Tanana MJ, Kuo PB, Pace BT, Villatte JL, Georgiou PG, Van Epps J, Imel ZE, Narayanan SS, & Atkins DC (2020). Machine learning and natural language processing in psychotherapy research: Alliance as example use case. *Journal of Counseling Psychology*, 67(4), 438–448. 10.1037/COU0000382 [PubMed: 32614225]
- Hagberg hagberg AA, -Los, lanlgov, Schult DA., & Swart swart PJ(2008). Exploring Network Structure, Dynamics, and Function using NetworkX.
- Hasson-Ohayon I, Gumley A, McLeod H, & Lysaker PH (2020). Metacognition and Intersubjectivity: Reconsidering Their Relationship Following Advances From the Study of Persons With Psychosis. *Frontiers in Psychology*, 11. 10.3389/FPSYG.2020.00567
- Imel ZE, Steyvers M, & Atkins DC (2015). Computational psychotherapy research: scaling up the evaluation of patient-provider interactions. *Psychotherapy (Chicago, Ill.)*, 52(1), 19–30. 10.1037/A0036841 [PubMed: 24866972]
- Kane JM (2013). Improving patient outcomes in schizophrenia: achieving remission, preventing relapse, and measuring success. *The Journal of Clinical Psychiatry*, 74(9), e18. 10.4088/JCP.12117TX1C [PubMed: 24107769]
- Kane JM, & McGlashan TH (1995). Treatment of schizophrenia. *Lancet (London, England)*, 346(8978), 820–825. 10.1016/S0140-6736(95)91630-X [PubMed: 7545770]
- Kay SR, Fiszbein A, & Opler LA (1987). The Positive and Negative Syndrome Scale (PANSS) for Schizophrenia. *Schizophrenia Bulletin*, 13(2), 261–276. 10.1093/SCHBUL/13.2.261 [PubMed: 3616518]
- Korsbek L (2013). Illness insight and recovery: how important is illness insight in peoples’ recovery process? *Psychiatric Rehabilitation Journal*, 36(3), 222–225. 10.1037/PRJ0000018 [PubMed: 24059633]
- Krupnik V (2019). Bayesian approach to psychotherapy integration: Strategic modification of priors. *Frontiers in Psychology*, 10(FEB), 356. 10.3389/FPSYG.2019.00356/BIBTEX [PubMed: 30873079]
- Leonhardt BL, Benson K, George S, Buck KD, Shaieb R, & Vohs JL (n.d.). Targeting Insight in First Episode Psychosis: A Case Study of Metacognitive Reflection Insight Therapy (MERIT). *Journal of Contemporary Psychotherapy*, 46. 10.1007/s10879-016-9332-9
- Leonhardt BL, Huling K, Hamm JA, Roe D, Hasson-Ohayon I, McLeod HJ, & Lysaker PH (2017). Recovery and serious mental illness: a review of current clinical and research paradigms and future directions. *Expert Review of Neurotherapeutics*, 17(11), 1117–1130. 10.1080/14737175.2017.1378099 [PubMed: 28885065]
- Levis M, Leonard Westgate C, Gui J, Watts BV, & Shiner B (2021). Natural language processing of clinical mental health notes may add predictive value to existing suicide risk models. *Psychological Medicine*, 51(8), 1. 10.1017/S0033291720000173 [PubMed: 33267920]
- Limongi R, Silva AM, MacKinley M, Ford SD, & Palaniyappan L (2023). Active Inference, Epistemic Value, and Uncertainty in Conceptual Disorganization in First-Episode Schizophrenia.

Schizophrenia Bulletin, 49(Supplement_2), S115–S124. 10.1093/SCHBUL/SBAC125 [PubMed: 36946528]

- Lysaker PH, Cheli S, Dimaggio G, Buck B, Bonfils KA, Huling K, Wiesepepe C, & Lysaker JT (2021). Metacognition, social cognition, and mentalizing in psychosis: are these distinct constructs when it comes to subjective experience or are we just splitting hairs? *BMC Psychiatry*, 21(1). 10.1186/S12888-021-03338-4
- Lysaker PH, Gagen E, Klion R, Zalzal A, VoHS J, Faith LA, Leonhardt B, Hamm J, & Hasson-Ohayon I (2020). Metacognitive Reflection and Insight Therapy: A Recovery-Oriented Treatment Approach for Psychosis. *Psychology Research and Behavior Management*, 13, 331. 10.2147/PRBM.S198628 [PubMed: 32308511]
- Lysaker PH, Hamm JA, Hasson-Ohayon I, Pattison ML, & Leonhardt BL (2018). Promoting recovery from severe mental illness: Implications from research on metacognition and metacognitive reflection and insight therapy. *World Journal of Psychiatry*, 8(1), 1. 10.5498/WJP.V8.I1.1 [PubMed: 29568726]
- Lysaker PH, & Klion RE (2017). Recovery, Meaning-Making, and Severe Mental Illness: A Comprehensive Guide to Metacognitive Reflection and Insight Therapy. In *Recovery, Meaning-Making, and Severe Mental Illness*. Routledge.
- Lysaker PH, Kukla M, Belanger E, White DA, Buck KD, Luther L, Firmin RL, & Leonhardt B (2015). Individual Psychotherapy and Changes in Self-Experience in Schizophrenia: A Qualitative Comparison of Patients in Metacognitively Focused and Supportive Psychotherapy. *Psychiatry*, 78(4), 305–316. 10.1080/00332747.2015.1063916 [PubMed: 26745684]
- Lysaker PH, Kukla M, Leonhardt BL, Hamm JA, Schnakenberg Martin A, Zalzal AB, Gagen EC, & Hasson-Ohayon I (2020). Meaning, integration, and the self in serious mental illness: Implications of research in metacognition for psychiatric rehabilitation. *Psychiatric Rehabilitation Journal*, 43(4), 275–283. 10.1037/prj0000436 [PubMed: 32790437]
- Lysaker PH, Minor KS, Lysaker JT, Hasson-Ohayon I, Bonfils K, Hochheiser J, & VoHS JL (2019). Metacognitive function and fragmentation in schizophrenia: Relationship to cognition, self-experience and developing treatments. *Schizophrenia Research. Cognition*, 19. 10.1016/J.SCOG.2019.100142
- Lysaker PH, Ringer JM, Buck KD, Grant M, Olesek K, Leudtke BL, & Dimaggio G (2012). Metacognitive and social cognition deficits in patients with significant psychiatric and medical adversity: a comparison between participants with schizophrenia and a sample of participants who are HIV-positive. *The Journal of Nervous and Mental Disease*, 200(2), 130–134. 10.1097/NMD.0B013E3182439533 [PubMed: 22297309]
- Lysaker PH, VoHS J, Hamm JA, Kukla M, Minor KS, de Jong S, van Donkersgoed R, Pijnenborg MHM, Kent JS, Matthews SC, Ringer JM, Leonhardt BL, Francis MM, Buck KD, & Dimaggio G (2014). Deficits in metacognitive capacity distinguish patients with schizophrenia from those with prolonged medical adversity. *Journal of Psychiatric Research*, 55(1), 126–132. 10.1016/J.JPSYCHIRES.2014.04.011 [PubMed: 24811777]
- Lysaker PH, VoHS J, Minor KS, Irarrázaval L, Leonhardt B, Hamm JA, Kukla M, Popolo R, Luther L, Buck KD, Wasmuth S, & Dimaggio G (2015). Metacognitive Deficits in Schizophrenia: Presence and Associations With Psychosocial Outcomes. *The Journal of Nervous and Mental Disease*, 203(7), 530–536. 10.1097/NMD.0000000000000323 [PubMed: 26121151]
- Minor KS, Marggraf MP, Davis BJ, Mickens JL, Abel DB, Robbins ML, Buck KD, Wiehe SE, & Lysaker PH (2022). Personalizing interventions using real-world interactions: Improving symptoms and social functioning in schizophrenia with tailored metacognitive therapy. *Journal of Consulting and Clinical Psychology*, 90(1), 18–28. 10.1037/CCP0000672 [PubMed: 34410749]
- Montani I, Honnibal M, Honnibal M, Landeghem S.Van, Boyd A, Peters H, McCann PO, geovedi jim, O'Regan J, Samsonov M, Altinok D, Orosz G, Kok D. de, Kristiansen SL, Bournhonesque R, Miranda L, Kannan M, Baumgartner P, Edward murat. (2022). explosion/spaCy: v3.4.2: Latin and Luganda support, Python 3.11 wheels and more. 10.5281/ZENODO.7228125
- Monticelli F, Imperatori C, Carcione A, Pedone R, & Farina B (2018). Cooperation in psychotherapy increases metacognitive abilities: a single-case study. *Rivista Di Psichiatria*, 53(6), 336–340. 10.1708/3084.30768 [PubMed: 30667401]
- Morin A (2005). Possible links between self-awareness and inner speech.

- Moritz S, & Lysaker PH (2018). Metacognition - What did James H. Flavell really say and the implications for the conceptualization and design of metacognitive interventions. *Schizophrenia Research*, 201, 20–26. 10.1016/J.SCHRES.2018.06.001 [PubMed: 29903626]
- Müller H, Laier S, & Bechdolf A (2014). Evidence-based psychotherapy for the prevention and treatment of first-episode psychosis. *European Archives of Psychiatry and Clinical Neuroscience*, 264 Suppl 1(1), 17–25. 10.1007/S00406-014-0538-0
- Nikzad AH, Cong Y, Berretta S, Hänsel K, Cho S, Pradhan S, Behbehani L, DeSouza DD, Liberman MY, & Tang SX (2022). Who does what to whom? graph representations of action-predication in speech relate to psychopathological dimensions of psychosis. *Schizophrenia* 2022 8:1, 8(1), 1–10. 10.1038/s41537-022-00263-7
- Owen MJ, Sawa A, & Mortensen PB (2016). *Schizophrenia*. *Lancet* (London, England), 388(10039), 86–97. 10.1016/S0140-6736(15)01121-6 [PubMed: 26777917]
- Palaniyappan L, & Venkatasubramanian G (2022). The Bayesian brain and cooperative communication in schizophrenia. *Journal of Psychiatry & Neuroscience: JPN*, 47(1), E48–E54. 10.1503/JPN.210231 [PubMed: 35135834]
- Palmer M, Kingsbury P, & Gildea D (2005). The Proposition Bank: An Annotated Corpus of Semantic Roles. *Computational Linguistics*, 31(1), 71–105. 10.1162/0891201053630264
- Pennebaker JW, Boyd RL, Jordan K, & Blackburn K (2015). The development and psychometric properties of LIWC2015. 10.15781/T29G6Z
- Ramakrishna A, Greer T, Atkins D, & Narayanan S (2018). Computational modeling of conversational humor in psychotherapy. *Interspeech*, 2018, 2344. 10.21437/INTERSPEECH.2018-1583 [PubMed: 34307638]
- Rieber RW (Robert W), & Carton AS (n.d.). *The Collected Works of L.S. Vygotsky. Volume 1, Problems of General Psychology: Including the Volume Thinking and Speech.*
- Ryu J, Heisig S, McLaughlin C, Katz M, Mayberg HS, & Gu X (2023). A natural language processing approach reveals first-person pronoun usage and non-fluency as markers of therapeutic alliance in psychotherapy. *IScience*, 26(6). 10.1016/J.ISCI.2023.106860
- Tanana MJ, Soma CS, Kuo PB, Bertagnolli NM, Dembe A, Pace BT, Srikumar V, Atkins DC, & Imel ZE (2021). How do you feel? Using natural language processing to automatically rate emotion in psychotherapy. *Behavior Research Methods*, 53(5), 2069–2082. 10.3758/S13428-020-01531-Z [PubMed: 33754322]
- Tang SX, Cong Y, Nikzad AH, Mehta A, Cho S, Hänsel K, Berretta S, Dhar AA, Kane JM, & Malhotra AK (2022). Clinical and computational speech measures are associated with social cognition in schizophrenia spectrum disorders. *Schizophrenia Research*. 10.1016/J.SCHRES.2022.06.012
- Van Staden CW, & Fulford KWM (2004a). Changes in semantic uses of first person pronouns as possible linguistic markers of recovery in psychotherapy. *The Australian and New Zealand Journal of Psychiatry*, 38(4), 226–232. 10.1080/J.1440-1614.2004.01339.X [PubMed: 15038801]
- Van Staden CW, & Fulford KWM (2004b). Changes in semantic uses of first person pronouns as possible linguistic markers of recovery in psychotherapy. *The Australian and New Zealand Journal of Psychiatry*, 38(4), 226–232. 10.1080/J.1440-1614.2004.01339.X [PubMed: 15038801]
- Vine V, Boyd RL, & Pennebaker JW (2020). Natural emotion vocabularies as windows on distress and well-being. *Nature Communications*, 11(1). 10.1038/S41467-020-18349-0
- Vita A, & Barlati S (2018). Recovery from schizophrenia: is it possible? *Current Opinion in Psychiatry*, 31(3), 246–255. 10.1097/YCO.0000000000000407 [PubMed: 29474266]
- Vohs JL, Leonhardt BL, James AV, Francis MM, Breier A, Mehdiyoun N, Visco AC, & Lysaker PH (2018). Metacognitive Reflection and Insight Therapy for Early Psychosis: A preliminary study of a novel integrative psychotherapy. *Schizophrenia Research*, 195, 428–433. 10.1016/J.SCHRES.2017.10.041 [PubMed: 29108671]

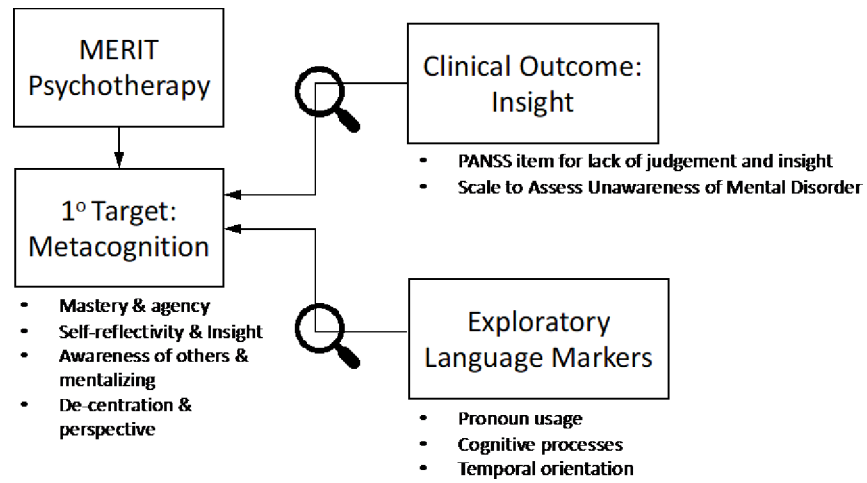
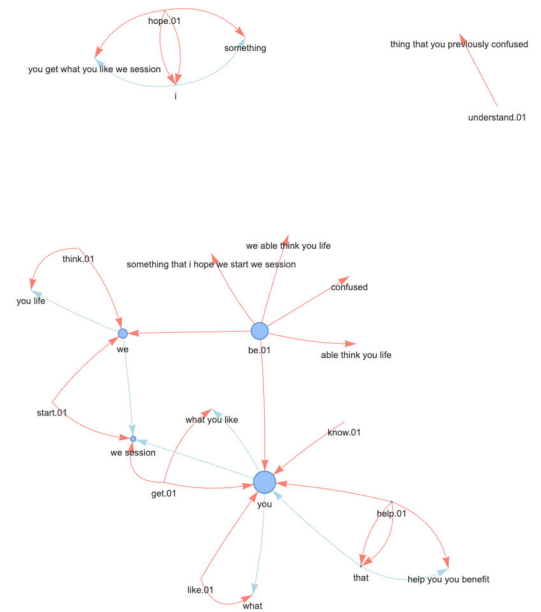


Figure 1. Therapeutic targets and outcome measures in Metacognitive Reflection and Insight Therapy (MERIT)

Note. PANSS = Positive and Negative Syndrome Scale for Schizophrenia.



A. Representation of agency as nodes with in- and out-degrees in action graph



B. Representing the centrality of linguistic entities as betweenness-centralities in action-predication graph

Figure 2. Semantic graph representation of therapy transcript

Note. This figure illustrates graph representation of the following sample of therapist speech: “Well something that I had hoped when we started our sessions is that we would be able to think about your life. Maybe understand things that you previously were confused about. But mostly I was hoping that you would get what you would like out of our sessions. That in some way would help, you know, help you to your benefit.” A. Action graph where nodes with active roles are connected to nodes with passive roles (all in blue). All nodes are in the same size. B. Action-Predication graph where predicates are connected to the arguments (red) and arguments with active role are connected to those with passive roles (blue). The size of the nodes is proportionate to their betweenness centrality.

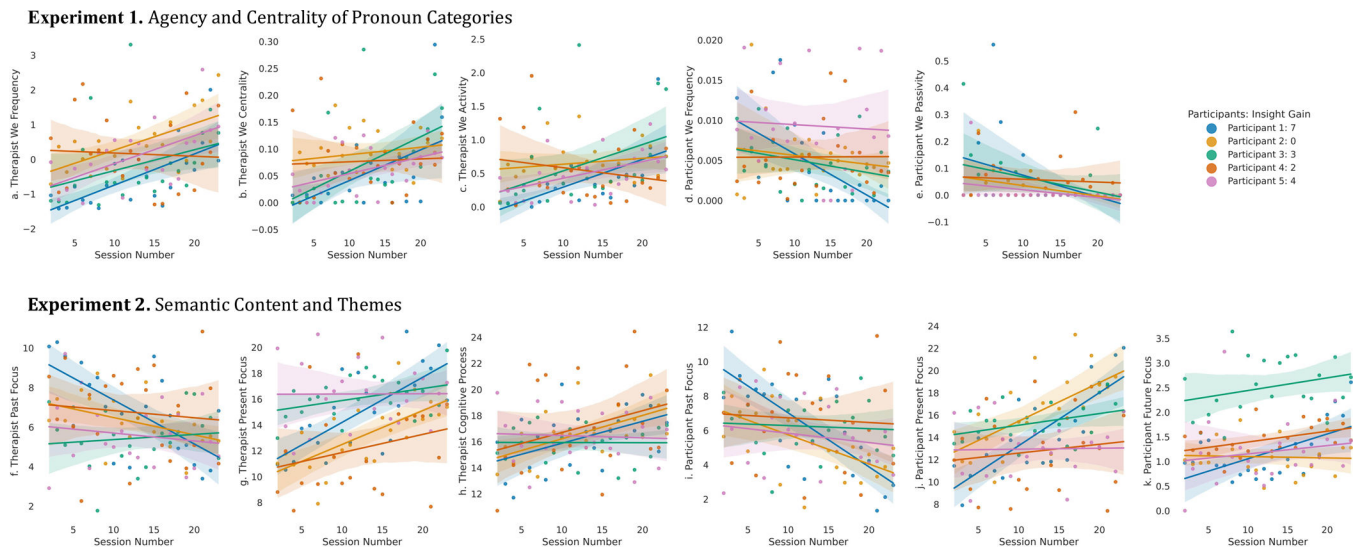


Figure 3. Individual differences in linguistic feature trajectories.

Note. Longitudinal changes in computational linguistic features I. Experiment 1 (a-c therapist features and d-e participant features) and II. Experiment 2 (f-h therapist features and i-k participant features). Insight gain is calculated for each participant by subtracting pre- and post-intervention scores on The Scale to Assess Unawareness of Mental Disorder (Table 1S).

Table 1

Computational linguistic features.

Feature Name	Definition
Normalized Pronoun Frequency	Number of instances of a pronoun category divided by the total number of words
Pronoun out-Degree	Number of outgoing edges emanating from the node representing a pronoun category (i.e. how much a pronoun category takes an active semantic role)
Pronoun in-Degree	Number of incoming edges landing on the node representing a pronoun category (i.e. how much a pronoun category takes a passive semantic role)
Pronoun Centrality	Betweenness centrality of the node representing a pronoun category (i.e. how much a pronoun category mediates connections between other entities)
LIWC Past Focus	Percentage of total words being past-tense verbs or references to past events/times – e.g. ago, did, and talked.
LIWC Present Focus	Percentage of total words being present-tense verbs or references to present events/times – e.g. today, is, and now.
LIWC Future Focus	Percentage of total words being future-tense verbs or references to future events/times – e.g. may, will, and soon.
LIWC Cognitive Processes	Percentage of total words being references to cognitive processes and activities – e.g. cause, know, and ought.
LIWC Perceptual Processes	Percentage of total words being references to perceptual processes and activities – e.g. look, heard, and feeling.
LIWC Biological Processes	Percentage of total words being references to biological processes and activities – e.g. eat, blood, and pain.
LIWC Affective Processes	Percentage of total words being references to affective processes and activities – e.g. happy and cried.
LIWC Social Processes	Percentage of total words being references to social processes and activities – e.g. mate, talk, and they.

Note. LIWC = Linguistic Inquiry and Word Count program.

Table 2

Changes in pronoun use over the course of MERIT.

	Normalized Frequency β (p)	In-Degree β (p)	Out-Degree β (p)	Centrality β (p)
Participant Speech				
All Pronouns	0.16 (0.06)			
<i>I</i>	0.01 (0.9)	-0.06 (0.5)	-0.04 (0.6)	-0.00 (0.9)
<i>You</i>	0.16 (0.03)*	0.03 (0.7)	0.07 (0.4)	0.10 (0.2)
<i>We</i>	-0.21 (0.02)*	-0.29 (0.002)** Bonf.	-0.06 (0.5)	-0.18 (0.08)
<i>They</i>	-0.17 (0.07)	-0.18 (0.06)	-0.09 (0.3)	-0.15 (0.1)
Therapist Speech				
All Pronouns	0.17 (0.04)*			
<i>I</i>	0.21 (0.02)*	-0.05 (0.6)	0.21 (0.022)*	0.25 (0.007)**
<i>You</i>	-0.19 (0.01)*	0.03 (0.7)	-0.21 (0.022)*	-0.13 (0.12)
<i>We</i>	0.38 (0.000)*** Bonf.	0.01 (0.9)	0.27 (0.003)** Bonf.	0.35 (0.000)*** Bonf.
<i>They</i>	-0.16 (0.08)	-0.13 (0.2)	-0.06 (0.517)	-0.11 (0.2)

Note. Beta-coefficient and p-Values of the mixed linear regression models to in-degree, out-degree and centrality of pronouns in semantic graph models and their normalized frequencies with the fixed effect of sessional progression and random effect of participants. Pronouns were classified into four categories representing the speaker (*I*- including I, me, my, etc.), interlocutor (*You*- including you, yours, yourself, etc.), speech participants (*We*- including, we, us, ours, etc.), and others (*They*- including she, he, they, hers, his, their, etc.). Significant results are tagged with asterisk. Results that survive Bonferroni correction for multiple comparisons are tagged with **Bonf.** (corrected $\alpha = 0.004$ for graph features and 0.0125 for normalized frequency comparisons).

Table 3

Change in temporal focus and mental processes over the course of MERIT.

LIWC Feature	Participant Speech		Therapist Speech	
	β coefficient	P-Value	β coefficient	P-Value
Time				
Past	-0.31	0.001** Bonf.	-0.24	0.009** Bonf.
Present	0.38	0.000*** Bonf.	0.34	0.000*** Bonf.
Future	0.19	0.003** Bonf.	0.19	0.02*
Mental Processes				
Cognitive	0.15	0.09	0.28	0.004** Bonf.
Perceptual	0.20	0.01*	0.19	0.01*
Biological	0.01	0.9	0.01	0.9
Affective	0.01	0.8	-0.20	0.03*
Social	-0.09	0.4	-0.17	0.04*

Note. Beta-coefficient and p-Values of mixed linear regression models to predict the frequency of temporal focus and mental processing categories per LIWC with the fixed effect of sessional progression and random effect of participants. Significant results are tagged with asterisk. Results that survive Bonferroni correction for multiple comparisons are tagged with **Bonf.** (corrected $\alpha = 0.01$).