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Associations between coherence and temporal parameters of narrative speech production in borderline personality disorder

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ABSTRACT

Narrative speech production (NSP), i.e., the conceptualization, linguistic formulation, and articulation of a story, is a multifaceted process underpinned by cognitive functions and mentalization ability, often impaired in individuals with borderline personality disorder (BPD). This study examines differences in coherence and temporal parameters between individuals with BPD and healthy controls (HCs) and explores associations between these factors in both groups. Spontaneous speech of 33 BPD and 31 HC individuals was recorded in three task types (telling their previous day, retelling a story, picture sequences), tapping different cognitive functions. Local and global coherence were extracted with contextual sentence vectors, while temporal parameters were extracted with automatic speech recognition. A series of linear mixed-effects models revealed that NSP of individuals with BPD is mainly characterized by significantly lower global coherence and speech rate and higher number of silent and filled pauses than HCs'. Global coherence displayed significant between-group differences only in picture tasks and correlated with picture arrangement. Spearman correlation matrix showed a significant negative association between global coherence and speech rate within the BPD group and an opposite tendency among HCs. Findings indicate that individuals with BPD might benefit from speaking at a slower pace to improve global coherence in their narratives.

1. Introduction

1.1. Narrative speech production as a complex behavior

Narrative speech production (NSP) involves conceptualization, linguistic formulation, and articulation of a monologue that presents a temporal-causal sequence of events from one's viewpoint (Bruner, 1990; Levelt, 1989; Mar, 2004). Conceptualization is the first, pre-verbal stage of NSP, involving the formulation of the intended message before it is verbally encoded. In this stage, the speaker sets the communicative intention, then selects and organizes relevant information, considering the intention, the listener's background (knowledge, preferences, etc.), and the discourse context (Barker et al., 2020; Levelt, 1989; Searle, 1983). By appropriately selecting and arranging this information, the speaker establishes coherence – a key principle of conceptualization – that ensures semantic unity within the discourse (De Beaugrande and Dressler, 1981; Kintsch and van Dijk, 1978). Coherence is typically divided into *local coherence*, i.e., the meaningful linkage between consecutive text units, and *global coherence*, i.e., the meaningful linkage between each unit and the overall text (Glosser and Deser, 1991). During NSP, the speaker must also simultaneously monitor their own speech and the listener's reactions (Alexander, 2006; Barker et al., 2020; Levelt,

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1983).

Several narrative elicitation tasks are used in experiments, including recollecting specific episodic memories, recalling previously read or heard stories and constructing stories based on picture sequences. Tasks that require voluntary retrieval of past experiences, such as recalling specific memories or read stories, rely heavily on episodic memory (Conway, 2009). Additionally, recalling verbal stimuli, such as read or heard stories, depends on language comprehension to process the input, followed by the creation of a situation model to represent the story visually (Mar, 2004). The episodic buffer coordinates these processes (Baddeley and Wilson, 2002; Svindt et al., 2023). In picture sequencing tasks, speakers must hold images in working memory, filter relevant details using executive attention, and organize them into a coherent temporal-causal sequence, a process that requires planning (Barker et al., 2020; Mar, 2004). Mentalization is essential for understanding the intentions and emotions of the characters depicted in the images (Langdon and Coltheart, 1999). Both picture sequencing and story recall tasks also draw on world knowledge stored in semantic memory and personal experiences stored in episodic memory (Cummings, 2019).

NSP is, therefore, a complex, goal-directed task, requiring world knowledge, domain-general cognitive functions, and mentalization ability (AbdulSabur et al., 2014; Alexander, 2006; Barker et al., 2020; Mar, 2004; Tomasello, 2003; Ye and Zhou, 2009). In its articulation phase, speech pauses – divided into silent (i.e., the absence of speech) and filled (e.g., uh, um, er) pauses – indicate the cognitive load of conceptualization, linguistic formulation (Butterworth, 1980; Goldman-Eisler, 1968), and the monitoring of speech output (Levelt, 1983). While silent pauses are thought to signal lexical search and predominantly occur in preplanned speech, filled pauses are considered to imply grammatical and content planning and predominantly occur in spontaneous speech (Chafe, 1980; Duez, 1982; Maclay and Osgood, 1959; Swerts, 1998). Articulation rate, i.e., the speed of producing consecutive syllables, is another temporal aspect of speech that has been found to be affected by the speaker's arousal (Scherer, 2003), processing speed (Kail, 1992), and working memory capacity (Hulme et al., 1984). Speech pauses and articulation rate together constitute speech rate. These three features are collectively called *temporal parameters*.

1.2. Identity, cognitive functioning and mentalization in borderline personality disorder

Individuals with borderline personality disorder (BPD) experience rapid shifts between affective states due to a marked reactivity of mood; their self and other representations alternate between extremes of idealization and devaluation; their self-image and sense of self are unstable (American Psychiatric Association [APA], 2013; Kernberg, 1975). These rapid shifts are mainly induced by interpersonal rejection (Chapman et al., 2014) or by their decision in situations where the reward is uncertain (Csukly et al., 2023). Due to their unstable sense of self, individuals with BPD often experience "painful incoherence" (Wilkinson-Ryan and Westen, 2000). Their fragmented experience of self and high reactivity to interpersonal stimuli are associated with incoherent oral narratives (Bois et al., 2023; Faggioli et al., 2024; Fuchs, 2007) and with their impaired ability to construct a story from pictures (e.g., Németh et al., 2018).

Beyond the symptoms of BPD, many individuals also exhibit subtle cognitive impairments and difficulties in mentalization. Studies consistently found slower processing speed (Abramovitch et al., 2021; D'Iorio et al., 2024; Ruocco, 2005; Unoka and Richman, 2016) as well as poor inhibition (D'Iorio et al., 2024; Fertuck et al., 2006; Le Gris and van Reekum, 2006), planning (Abramovitch et al., 2021; Fertuck et al., 2006; Le Gris and van Reekum, 2006; Ruocco, 2005), and verbal memory (Abramovitch et al., 2021; Fertuck et al., 2006; Le Gris and van Reekum, 2006; Ruocco, 2005) in individuals with BPD compared to healthy controls (HCs). Individuals with BPD are also known to have difficulties in understanding others' mental states, especially when they are exposed to complex stimuli (e.g., pictures and videos about interpersonal interactions) requiring cognitive as opposed to affective mentalization (Lazarus et al., 2014; McLaren et al., 2022; Németh et al., 2018). Picture arrangement tasks (e.g., Wechsler, 1998) are commonly used for measuring mentalization, on which BPD subjects are consistently reported to underperform HCs (Németh et al., 2018; Schaffer et al., 2015; Segal et al., 1992; Swirsky-Sacchetti et al., 1993). Given the symptoms and neuropsychological impairment mentioned above of BPD, it seems probable that NSP is compromised in people living with BPD.

1.3. Narrative speech production and psychopathology

Due to its complex nature, NSP can be viewed as a gateway to one's mind and personality (Allport, 1942; Bruner, 1990; Chafe, 1980; Goldman-Eisler, 1968; Pennebaker et al., 2003), making it a valuable biomarker of psychopathology (Andreasen, 1979a; Corcoran and Cecchi, 2020; Dikaios et al., 2023; Foltz et al., 2022; Low et al., 2020; Spruit et al., 2022; Voleti et al., 2023). During psychiatric interviews, patients share their personal history (anamnesis) in a narrative, which serves as a platform for clinicians to assess the coherence of thought process and the fluency and rate of speech (MacKinnon et al., 2016; Trzepacz and Baker, 1993). Low coherence is characteristic of *positive formal thought disorder (PTD)*, which reflects disorganized thought and speech. Conversely, low speech rate is associated with *negative formal thought disorder (NTD)*, which reflects impoverished thought and speech (Andreasen, 1979ab; Olah et al., 2024).

Extensive research has delved into narrative coherence in the BPD population, employing speech elicitation tasks that focus on recalling autobiographical memories (Adler et al., 2012; Bendstrup et al., 2021; Jørgensen et al., 2012; Rasmussen et al., 2017; Sajjadi et al., 2022) or describing the participants' and their parents' main traits (Lind et al., 2019). The robustness of these studies is evident in their findings, which consistently show that individuals with BPD tend to construct less coherent narratives than HCs. In general, narrative coherence measures the temporo-spatial orientation, the temporo-causal linearity, and the meaningful connections in narratives (Reese et al., 2011). However, these studies applied different manual evaluation scales (*Life Story Coherence*, Baerger & McAdams, 1999; *High-Point Analysis*, Peterson & McCabe, 1983; *Narrative Coherence Coding Scheme*, Reese et al., 2011), based on partially overlapping criteria, which makes it difficult to compare their results.

A few studies have also examined speech in BPD during psychotherapy sessions (Zimmermann et al., 2021) and interviews (Carter and Grenyer, 2012; Wang et al., 2020, 2021). Wang et al. (2020, 2021) identified speech rate, the number of long silent pauses, and the number of filled pauses as predictors in differentiating BPD and HC individuals. According to Carter and Grenyer (2012), the speech of individuals with BPD is characterized by longer silent pauses relative to that of HCs. Zimmermann et al. (2021) found a strong negative correlation between personality functioning and the duration of silent pauses in BPD patients. These suggest that temporal parameters are distinguishing aspects of speech production in BPD.

1.4. Purpose and novelty of the present study

This study aims to investigate differences in coherence and temporal parameters between individuals with BPD and HCs, as well as to explore unique associations between these variables in BPD that are not observed in HCs. Based on previous research, we hypothesize that (1) narratives of individuals with BPD will be less coherent and (2) their speech will feature a higher proportion (number and length) of pauses compared to HCs. Additionally, we explore (1) the effect of speech elicitation tasks (recalling the previous day, recalling the read story, picture sequencing tasks) on between-group differences, and (2) unique associations between coherence and temporal parameters within the

BPD group.

To address these questions, we recorded the NSP of 33 BPD and 31 HC individuals across three speech elicitation tasks (recounting the previous day, retelling a story, and describing picture sequences). Local and global coherence were extracted using a contextual sentence embedding model, while temporal parameters were measured via automatic speech recognition (ASR) using the Speech-GAP Test® (Kálmán et al., 2022). The novelty of this study lies in its cognitive approach to NSP in BPD, using various speech elicitation tasks to assess different cognitive functions, and its computational approach, applying natural language processing (NLP) methods to measure coherence, which have already been used in schizophrenia (Bedi et al., 2015; Corcoran and Cecchi, 2020; Elvevåg et al., 2007; Iter et al., 2018).

2. Methods

2.1. Participants

Participants were recruited by convenience sampling, on the one hand, i.e., from social media groups for individuals with BPD and other groups aimed at advertising experiments, and by snowball sampling, on the other hand, i.e., by advertising the experiment for potential participants through existing participants. For both groups, the inclusion criteria were to be a native Hungarian speaker and to have intact hearing and speech abilities. For individuals with BPD, a further inclusion criterion was to present clinical documentation confirming the BPD diagnosis (F60.3 Emotionally unstable personality disorder; World Health Organization, 1992). Comorbid disorders were not considered exclusion criteria, as they are also common in the general population. For HCs, the exclusion criteria were to have any psychiatric or neurological disorders. HCs self-reported their health status. Finally, 33 individuals with BPD and 31 HCs participated in the experiment (see Table 1). The two groups were matched based on the participant's gender, age, and years of education they had completed. Table 1 shows the demographic data of the BPD and HC groups.

2.2. Materials and procedure

Data collection was conducted in the following steps: 1) participants read a story about the origin of dishwashing without explicit information on the aim of reading; 2) as a distractor task, participants evaluated the story on three 5-point Likert scales assessing comprehensibility, interest, and modernity (Pléh, 1986); 3) participants were asked to recall their previous day; 4) participants were asked to recall the story about the origin of dishwashing (Pléh, 1986); 5) participants had to arrange three interrelated pictures showing a *family* ("family pictures") in chronological order, then construct a story based on the arranged sequence; 6) the previous task was repeated with three interrelated pictures showing *peer relations* ("peers pictures"); 7) the previous task was repeated with three interrelated pictures showing a *romantic relationship* ("romance pictures"). Fig. 1 presents the picture sequences used.

Participants' picture orders were documented and their speech was recorded with their written consent. The recording was done in a noise-free environment, using a Sony ICD-PX470 dictaphone and a RØDE Lavalier Go clip microphone. The procedure was conducted in line with the Declaration of Helsinki, and resulted in five speech recordings for each subject: "previous day," "read story," "family pictures," "peers pictures," and "romance pictures".

Table 1
Descriptive statistics of demographic data of BPD and HC group.

Variable	BPD	HC	Test	p
N	33	31	–	–
Sex, f:m	28:5	26:5	X^2 (1) = 0.012	0.914
Age, M (SD)	27.18 (6.92)	26.68 (8.08)	W = 571.000	0.436
Years of education, M (SD)	14.64 (2.56)	15.29 (2.74)	W = 453.500	0.435
Individuals with comorbid disorders, N (%)	23 (69.70)	–	–	–
- bipolar disorders	8 (37.78)	–	–	–
- depressive disorders	7 (30.43)	–	–	–
- anxiety disorders	6 (26.09)	–	–	–
- substance use disorders	4 (17.39)	–	–	–
- other personality disorders	3 (13.04)	–	–	–
- eating disorders	2 (8.70)	–	–	–
- attention deficit hyperactivity disorder	2 (8.70)	–	–	–
- sleep disorders	2 (8.70)	–	–	–
- schizophrenia spectrum disorders	1 (4.35)	–	–	–

BPD – borderline personality disorder, HC – healthy controls, Test – type and value of statistical tests applied, p – significance value of statistical tests, f:m – female:male ratio, M – mean, SD – standard deviation, N – number of subjects.

2.3. Feature extraction

2.3.1. Extracting temporal parameters of speech

Audio recordings were first manually split into different recordings by task. This step resulted in five speech samples for each participant, in accordance with the recording procedure.

To automatically estimate temporal parameters, a standard ASR system was used. We used the HTK tool (Young et al., 2006), modified to allow the use of a Hidden Markov Model/Deep Neural Network (DNN) hybrid set-up (Hinton et al., 2012). As acoustic features, we used 40 raw Mel-frequency filter bank energy values along with log-energy and the first and second-order derivatives ('FBANK + Δ + ΔΔ'). The DNN acoustic model was trained on a subset of 60 h of recordings from the BEA corpus (Neuberger et al., 2014); to better suit noisy acoustic conditions, it was extended to 240 h by adding noise, background speech, and reverberation to the recordings of the BEA corpus. Recognition was performed on the level of *phones*, consisting of Hungarian phonemes, silent and filled pauses, breath intakes and sighs (Moore and Skidmore, 2019). The output of the ASR system for a speech recording is a list of phones along with the starting and ending time points of each phone.

The acoustic temporal parameters investigated can be divided into three categories:

- *Utterance length*: the duration between the beginning and end of the response of the subject (the initial and final silent pauses excluded).
- *Speech rate* and *Articulation rate*: the number of phones uttered over either the whole duration of the utterance or over the duration excluding pauses.
- *Duration of pauses*, *Number of pauses*, *Average length of pauses* and *Frequency of pauses*: describing the amount of pauses in some way. These were calculated in two variations: for silent pauses only, and for filled pauses only.

These temporal parameters can all be derived from the output of the ASR system (i.e., from the time-aligned phone sequence) via simple calculations. This process led to 11 Speech-GAP temporal parameters overall (see Table 2).

2.3.2. Extracting the variables of coherence and recall

Automatic transcriptions were generated from the speech samples using Alrite (Alrite©; https://alrite.io/ai/hu/). The accuracy of the transcripts was manually verified, errors were corrected, and disfluencies (e.g., repetitions and verbal fillers; Iter et al., 2018) were eliminated. Contextual vector representations were then generated of the entire documents and their clauses using Sentence transformer (Reimers and Gurevych, 2019) based on BERT (Devlin et al., 2019). In this research, a Hungarian BERT-based Sentence transformer model (Osváth et al., 2023) was applied. Cosine similarities were then

Fig. 1. Picture sequences used for story construction. Each sequence contained three pictures. A unique identifier was assigned to each picture with a letter representing the sequence (F – family, A – peers/age group, R – romance) and a number between 1 and 3 in a randomized order, written on the back of the pictures.

Table 2
Temporal parameters.

Parameter	Metric	Description
Utterance length	s	the duration of the whole narrative
Articulation rate	phone/s	the number of phones per second excluding pauses
Speech rate	phone/s	the number of phones per second including pauses
Duration of pauses	ratio	the aggregated duration of pauses relative to the duration of the whole narrative
Number of pauses	ratio	the number of pauses relative to the number of speech sounds
Average length of pauses	s	the aggregated duration of pauses relative to the number of pauses
Frequency of pauses	phone/s	the number of pauses per second

s – second.

calculated between vectors using the following methods:

1) *Local coherence*: the average similarity between consecutive clauses. Table 3 shows examples for low and high local coherence.
2) *Global coherence*: the average similarity between each clause and the entire document. Table 3 shows examples for low and high global coherence.
3) *Recall*: the similarity between the entire document of the read and the recalled story.

2.4. Statistical analyses

Statistical analyses were conducted using JASP statistical software (JASP Team, 2024).

For hypothesis testing, a series of linear mixed-effects models were applied in a 2 × 5 design in which the dependent variables were the coherence and temporal parameters of NSP, the fixed effects were Group (BPD, HC) and Task (previous day, story recall, family pictures, peers pictures, romance pictures), and the random effect was the participant ID. To identify the differences between the BPD and HC groups, the simple main effect of the Group was calculated in models where the Group had a significant main effect. For post hoc analysis of the differences between tasks, the simple main effect of Group and Task was analyzed in models where the interaction of Group and Task was significant.

To explore the associations between recall performance and NSP variables in the "read story", first, we examined the difference between the two groups regarding the recall performance with a two-tailed Mann-Whitney test, then, we conducted a Spearman correlation analysis between recall performance and NSP variables in the two groups separately. To reveal the patterns of NSP in BPD, Spearman correlation analysis was conducted between the variables of coherence and temporal parameters of speech in the BPD and HC groups separately, controlled for tasks. Only those variables were included that previously showed significant between-group differences.

3. Results

3.1. Difference between groups

The main effect of the Group was significant in models with the following dependent variables: global coherence ($F = 6.792$, $p = .011$), with the narratives of the BPD group conveying lower global coherence; articulation ($F = 8.211$, $p = .006$) and speech rate ($F = 10.635$, $p = .002$), with the speech of the BPD group showing lower articulation and speech rate; number of silent ($F = 4.103$, $p = .047$) and filled pauses ($F = 15.586$, $p < .001$), with the speech of the BPD group exhibiting higher number of silent and filled pauses; and frequency ($F = 9.239$, $p = .003$) and duration of filled pauses ($F = 4.417$, $p = .040$), with the speech of the BPD group displaying higher frequency and duration of filled pauses relative to HCs' (see Table 4). Fig. 2 illustrates the global coherence of a BPD and a HC narrative, showing a sharp difference between them.

3.2. Difference between speech elicitation tasks

The interaction of Group and Task was also significant with the following dependent variables from the models mentioned above: global coherence, articulation rate, and number of silent pauses (see Table 4).

Table 3
Examples for low and high levels of local and global coherence from the "family" pictures task.

Coherence		Low (BPD narratives)	High (HC narratives)
Local	*Hungarian (original)*	Hát most elsőre az jött, hogy itt van egy magányos lány, aki természetkedvelő meg kalandvágyó, ő nem akar férjet, meddő, és örökbe fogad két gyereket. És velük túrázik.	Tehát ebben a történetben tulajdonképpen az történt, hogy egy anyuka elment a két gyerekével kirándulni, és a kisfiú, aki a nagyobbik, és ő már tud járni, a kisebbik nem, ő kiválasztott egy útvonalat, amin szerettek volna menni, de sajnos ezt átszelte egy folyó, és a köveken a kisfiú még nem tudott volna átmenni, ezért nagyon szomorú lett, és az anyukájának meg kellett vigasztalni, és azzal tudta csak, hogy egy másik útvonalat választhatott, amin aztán továbbindultak, és így folytatták a kirándulást.
	English (translated)	Well, what came to mind at first that there's a lonely girl who's a nature lover and adventurous, she doesn't want a husband, she's barren, and she's adopting two kids. And she's hiking with them.	So what actually happened in this story was that a mom went on a hike with her two children, and the little boy, who is the older one, can already walk, the younger one can't, she chose a route that they wanted to go, but unfortunately a river crossed it, and the little boy couldn't have passed the stones yet, so he became very sad, and his mom had to comfort him, and she did it by letting he choose another route, which they then moved on and continued their trip.
Global	*Hungarian (original)*	Mentek csoportos öngyilkosságra. Tehát nem az, hogy öngyilkosság, hanem a gyerek akarja, hogy fölvegyék, felveszi, sétálnak, és akkor elmennek a folyópartra. Ennyi. És aztán folytatódik. Nem folytatódik, ennyi.	Hát egy anyuka két kisgyerekével elment kirándulni az erdőbe, elmentek egy közeli patakhoz, megnézték az ott lévő élővilágot, például a halakat, és amikor hazafele indultak már távolabb a folyótól, a kislány elesett, beütötte a térdét, és az anyukája itt próbálja megvigasztalni.
	English (translated)	They went for group suicide. So it's not suicide, but the kid who wants to be picked up, she picks him up, they walk, and then they go to the riverbank. That's all. And then it continues. It doesn't continue, that's all.	Well, a mom went for a hike with her two small children in the forest, they went to a nearby stream, looked at the wildlife there, for example the fish, and when they were heading home farther away from the river, the little girl fell, hit her knee, and her mom is here trying to comfort her.

Global coherence and articulation tempo showed significant between-group differences in all the picture arrangement tasks, but not in other tasks, while in the case of the number of silent pauses, the difference was significant only in the "peers pictures" (see Table 5).

To explore possible factors underlying the aforementioned between-group differences within the picture tasks, we ran a series of χ^2 Tests of Independence, one for each picture sequence, to reveal differences between the two groups in their ordering preferences. Table 6 shows the orders most frequently chosen and the results of the tests. Results revealed a significant difference between the two groups in their typical picture arrangement of the romance pictures ($\chi^2(4) = 19.298$, $p < .001$, $V = 0.55$). There were no significant group differences in the family or peers pictures. Then, we conducted a two-tailed Mann-Whitney test to inspect the differences between the BPD and HC groups' typical order of the romance pictures in those variables which showed significant differences between the BPD and HC groups in this sequence, i.e., global coherence and articulation rate. Results showed significant differences between the two typical picture orders only in global coherence ($W = 278.000$, $df = 39$, $p = .007$), with the typical order of the BPD group exhibiting significantly lower global coherence ($N_{BPD} = 11$, $N_{HC} = 2$, $M = 0.102$, $SD = 0.006$) compared to that of HCs ($N_{BPD} = 7$, $N_{HC} = 21$, $M = 0.116$, $SD = 0.038$).

Regarding recall performance, no significant between-group difference was found ($W = 396.500$, $p = .124$). In line with results from the Group × Task interaction, correlation analysis has not revealed any significant associations between recall performance and NSP variables in either group (see Fig. 3).

3.3. Associations between coherence and temporal parameters

Fig. 4 illustrates the Spearman correlation coefficients between global coherence and temporal parameters within the BPD and HC groups. Within the BPD group, global coherence was significantly negatively correlated to speech rate ($r = -0.30$, $p < .001$) and positively to the number of silent ($r = 0.20$, $p = .010$) and filled pauses ($r = 0.20$, $p = .010$). The opposite tendency can be observed among HCs regarding the relationship between global coherence and speech rate as well as between global coherence and the number of silent pauses. Within the HC group, a significant association was only found between global coherence and the frequency of filled pauses ($r = 0.18$, $p = .024$).

4. Discussion

This study aimed to examine differences between individuals with BPD and HCs in terms of different types of coherence and various temporal parameters of NSP. We also explored unique associations between these two classes of NSP features in individuals with BPD.

Our first hypothesis was that narratives of individuals with BPD would be less coherent than those of HCs. Findings partly support our hypothesis, as the narratives of individuals with BPD exhibit significantly lower global coherence than those of HCs. However, there was no significant difference between the two groups in local coherence. This result aligns with the findings of Sajjadi et al. (2022), who reported that topic maintenance in narratives is negatively associated with Impulsivity, Risk-taking, Hostility, and Depressivity pathological personality traits linked to BPD. Among these, Impulsivity and Hostility have been found to be related to lower inhibition (Fossati et al., 2018). The authors also reported a negative association between topic maintenance and Empathy (Sajjadi et al., 2022), a dimension of personality functioning related to mentalization (APA, 2013). Dimitrova and Simms (2022) also found a negative association between narrative coherence and Empathy.

One possible explanation for poorer global coherence is deficits in mentalization ability in BPD. Behavioral studies found positive correlations between narrative coherence and the ability to understand others' mental states in various populations (Bylemans et al., 2023; Fernández, 2013; Foldager et al., 2024; Lind et al., 2020). Brain imaging studies on university students have reported increased activation in the default mode network – involved in mentalization (Yeshurun et al., 2021) – during low-coherence speech, possibly as a compensatory mechanism to restore coherence. (Morales et al., 2022; Wu et al., 2022). Other studies have shown that during social-cognitive tasks, BPD participants exhibit hypoactivation in brain regions involved in theory of mind (ToM) processes (Dziobek et al., 2011; Mier et al., 2013), along

Table 4
Descriptive statistics of BPD and HC group and the main effects of Group and Task factors.

Dependent variable	BPD	HC	Group		Task		Group × Task	
	M (SD)	M (SD)	F	p	F	p	F	p
Coherence			df = 1, 62.00		df = 4, 248.00		df = 4, 248.00	
Local coherence	0.451 (0.065)	0.439 (0.062)	2.021	0.160	16.516	<0.001	0.660	0.620
Global coherence	0.100 (0.004)	0.117 (0.036)	6.792	0.011	7.165	<0.001	3.686	0.006
Temporal parameters of speech								
Utterance length	119.797 (154.481)	115.741 (102.661)	0.051	0.821	27.843	<0.001	0.969	0.425
Articulation rate	14.301 (1.364)	15.193 (1.423)	8.211	0.006	12.634	<0.001	3.447	0.009
Speech rate	8.824 (2.104)	10.192 (1.834)	10.635	0.002	4.753	0.001	1.616	0.173
Number of silent pauses	0.049 (0.016)	0.043 (0.013)	4.103	0.047	5.616	<0.001	2.677	0.032
Number of filled pauses	0.024 (0.012)	0.015 (0.008)	15.586	<0.001	1.541	0.191	0.328	0.859
Frequency of silent pauses	0.434 (0.091)	0.441 (0.082)	0.166	0.685	1.033	0.391	1.006	0.405
Frequency of filled pauses	0.214 (0.097)	0.160 (0.074)	9.239	0.003	1.111	0.352	0.073	0.990
Duration of silent pauses	0.330 (0.128)	0.286 (0.095)	3.214	0.078	2.470	0.045	1.069	0.372
Duration of filled pauses	0.055 (0.027)	0.043 (0.024)	4.417	0.040	1.075	0.369	0.152	0.962
Average length of silent pauses	0.797 (0.410)	0.660 (0.232)	3.899	0.053	1.941	0.104	0.920	0.453
Average length of filled pauses	0.251 (0.069)	0.266 (0.076)	1.155	0.287	1.991	0.096	0.531	0.713

BPD – borderline personality disorder, HC – healthy controls, M – mean, SD – standard deviation, F – score of the F-test, df – degrees of freedom, p - significance value of the F-score.

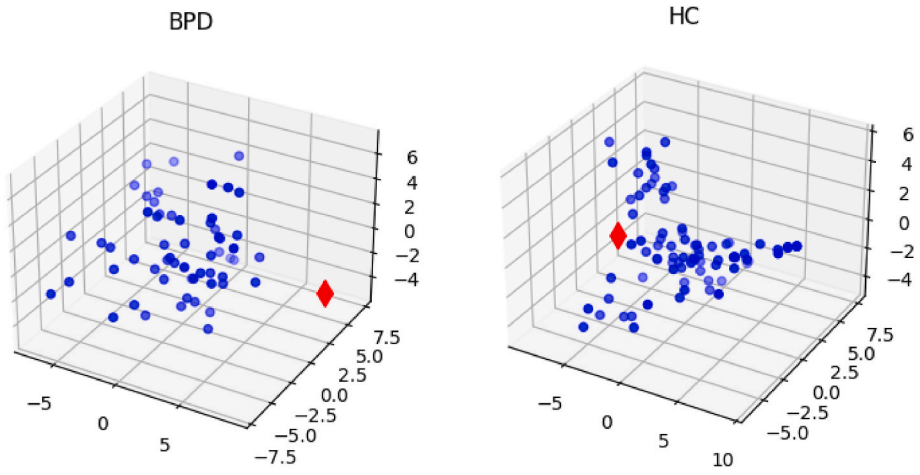

Fig. 2. The distance between the topic of the whole narrative (red) and each clause (blue) in a BPD and a HC narrative. The high-dimensional document (red) and clause vectors (blue) of a BPD (25-year-old woman, 15 completed years of study, *global coherence* = 0.098) and a HC individual's (24-year-old woman, 16 completed years of study, *global coherence* = 0.112) "previous day" narrative were transformed into a three-dimensional space.

Table 5
Simple main effects of the Group × Task interaction in variables where Group × Task interaction was significant.

Dependent variable	Previous day		Read story		Family pictures		Peers pictures		Romance pictures	
	z	p	z	p	z	p	z	p	z	p
Global coherence	−2.328	0.100	−2.004	0.225	−3.104	0.010	−2.739	0.031	−2.609	0.010
Articulation rate	−1.447	0.740	−1.867	0.310	−2.860	0.021	−3.366	0.004	−3.404	0.003
Number of silent pauses	0.910	1.000	0.627	1.000	1.779	0.376	2.987	0.014	2.279	0.113

z – score of the z-test, p – significance value of the z-score.
Bonferroni correction was applied to p values.

Table 6
Between-group differences of picture orders.

Sequence	BPD		HC		χ^2 test			
	Typical order	N (%)	Typical order	N (%)	χ^2	df	p	V
Family	F01–F03–F02	11 (33.33)	F03–F02–F01	11 (35.48)	4.882	5	0.431	0.28
Peer relations	A02–A01–A03	21 (63.64)	A02–A01–A03	22 (70.97)	8.580	4	0.072	0.37
Romantic relationship	R03–R02–R01	11 (33.33)	R03–R01–R02	21 (67.74)	19.298	4	<0.001	0.55

Picture orders should be interpreted from left to right.
BPD – borderline personality disorder, HC – healthy controls, N – number of subjects applied the typical order, % – percentage of subjects applied the typical order, χ^2 – score of the χ^2 test, df – degrees of freedom, p – significance value of the χ^2 score, V – Cramer's V effect size of the χ^2 test.

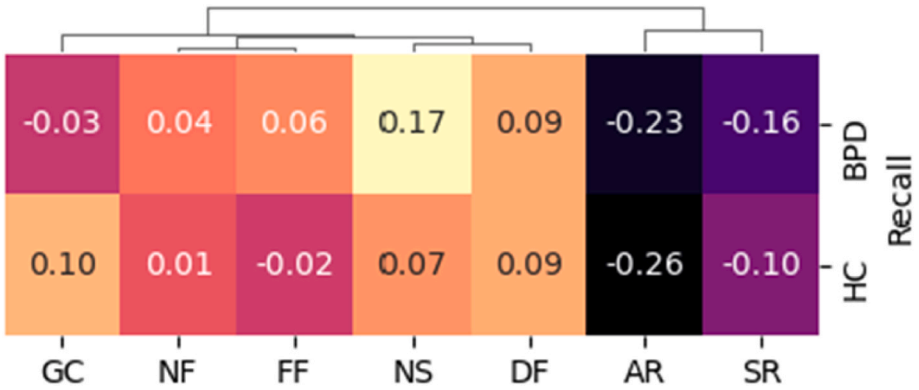

Fig. 3. Clustermap of Spearman correlation coefficients between recall and NSP variables within the BPD and HC groups. BPD – borderline personality disorder, HC – healthy controls, GC – global coherence, NF – number of filled pauses, FF – frequency of filled pauses, NS – number of silent pauses, DF – duration of filled pauses, AR – articulation rate, SR – speech rate.

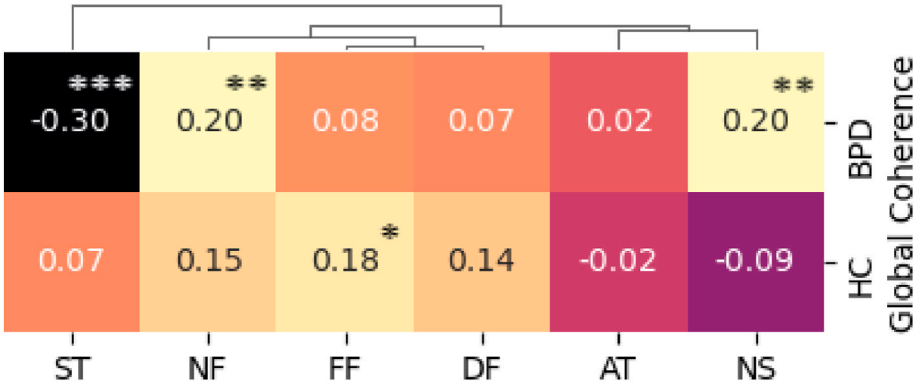

Fig. 4. Clustermap of Spearman correlation coefficients between global coherence and temporal parameters within the BPD and HC groups, controlled for tasks. BPD – borderline personality disorder, HC – healthy controls, ST – speech rate, NF – number of filled pauses, FF – frequency of filled pauses, DF – duration of filled pauses, AT – articulation rate, NS – number of silent pauses. *p < .05 **p < .01 ***p < .001.

with weaker connectivity between the anterior cingulate cortex and ToM-related areas (O'Neill et al., 2015) compared to HCs. These findings suggest that individuals with BPD may struggle to shift their attention from self-relevant to task-relevant information, for example, interpreting the story characters' mental states and the listener's reactions to off-topic utterances during NSP.

On the other hand, lower global coherence can also be explained by poor inhibition in BPD. Studies found a positive association between global coherence and inhibition in individuals with stroke (Barker et al., 2017), schizophrenia (Martin et al., 2016), Parkinson's disease (Rogalski et al., 2022), and healthy older adults (Wright et al., 2014). Hoffman (2019) and Hoffman et al. (2018, 2020) found positive associations between global coherence and semantic control, i.e., the selection and inhibition of semantic knowledge based on its relevance (Jackson, 2021), in healthy older adults and stroke patients. In line with these, positive associations have been found in various populations between global coherence and the activation in the left inferior frontal gyrus (lIFG; Hoffman, 2019; Marini and Urgesi, 2012; Morales et al., 2022), known for its role in semantic control. In BPD patients, decreased gray matter volume has been found in the lIFG (Lou et al., 2021), and its activation has been associated with improvements in behavioral constraint (Perez et al., 2016). These suggest that individuals with BPD might have difficulties with inhibiting items from their semantic knowledge that are irrelevant to the topic under discussion, which makes their narrative tangential.

Our second hypothesis was that the speech of individuals with BPD would exhibit a higher proportion (number and duration) of pauses compared to that of HCs. Partly in line with Wang et al. (2020, 2021), the results revealed that the speech of individuals with BPD is characterized by significantly lower articulation and speech rates, a significantly higher number of silent and filled pauses, as well as a significantly higher frequency and duration of filled pauses relative to HCs. From these features, speech rate and the various measures of filled pauses were unrelated to tasks. The higher proportion of filled pauses might be explained by greater difficulties during conceptualization and sentence construction in individuals with BPD relative to HCs. Filled pauses often appear at points where the speaker faces multiple competing solutions (e.g., multiple possible concepts, such as picture interpretations, or competing sentence structures) causing uncertainty (Kosmala and Crible, 2022; Maclay and Osgood, 1959). As speech rate is a composite metric of articulation rate and pauses, lower speech rate in BPD can either indicate slower processing speed, lower working memory capacity, or difficulties in verbal planning.

Our first question was whether the type of speech elicitation task affects the differences between the BPD and HC groups in terms of coherence and temporal parameters. Global coherence, articulation rate, and the number of silent pauses showed significant differences between the two groups only in the picture tasks. Regarding articulation rate, the between-group difference increased progressively across the tasks, indicating increasing cognitive fatigue in BPD due to task accumulation, possibly affecting speech motor performance. The number of silent pauses showed a significant between-group difference only in "peers pictures". There was not any significant association between NSP variables and recall performance. In accordance with previous studies (Németh et al., 2018; Schaffer et al., 2015; Segal et al., 1992; Swirsky-Sacchetti et al., 1993), the typical picture order created by

individuals with BPD significantly deviated from that of HCs in "romance pictures". To interpret and meaningfully arrange these often ambiguous pictures is a cognitively demanding task since the individual must (1) filter out relevant items from the complex visual stimuli, (2) understand the characters' mental states and the interactions between them, and (3) identify causal and temporal relationships between the pictures. Given this complexity, the BPD group's picture arrangement style might be explained by their difficulty with the inhibition of irrelevant visual stimuli, and deficits in mentalization. Results also revealed that BPD individuals' typical picture order was associated with significantly lower global coherence relative to HCs'. It seems probable that the creation of meaningful connections between verbal (i.e., text units) and nonverbal (i.e., pictures) items require a common underlying mechanism, namely, central coherence, i.e., the ability to integrate individual elements into a coherent whole (Frith and Happé, 1994; Pellicano et al., 2005).

Our second question explored the relationship between coherence and temporal parameters in the BPD group. Global coherence was negatively correlated with speech rate and positively correlated with the number of silent and filled pauses in individuals with BPD. In contrast, the opposite, non-significant trend was observed among HCs for speech rate and silent pauses. PTD, including low global coherence (or loose associations), is commonly observed in schizophrenia and manic episodes of bipolar disorder (Covington et al., 2005; Dikaios et al., 2023; Yalincetin et al., 2017) and is linked to poor inhibition (Bora et al., 2019). NTD, including low speech rate, is a feature of schizophrenia and depression (Dikaios et al., 2023; Low et al., 2020; Yalincetin et al., 2017) and is associated with working memory deficits (Bora et al., 2019; Yalincetin et al., 2017). Since BPD shares genetic links with these disorders (Witt et al., 2017), it is unsurprising that they exhibit transdiagnostic features. However, these features may differ in their exact manifestation and underlying mechanisms across disorders (Hopwood et al., 2023). There is a general pattern in psychopathology of higher speech rate (or pressured speech) resulting in looser associations (Robinson et al., 2015; Trzepacz and Baker, 1993). When BPD individuals speak relatively faster, too many – often irrelevant – items may enter their working memory, leading to lower global coherence or looser associations. To maintain global coherence, individuals with BPD may need to reduce their speech rate to filter irrelevant information from working memory. Additionally, slower speech rate would also help them track the listener's and the story characters' mental states.

Despite the insights gained from this study, several limitations must be acknowledged. First, the cross-sectional design prevents us from capturing stable characteristics of NSP in BPD. Second, the relatively small sample size increases susceptibility to outliers, limiting the generalizability of our findings. Third, the absence of neuropsychological testing is a notable limitation, as cognitive functions such as attention and executive control could have impacted NSP. Additionally, no psychological prescreening was conducted for HCs, raising the possibility that undiagnosed psychiatric conditions may have influenced the results. Finally, the lack of data on pharmacotherapy among BPD participants is a significant limitation, as medication could have affected speech production (Gabbert et al., 2002). To address these issues, we are conducting a follow-up study with a larger sample, incorporating psychological prescreening for HCs, documenting pharmacotherapy among BPD patients, and neuropsychological testing.

In conclusion, NSP, including the preservation of global coherence, seems to be a cognitively challenging task for people with BPD, as indicated by slower speech rate and higher proportion of silent and filled pauses. The ability to maintain global coherence seems to be associated with the ability to interpret picture sequences. Lower global coherence in narratives, coupled with disrupted picture arrangement patterns, suggests difficulties in integrating information into a coherent whole, a cognitive process crucial for maintaining a continuous sense of identity.

CRediT authorship contribution statement

Fanni Felletár: Writing – review & editing, Writing – original draft, Conceptualization, Methodology, Investigation, Formal analysis, Visualization. **Gábor Gosztolya:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Software. **Zijian Gy Yang:** Writing – original draft, Formal analysis, Data curation, Visualization. **Ildikó Hoffmann:** Writing – review & editing, Writing – original draft, Supervision, Methodology. **Anna Babarczy:** Writing – review & editing, Writing – original draft, Supervision, Methodology. **Zsolt Sz Unoka:** Writing – review & editing, Writing – original draft, Supervision.

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Declaration of competing interest

None.

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