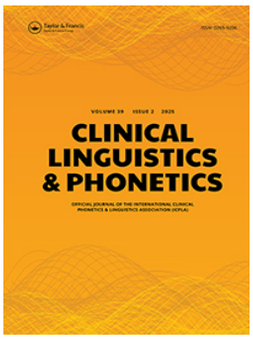

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From semantic concreteness to concretism in schizophrenia: An automated linguistic analysis of speech produced in figurative language interpretation

Valentina Bambini[a*], Federico Frau[a*], Luca Bischetti[a], Giulia Agostoni[b,c], Cristian Mevio[d], Chiara Battaglini[a], Margherita Bechi[b], Mariachiara Buonocore[b], Jacopo Sapienza[b,e], Marco Spangaro[b], Carmelo Guglielmino[b], Federica Cocchi[b], Roberto Cavallaro[b,c], and Marta Bosia[b,c]

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ABSTRACT

Lack of abstract thinking, known as *concretism*, is a well-known psychopathological feature of schizophrenia, reflecting the tendency to adhere to concrete aspects of stimuli and figurative language comprehension difficulties. Inspired by the similarity between 'concretism' as defined in psychopathology and 'concreteness' as defined in linguistics, namely a semantic dimension linked to perceptual experience, we tested the novel hypothesis that impairment in deriving figurative meanings is related to impairment at the semantic level, involving concreteness. We analysed speech samples from 63 individuals with schizophrenia and 47 controls, who were asked to verbalise the meaning of idioms, metaphors, and proverbs. By automatically extracting linguistic features from speech, we observed that answers in the schizophrenia group exhibited higher word concreteness and the related measure of word imageability, especially in proverbs, while not differing from controls' ones in lexical richness and speech-time composition. Concreteness in verbalisations produced by individuals with schizophrenia negatively predicted their ability to understand proverbs and their global pragmatic and cognitive profile. This study supports the idea that concretism is rooted in semantics, linking the tendency to concrete figurative interpretations and a bias towards concrete words. In this view, impairment in figurative language understanding can be seen as a difficulty in abstracting away from perceptual-related properties associated with linguistic inputs, in the broader context of multisensory integration disruption. The study discloses new areas of interest for the automated analysis of speech in psychosis, pointing to the importance of considering concreteness for better characterising linguistic profiles and identifying clinically relevant linguistic dimensions.

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Introduction

'Formal thought disorder' has been at the centre of the clinical description of schizophrenia since Bleuler's early work (Bleuler, 1911), referring to a plethora of psychopathological manifestations, leading to disorganised streams of thoughts, unusual and irrelevant conceptual associations, including biases towards more *concrete* modes of thinking (Kircher et al., 2018; Spitzer, 1997). Instances of concrete thinking in schizophrenia have been largely documented in classic literature: whether it manifests as an inability to grasp similarities among objects, to change strategies during a task, or to generalise relevant aspects from a situation, concretism can be briefly summarised as a generalised difficulty in going beyond immediate experience whenever it is required to adopt an abstract mode of thinking (Goldstein, 1959; Wright, 1975).

Among the various manifestations of concretism in schizophrenia, the literature includes also difficulty in understanding figurative expressions, such as metaphors and proverbs, as documented in early and more recent studies (Goldstein, 1959; Mossaheb et al., 2014; Rossetti et al., 2018; Spitzer, 1993). Individuals with schizophrenia might fail to go beyond the literal meaning of these expressions, being rather more likely to remain anchored to the most immediate, concrete, and literal sense of words (Harrow, 1974; Kircher et al., 2007). In this view, concretism is tightly connected with pragmatic disorder, namely a general communicative impairment hampering the ability to manage articulated discourse and use language appropriately to context, as required also in the case of figurative language understanding (Bambini et al., 2016; Colle et al., 2013). Specifically, studies showed that approximately 20% of individuals with schizophrenia fail in a multiple-choice task of figurative language understanding, and this percentage goes up to 77% in a verbal explanation task (Bambini et al., 2016), with proverbs being the most challenging type of figurative expression (compared to idioms and metaphors), possibly due to their abstract moral content (Bambini et al., 2020).

From Bleuler's initial idea of 'disordered conceptual associations', concretism in schizophrenia has received several explanations, related to more general difficulties in abstract conceptualisation (Wright, 1975), altered organisation of semantic networks in associative memory (Spitzer, 1993) or, more recently, impaired cognitive and sociocognitive mechanisms (see Frau et al., 2024). Little consideration has been paid to the idea that concretism – at least for what concerns its pragmatic manifestation – could be linked to difficulties in core aspects of language processing. This work starts precisely from the idea that the tendency to concrete interpretations of non-literal language might be related to difficulties in semantics, specifically to a bias towards concrete features of the semantic representation of words. In particular, this work is inspired by the similarity between the definition of concretism in psychopathology – as adherence to the physical stimulus situation (Harrow, 1974) – and the definition of concreteness in linguistics – intended as the semantic dimension of words linked to perceptual experience, whereby *table* is more concrete than *innocence* as «more verifiable in the world» (Closs Traugott, 1985, p. 165). Psycholinguistic studies have largely documented the impact of concreteness for the brain (Barber et al., 2013; Canal et al., 2022), highlighting also its strict link with another series of measures that reflect the multimodal experience of concepts, such as imageability, i.e. the ease with which a word can arouse mental images (Bird et al., 2001).

Furthermore, the hypothesis of a bias towards concreteness at the core of concretism finds support in theoretical models of metaphor processing as well as in empirical evidence on semantic alterations in schizophrenia. At the theoretical level, the idea of the study is compatible with models in pragmatics arguing that the process of understanding non-literal language relies on elaborating a semantic concept and its properties, including dropping features that are logically salient but not relevant for figurative meanings (Carston, 2010a; Sperber & Wilson, 2008). Individuals with schizophrenia might have difficulties in such a conceptual elaboration, particularly in abstracting beyond the concrete, sensory-based properties of the concepts encoded in figurative expressions. For instance, in *That lawyer is a shark*, concrete features of the concept *shark* (e.g. 'swims' or 'has a fin') might be retained instead of more abstract ones (e.g. 'being ruthless' or 'being aggressive'), resulting in a verbal explanation such as 'That lawyer swims very fast', typically considered as a manifestation of 'concretism'.

At the empirical level, the bias towards concreteness is supported by evidence showing that language impairment in schizophrenia is multi-dimensional (Bambini, Frau, et al., 2022; Covington et al., 2005; Schneider et al., 2023), spanning from the structural and lexical level and impacting the pragmatic dimension (Dalal et al., 2024; Marini et al., 2008), as well as the symptomatologic profiles (Bambini, Frau, et al., 2022). Furthermore, semantics was shown to be especially vulnerable in schizophrenia (Kuperberg, 2010), with evidence of altered activation of semantic networks (Pomarol-Clotet et al., 2008; Spitzer et al., 1994), as well as disorganisation of semantic memory processes (Rossell & Batty, 2008). There is also evidence that the specific semantic dimension of concreteness might be altered in schizophrenia, as indicated by the lack of the typical greater activation of the dorsolateral prefrontal cortex for concrete compared to abstract concepts (Kuperberg et al., 2008) and greater priming effects of figurative expressions on concrete rather than abstract words (Spitzer, 1993). Interestingly, other semantic aspects were shown not to be compromised, such as those involving word comprehension (Rossell & Batty, 2008) and compositional semantics (Moro et al., 2015), as well as the distribution of semantic classes and semantic paraphasias in spontaneous speech (Buck & Penn, 2015; Perlini et al., 2012). These differences are particularly relevant, as they seem to suggest that the concrete bias might change across tasks and be specific to tasks requiring reasoning over abstract meanings, as in figurative language interpretation.

The present study

This study aimed to test the novel hypothesis that the pragmatic manifestation of concretism in schizophrenia, i.e. impairment in figurative language understanding, reflects a bias towards concrete properties of the semantic representation of concepts (e.g. concreteness). If this hypothesis is confirmed, then verbal articulation of the meaning of non-literal expressions is expected to exhibit a higher use of concrete words.

We tested this hypothesis by using a verbal explanation task, where participants were asked to explain the meaning of different figurative expressions. We applied an automated pipeline on participants' speech samples, to extract semantic properties of words (concreteness and the related measure of imageability), alongside control linguistic measures (e.g. speech fluency and lexical variables), capitalising on the largely documented accuracy of computational methods in capturing linguistic correlates of psychopathological processes in

schizophrenia (Bambini, Frau, et al., 2022; Corcoran et al., 2020; Elvevåg et al., 2007; He et al., 2024; Hitczenko et al., 2021).

We expected to observe higher values of concreteness in responses produced by participants with schizophrenia compared to controls. We also expected that in the schizophrenia group word concreteness would be linked to accuracy in providing a correct interpretation of figurative expressions, as well as to global pragmatic performance. Finally, we expected that word concreteness would be associated with clinical, psychopathological, cognitive, and sociocognitive measures in the schizophrenia group, as the latter measures have been frequently associated with pragmatic impairment in this population (Bambini et al., 2016, 2020).

Finally, we tested whether the effect of word concreteness generalises to other tasks, by applying the same pipeline to a different speech elicitation task, namely a semi-structured interview, available from a previous study (Bambini, Frau, et al., 2022). We expected to find no differences between groups in the use of concrete words in the semi-structured interview, consistently with the idea that the bias towards more concrete aspects of the semantic representation of words reflects difficulties that arise specifically from reasoning about abstract and figurative meanings.

Methods

Participants

Data from 63 individuals with a diagnosis of schizophrenia based on DSM-5 criteria (American Psychiatric Association, 2013) recruited from the Department of Clinical Neurosciences, IRCCS San Raffaele Scientific Institute, Milan, Italy, were retrieved from a previous larger study (Bambini, Frau, et al., 2022). All participants were native speakers of Italian and met the following inclusion criteria: age 18–65 years, reflecting the typical adulthood age range and with the 65 years cut-off to reduce the risk of comorbid dementia; being clinically stabilised and treated with a stable dose of the same antipsychotic therapy for at least 6 months. Exclusion criteria were: severe traumatic brain injury or neurological disorders, intellectual disability, alcohol or substance abuse in the preceding 6 months, and severe psychotic exacerbation in the preceding 3 months. Additionally, data from 47 Italian-speaking healthy participants to include as controls of the participants with schizophrenia were retrieved from previous studies documenting the validation of the pragmatic assessment tools (Arcara & Bambini, 2016; Bischetti et al., 2024), balancing for age and education in the two groups. A sensitivity power analysis performed using G*Power, version 3.1.9.6 (Faul et al., 2009), showed that with $\alpha = .05$ the size of our samples is sufficient to detect medium-size effects (i.e. Cohen's $d \geq 0.54$) with 80% power.

All participants provided informed consent. The study was approved by the local ethical committee, following the principles of the Declaration of Helsinki.

Assessment

Both groups were assessed for pragmatic skills with the Assessment of Pragmatic Abilities and Cognitive Substrates test (APACS; Arcara & Bambini, 2016), a validated tool to assess pragmatic abilities in Italian-speaking individuals, which includes six tasks encompassing

both the production (Interview and Description) and the comprehension modalities (Narratives, Figurative Language 1, Humor, and Figurative Language 2). The two tasks assessing figurative language comprehension vary for the task format, with Figurative Language 1 using a multiple-choice task and Figurative Language 2 a verbal explanation task. Finally, three composite scores are derived from the six task scores, namely APACS Production (derived from the two expressive tasks), APACS Comprehension (derived from the four receptive tasks), and APACS Total (reflecting the global score).

Participants in the schizophrenia group were further evaluated for psychopathology, with the Positive and Negative Syndrome Scale for Schizophrenia (PANSS; Kay et al., 1987), including the disorganisation dimension (van der Gaag et al., 2006), cognitive skills, with the Italian version of the Brief Assessment of Cognition in Schizophrenia (BACS; Anselmetti et al., 2008; Keefe, 2004), using the average equivalent score as an overall measure of the cognitive profile,[1] and social cognition, with Theory of Mind Picture Sequencing Task (ToM-PST; Brüne, 2003).

A detailed description of the measures included in the study is provided in Supplementary material (Section 1, Table S1).

Speech samples and automated analysis

Elicitation task

We used the speech samples elicited from the participants during the Figurative Language 2 task included in the APACS test. In particular, the prompting items included five highly familiar idioms (e.g. *My brother is always in the red*) extracted from existing norms (Tabossi et al., 2011), five novel metaphors (e.g. *Some voices are trumpets*) from a previous study (Bambini et al., 2013), and five common proverbs (e.g. *A swallow does not make a summer*) from a dictionary of Italian proverbs (Guazzotti & Oddera, 2006).

Verbal explanations were recorded using a one-channel audio recorder oriented towards the participant. The recordings were acquired in a quiet room within a controlled laboratory setting, then converted to.wav files to be imported into the PRAAT software (Boersma & Weenink, 2021), with a standard quality of 44.10 kHz (capturing 44,100 samples per second).

Automated analysis

The audio recordings of participants' verbal explanations were pre-processed and transcribed before undergoing the automated pipeline for the extraction of linguistic measures (Supplementary material, Section 2; see also Figure 1).

Linguistic measures (Table 1) included semantic variables (word concreteness and imageability), alongside control variables related to speech fluency and lexical richness (response length, number of pauses, pause-to-word ratio, lexical frequency, and type-token ratio).

[1]Equivalent scores are a five-point interval scale obtained for neuropsychological tests from their adjusted scores (i.e. accounting for age and education level) and reflecting the level of impairment based on the population distribution (Facchin et al., 2022; score values: 0 = impaired performance, 1 = borderline performance, 2–3 = unimpaired performance, and 4 = performance equal or better than the median value). The BACS average equivalent score is the mean of the equivalent scores from each subtask of the BACS (Anselmetti et al., 2008), already used as a measure of global cognitive functioning in previous studies (Bambini et al., 2016).

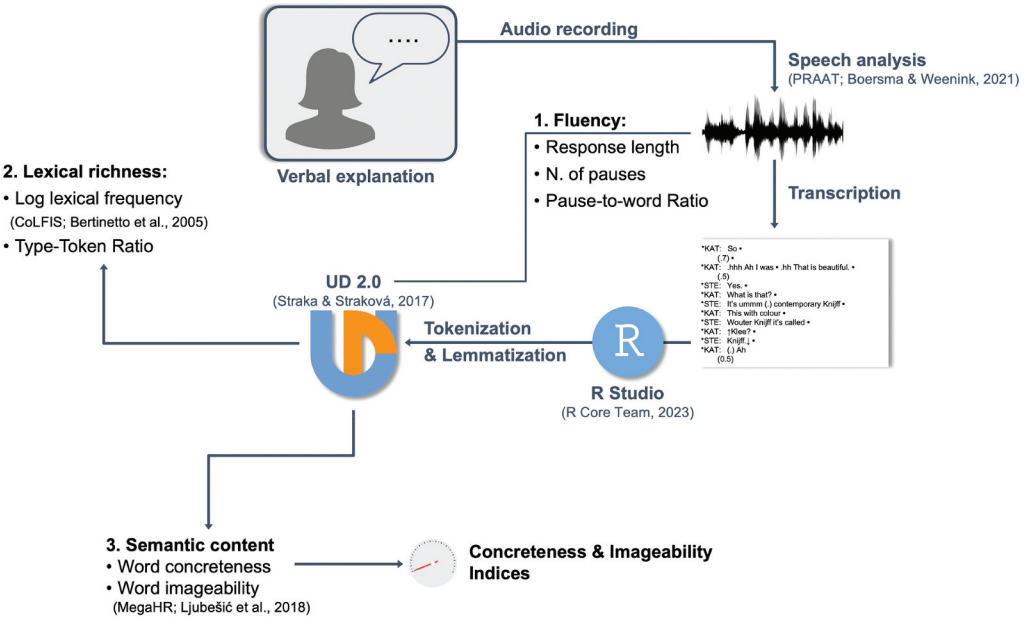

Figure 1. The automated pipeline applied to participants' verbal explanations for the APACS Figurative Language 2 task. Verbal explanations were first audio-recorded and analysed with PRAAT software to identify silent pauses. Audio samples were then transcribed, imported on RStudio software, and tagged using universal dependencies (UD 2.0) treebank. From tokenised and lemmatised transcripts, we extracted fluency and lexical richness measures, as well as semantic variables (word concreteness and imageability), then normalised and standardised as concreteness and imageability indices.

Table 1. Description of linguistic features.

Linguistic dimensions	Measures	Description
Fluency	Response length	Total number of words uttered by the participants in their responses.
	Number of pauses	Total number of long silent pauses (defined as silences ≥ 1 second) and filled pauses (e.g. "uhm", "ehm", etc.) for each response.
	Pause-to-word ratio	Total number of pauses divided by the total number of words for each response.
Lexical Richness	Lexical frequency (log-transformed)	Log-transformed frequency value of words uttered by the participants, extracted from the Corpus and Frequency Lexicon of Written Italian (CoLFIS); it indicates whether participants used more low- or high-frequency words.
	Type-token ratio	The number of unique words (types) divided by the total number of words (tokens) in each response; this measure is considered an indicator of lexical variety.
Semantics	Concreteness index	The percentage of concreteness content for each response, obtained by averaging and standardising concreteness ratings (i.e. to what extent a concept denoted by a word can be experienced by the senses) for single lemmas, extracted from MEGAHR; it indicates whether participants use words rated as more or less concrete.
	Imageability index	The percentage of imageability content for each response, obtained by averaging and standardising imageability ratings (i.e. how easily a concept denoted by a word can arouse mental images) extracted from MEGAHR; it indicates whether participants used words rated as more or less imageable.

Concreteness and imageability values were extracted for lemmas using rating values of the MEGAHR-Crossling repository (Ljubešić et al., 2018), which provides simulated ratings predicted via supervised learning from the MEGAHR (Peti-Stantić et al., 2021), the MRC Psycholinguistic (Wilson, 1988), and the BWK (Brysbaert et al., 2014) databases for 77 languages. Concreteness and imageability ratings covered 94.42% of lemmas in our transcripts. Lexical frequency values (log-transformed) were extracted for tokens from the Corpus and Frequency Lexicon of Written Italian (CoLFIS; Bertinetto et al., 2005), covering 94.47% of tokens in our dataset. Type-token ratio was computed after removing stop words from the transcripts using Python's Natural Language Toolkit (NLTK; Bird et al., 2009) list of Italian stop words.

The automated pipeline was developed in R Studio (R Core Team, 2023).

Statistical analysis

The rationale of the analysis included three steps. In step (i), we investigated differences between the schizophrenia and control groups in semantic variables (concreteness and imageability) and control variables (i.e. response length, number of pauses, pause-to-word ratio, lexical frequency, and type-token ratio). Groups were compared using independent-sample *t*-tests (after checking for the homoskedasticity and normality assumptions), with *p*-values adjusted for False Discovery Rate (FDR; Benjamini & Hochberg, 1995). We further inspected group differences for semantic variables in the different item types (i.e. idioms, metaphors, and proverbs) using Linear Mixed-effects Models (LMMs), with Group × Item Type (i.e. idioms, metaphors, and proverbs) as fixed predictors. Random structure was determined upon convergence following a parsimonious approach. Post-hoc pairwise comparisons were performed on the estimated means, with Tukey *p*-value correction. We exploratorily inspected group differences for semantic variables at the item level.

In step (ii), we tested whether semantic variables predicted participants' accuracy in APACS Figurative Language 2 (i.e. verbal explanation task), as well as in the global pragmatic performance. We fitted a Generalized Linear Mixed-effects Model (GLMM) on APACS Figurative Language 2 score (binomial: 0 = incorrect, 1 = correct), with semantic variables included as fixed effects in interaction with Group and Item Type, alongside control linguistic variables included as covariates. The inclusion of fixed effects was determined via likelihood-ratio tests, while random structure was determined upon model convergence. We fitted a series of linear models with APACS Figurative Language 1 (i.e. a multiple-choice task), APACS Comprehension, and APACS Total scores as dependent variables, including semantic variables in interaction with Group as predictors.

In step (iii), we explored correlation patterns between semantic variables and psychopathological, cognitive, and sociocognitive measures in the schizophrenia group using Pearson's correlations.

All statistical analyses were run in R, v. 4.3.1 (R Core Team, 2023), with the R Studio editor, v. 2023.09.1 + 494.

Generalisability check

We investigated the generalisability of word concreteness effects to another task, by considering speech samples elicited with the APACS Interview task (focusing on autobiographical topics, i.e. family, home, work, and organisation of the day) from the same sample of

participants with schizophrenia and a subset of the control group (68%, 32 participants; Age, $M = 44.28$, $SD = 11.62$; Education, $M = 12.91$, $SD = 3.40$). APACS interviews from the sample of individuals with schizophrenia were already analysed in a previous study (Bambini, Frau, et al., 2022), but not for concreteness.

Speech samples collected via the APACS Interview tasks underwent the same pre-processing pipeline applied to APACS Figurative Language 2 task (Supplementary material, Section 2). Semantic and control variables were extracted from the transcripts, with concreteness and imageability ratings covering 92.81% of the lemmas and lexical frequency values covering 85.54% of tokens in the dataset. The statistical analysis followed the same rationale as in step (i) above (see "Statistical Analysis").

Results

Sample description and assessment

Table 2 shows sample characteristics and the results of the global assessment. Overall, participants with schizophrenia showed lower pragmatic skills in all APACS measures, including the Figurative Language 2 task. The correlations among assessment variables in the schizophrenia group are reported in Supplementary Figures S1 and S2.

Group comparisons across linguistic variables

Compared to controls (Table 3), participants with schizophrenia produced longer verbal explanations (higher number of words) with more pauses yet equal pause-to-word ratio.

Table 2. Demographic and assessment measures (mean and standard deviations) of participants with schizophrenia and controls, alongside group comparisons for global pragmatic variables.

Measures	Schizophrenia Mean (SD)	Controls Mean (SD)	*t*-value	*p*-value	Cohen's *d*
Age	39.37 (10.93)	42.15 (13.12)	$t(108) = 1.21$	$p = .228$	0.23
Education	11.89 (2.76)	12.79 (3.18)	$t(108) = 1.58$	$p = .117$	0.30
Sex (F/M)	24/39	28/19	–	–	–
APACS Figurative Language 2	18.89 (5.25)	27.43 (2.79)	$t(97.14) = 10.92$	**$p < .001$**	1.95
Idioms	8.61 (1.75)	9.89 (0.34)	$t(67.15) = 5.52$	**$p < .001$**	0.93
Metaphors	7.24 (2.39)	9.52 (1.01)	$t(87.05) = 6.77$	**$p < .001$**	1.19
Proverbs	3.03 (2.35)	8.04 (2.11)	$t(106) = 11.45$	**$p < .001$**	2.23
APACS Production	.93 (.06)	.99 (.02)	$t(75.74) = 6.42$	**$p < .001$**	1.10
APACS Comprehension	.74 (.15)	.95 (.03)	$t(69.10) = 10.37$	**$p < .001$**	1.76
APACS Total	.84 (.10)	.97 (.02)	$t(68.62) = 10.50$	**$p < .001$**	1.78
Illness onset	24.43 (6.51)	–	–	–	–
Illness duration	15.08 (10.69)	–	–	–	–
Chlorpromazine-equivalent dose (mg/d)	450.33 (202.04)	–	–	–	–
PANSS Positive	17.11 (4.11)	–	–	–	–
P 2 Item	2.62 (1.22)	–	–	–	–
PANSS Negative	20.87 (4.93)	–	–	–	–
N 5 Item	3.44 (1.04)	–	–	–	–
PANSS General	38.59 (6.55)	–	–	–	–
PANSS Disorganization	21.17 (5.20)	–	–	–	–
BACS (Average Equivalent Score)	1.54 (0.90)	–	–	–	–
ToM-PST (Total score)	44.63 (11.97)	–	–	–	–

APACS = Assessment of Pragmatic Abilities and Cognitive Substrates, PANSS = Positive and Negative Syndrome Scale, BACS = Brief Assessment of Cognition in Schizophrenia, ToM-PST = Theory of Mind Picture Sequencing Task.
Non-integer degrees of freedom are due to Welch independent *t*-test computation, used in the case of heteroskedasticity.

Table 3. Descriptive statistics (mean and standard deviations) and group comparisons for the linguistic variables (control and semantic content variables) extracted from responses in the APACS Figurative Language 2 task.

Measures	Schizophrenia Mean (SD)	Controls Mean (SD)	*t*-value	*p*-value	Cohen's *d*
Response length	14.30 (8.83)	10.90 (5.01)	$t(101.53) = 2.53$	$\mathbf{p = .042}$	0.47
N. of pauses	1.25 (0.83)	0.88 (0.59)	$t(107.73) = 2.73$	$\mathbf{p = .032}$	0.51
Pause-to-word ratio	.09 (.05)	.08 (.07)	$t(80.53) = 0.51$	$p = .720$	0.10
Lexical frequency (log)	5.30 (0.30)	5.33 (0.27)	$t(108) = -0.58$	$p = .720$	0.11
Type-token ratio	.99 (.01)	.99 (.01)	$t(108) = -0.54$	$p = .720$	0.10
Concreteness index (total)	63.90 (2.30)	62.50 (1.79)	$t(108) = 3.44$	$\mathbf{p = .005}$	0.68
Idioms	65.20 (2.70)	64.60 (3.30)	$t(108) = 1.20$	$p = .602$	0.23
Metaphors	62.80 (4.04)	62.20 (2.82)	$t(107.56) = 0.92$	$p = .668$	0.17
Proverbs	63.60 (3.60)	60.70 (2.80)	$t(108) = 4.70$	$\mathbf{p < .001}$	0.91
Imageability index (total)	71.06 (1.58)	70.10 (1.23)	$t(108) = 3.45$	$\mathbf{p = .002}$	0.68
Idioms	71.37 (1.98)	71.28 (2.15)	$t(108) = 0.21$	$p = .838$	0.04
Metaphors	70.76 (2.66)	70.22 (1.92)	$t(107.91) = 1.24$	$p = .293$	0.23
Proverbs	71.08 (2.45)	68.82 (1.96)	$t(108) = 5.22$	$\mathbf{p < .001}$	1.01

All *p*-values are FDR adjusted. Degrees of freedom in the *t*-tests vary due to missing values on some tests. Non-integer degrees of freedom are due to Welch independent *t*-test computation, used in the case of heteroskedasticity.

Responses in the schizophrenia group were also characterised by higher Concreteness and Imageability, especially in the case of proverbs, but did not differ in lexical frequency and type-token ratio.

Due to collinearity between Concreteness and Imageability across responses ($r(1614) = .89$, $p < .001$), we kept only the Concreteness Index in the further steps of the analysis.

In the LMM with Concreteness as the dependent variable, we found a significant main effect of Group and a significant Group × Item Type interaction, indicating that individuals with schizophrenia used more concrete words in explaining Proverbs compared to Metaphors (Table 4 and Figure 2(a)).

The post-hoc pairwise comparisons on the estimated marginal means confirmed that, compared to controls, participants with schizophrenia produced significantly more concrete words in Proverbs only (Table 5).

Finally, the item-based analysis revealed that greater concreteness and imageability were observed in responses given by participants with schizophrenia for all proverbs and one metaphor but not idioms. Results are reported in Supplementary material (Table S5), along with examples of responses (Table S6).

Effect on accuracy in figurative interpretations and pragmatic abilities

The GLMM on APACS Figurative Language 2 accuracy showed a main effect and interaction of Group and Item Type, with participants with schizophrenia exhibiting a higher probability of providing an incorrect explanation compared to controls, especially in the difference between metaphors and proverbs. The model also showed a significant interaction between Concreteness and Item Type in the difference between metaphors and proverbs, indicating that in both groups, as concreteness increases, accuracy decreases in proverbs compared to metaphors (Table 6 and Figure 2(b)).

The model on APACS Figurative Language 1 accuracy showed main effects of Group and Concreteness, as well as a significant Group × Concreteness interaction, indicating that participants with schizophrenia performed worse than controls, especially when they used

Table 4. Output of the linear mixed-effects model with the z-centred Concreteness index as the dependent variable.

Fixed Effects	B	SE	95% CI	*t*-value	*p*-value
(Intercept)	−0.03	0.13	[−0.28, 0.22]	−0.25	.801
Group: CNT vs SCZ	0.15	0.05	[0.05, 0.25]	2.81	**.005**
Item type: Idi vs Met	−0.37	0.31	[−0.97, 0.23]	−1.20	.230
Item type: Met vs Prov	−0.01	0.31	[−0.62, 0.59]	−0.05	.962
Group: CNT vs SCZ × Item type: Idi vs Met	0.04	0.09	[−0.14, 0.23]	0.46	.646
Group: CNT vs SCZ × Item type: Met vs Prov	0.31	0.09	[0.12, 0.49]	3.27	**.001**
Random Effects	**Variance**	**SD**			
$Intercept_{Subject}$	0.04	0.19			
$Intercept_{Item}$	0.23	0.48			
Residuals	0.57	0.77			
$ICC_{SubjectItem}$	0.32				
Model fit	Marginal	Conditional			
R^2	.046	.350			

B = model estimates; SE = standard error; CI = confidence intervals; CNT = control group; SCZ = schizophrenia group. Concreteness Index was trimmed for missing values and values exceeding |2.5| standard deviations (4% of observations). Model formula: Concreteness Index (*z*-scaled) ~ Group * Item type + (1 | Subject) + (1 | Item).
Group was included with sum contrast coding (Controls = reference level); Item Type was included with forward difference contrast coding (Idioms vs. Metaphors, Metaphors vs. Proverbs).

more concrete words. The models with APACS Comprehension and APACS Total scores showed main effects of Group and Concreteness, with no significant interactions, indicating that both APACS scores were significantly lower in the schizophrenia group and were associated with word concreteness in both groups (Table 7 and Figure 2(c)).[2]

Relation to demographic, clinical, psychopathological, and cognitive variables

Concreteness was associated with Education and the Chlorpromazine-equivalent dose (Figure 3(a)), indicating that individuals with lower education and higher chlorpromazine intake exhibited higher concrete content in their responses (especially for proverbs). Concreteness was also associated with cognitive and sociocognitive skills, indicating that individuals with better preserved cognitive and sociocognitive functioning used less concrete vocabulary in their figurative language interpretations (Figure 3(b)). While Concreteness did not correlate with psychopathology, the broader correlation analysis reported in the Supplementary material (Figure S1) showed that psychopathology was related to figurative language measures and pragmatics, which were also related to both neurocognitive and sociocognitive skills (Figure S2).

Generalisability check

The descriptive statistics for the linguistic measures extracted from the APACS Interview tasks are reported in the Supplementary Table S7. The linear model on Concreteness (Group

[2]Acknowledging that concreteness aspects might tap into vocabulary knowledge, which in turn is known to be related to Education (Walker et al., 2009), we re-ran all models in sections 3.1, 3.2., and 3.3 including participants' education level (in years) as a covariate, to rule out that concreteness effects might be due to a poorer vocabulary. All significant effects in our predictors of interest remained regardless of the inclusion of education as a covariate (see Supplementary Table S2-4), suggesting that differences in word concreteness between groups are independent of cultural background.

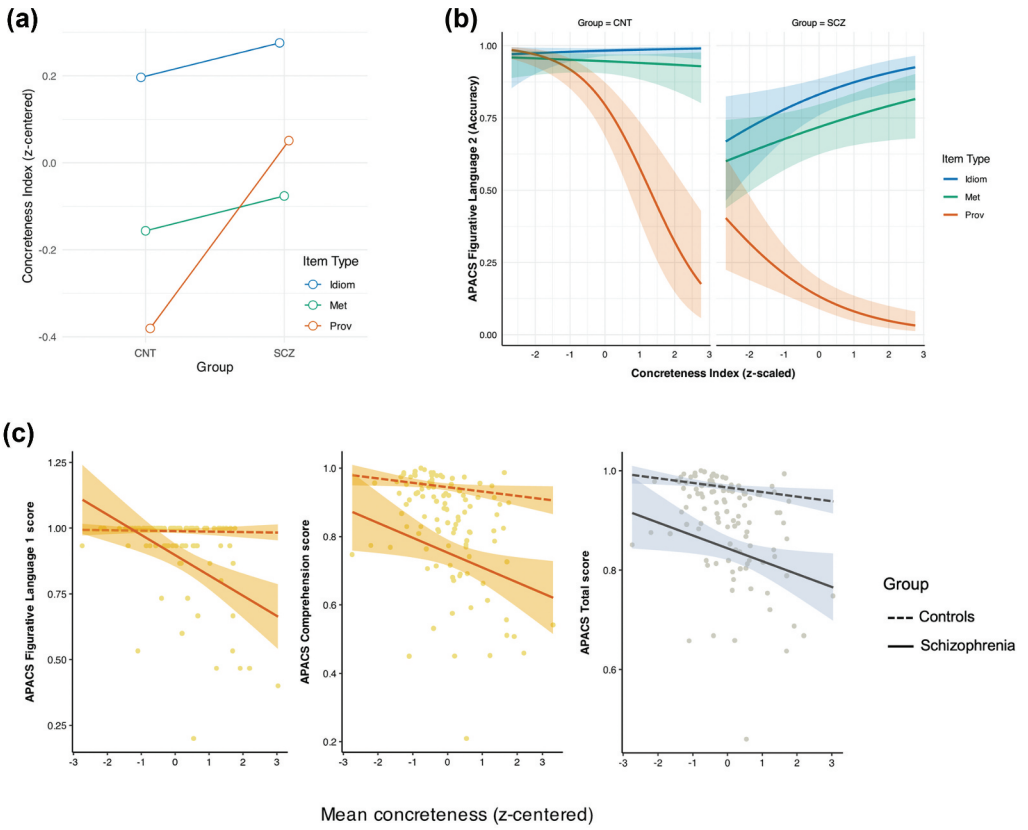

Figure 2. Output of the analysis on concreteness across groups, item types, and pragmatic measures. Panel (a) depicts the estimated standardised means of concreteness across groups (i.e. controls and people with schizophrenia) and item types (i.e. idioms, metaphors, and proverbs). Panel (b) shows the estimated accuracy score probabilities in the APACS Figurative Language 2 task as predicted by item types (i.e. idioms, metaphors, and proverbs) in interaction with concreteness (*z*-scaled) across groups. Panel (c) Shows the correlation between mean concreteness and the APACS Figurative Language 1 proportional score, APACS Comprehension Composite score, and APACS Total score in the schizophrenia and the control groups. CNT = control group; SCZ = schizophrenia group; Met = Metaphors; Prov = Proverbs; APACS = Assessment of Pragmatic Abilities and Cognitive Substrates.

Table 5. Post-hoc pairwise comparisons on the estimated means between groups across item types.

Item type	B	SE	*t*-ratio	*p*-value
Idioms	−0.02	0.08	−0.24	.811
Metaphors	−0.06	0.08	−0.82	.414
Proverbs	−0.37	0.08	−4.89	**<.001**

B = estimates; SE = standard error. The control group was coded as the baseline in the reported contrasts.

as sum-contrast-coded predictor, with Control as the baseline) showed that the two groups did not significantly vary in word concreteness ($B = -0.71$, $SE = 0.43$, t-value $= -1.64$, p-value $= .104$) and the difference became even more negligible when

Table 6. Output of the generalised linear mixed-effects model with APACS Figurative Language accuracy score as the dependent variable with Likelihood-Ratio Tests (LRT).

Fixed Effects	OR	SE	95% CI	*z*-value	*p*-value
(Intercept)	4.36	0.98	[2.80, 6.77]	6.53	<.001
Response length	0.99	0.13	[0.76, 1.29]	−0.07	.943
N. of pauses	0.78	0.10	[0.60, 1.01]	−1.86	.064
Pause-to-word ratio	0.95	0.09	[0.78, 1.15]	−0.53	.598
Lexical Frequency (log)	1.02	0.10	[0.84, 1.23]	0.17	.867
Type-token ratio	1.12	0.08	[0.96, 1.29]	1.43	.152
Group: CNT vs SCZ	0.08	0.03	[0.04, 0.15]	−7.66	**<.001**
Item type: Idi vs Met	0.40	0.20	[0.15, 1.08]	−1.81	.070
Item type: Met vs Prov	0.12	0.06	[0.04, 0.30]	−4.48	**<.001**
Concreteness Index	0.85	0.10	[0.68, 1.07]	−1.40	.162
Group: CNT vs SCZ × Item type: Idi vs Met	1.70	1.08	[0.49, 5.90]	0.83	.406
Group: CNT vs SCZ × Item type: Met vs Prov	0.27	0.14	[0.10, 0.75]	−2.50	**.012**
Group: CNT vs SCZ × Concreteness Index	1.36	0.31	[0.88, 2.12]	1.37	.170
Item type: Idi vs Met × Concreteness Index	0.80	0.23	[0.45, 1.41]	−0.78	.437
Item type: Met vs Prov × Concreteness Index	0.43	0.10	[0.26, 0.69]	−3.47	**.001**
(Group: CNT vs SCZ × Item type: Idi vs Met) × Concreteness Index	1.20	0.67	[0.40, 3.57]	0.33	.743
(Group: CNT vs SCZ × Item type: Met vs Prov) × Concreteness Index	1.21	0.57	[0.48, 3.06]	0.40	.687
Random Effects	**Variance**	**SD**			
$Intercept_{Subject}$	1.07	1.04			
$Intercept_{Item}$	0.44	0.66			
Group: CNT vs. SCZ_{Item}	0.25	0.50	−.44		
$ICC_{SubjectItem}$	0.32				
Model fit	Marginal	Conditional			
R^2	.467	.638			
Likelihood-Ratio Tests (LRT)					
Fixed factors	AIC	BIC	Loglik	Chi Test	*p*-value
Control variables	1342.1	1395.7	−661.03	$\chi^2(5) = 16.99$	**.005**
Control variables + (Group × Item type)	1295.4	1375.8	−632.71	$\chi^2(5) = 56.64$	**<.001**
Control variables + (Group × Item type × Concreteness Index)	1282.4	1394.9	−620.20	$\chi^2(6) = 25.02$	**<.001**

OR = odds ratio; SE = standard error; CI = confidence intervals; CNT = control group; SCZ = schizophrenia group. Missing values and Concreteness Index values exceeding |2.5| standard deviations were removed (4.85% of observations).
Model formula: Accuracy ~ Control variables (*z*-scaled) + Group * Item Type * Concreteness Index (*z*-scaled) + (1 | Subject) + (1 + Group | Item).
Group was included with sum contrast coding (Controls = reference level); Item Type was included with forward difference contrast coding (Idioms vs. Metaphors, Metaphors vs. Proverbs).

interview length (in words) was included as a covariate (Group: $B = 0.03$, $SE = 0.40$, t-value = 0.07, p-value = .948).

Discussion

This study explores the novel hypothesis that the pragmatic side of concretism, manifesting as an impairment in understanding figurative expressions, reflects difficulties in the semantic dimension of concreteness, particularly in dealing with the concrete aspects of word concept representation. We analysed the speech produced to explain the meaning of non-literal sentences (i.e. idioms, metaphors, and proverbs) provided by participants with

Table 7. Output of linear models on pragmatic performance as measured with the APACS test.

Dependent variable	Predictors	B	SE	*t*-value	*p*-value
APACS Figurative Language 1	Group: CNT vs SCZ	−0.09	0.03	−3.45	**<.001**
	Concreteness Index (mean)	−0.04	0.01	−2.83	**.006**
	Group: CNT vs SCZ × Concreteness Index (mean)	−0.08	0.03	−2.70	**.008**
APACS Composite Comprehension	Group: CNT vs SCZ	−0.19	0.02	−8.24	**<.001**
	Concreteness Index (mean)	−0.03	0.01	−2.30	**.024**
	Group: CNT vs SCZ × Concreteness Index (mean)	−0.03	0.02	−1.26	.210
APACS Total	Group: CNT vs SCZ	−0.12	0.01	−8.30	**<.001**
	Concreteness Index (mean)	−0.02	0.01	−2.28	**.025**
	Group: CNT vs SCZ × Concreteness Index (mean)	−0.02	0.02	−1.07	.286

B = estimates; SE = standard error; APACS = Assessment of Pragmatic Abilities and Cognitive Substrates. The control group was coded as the baseline in the reported contrasts.

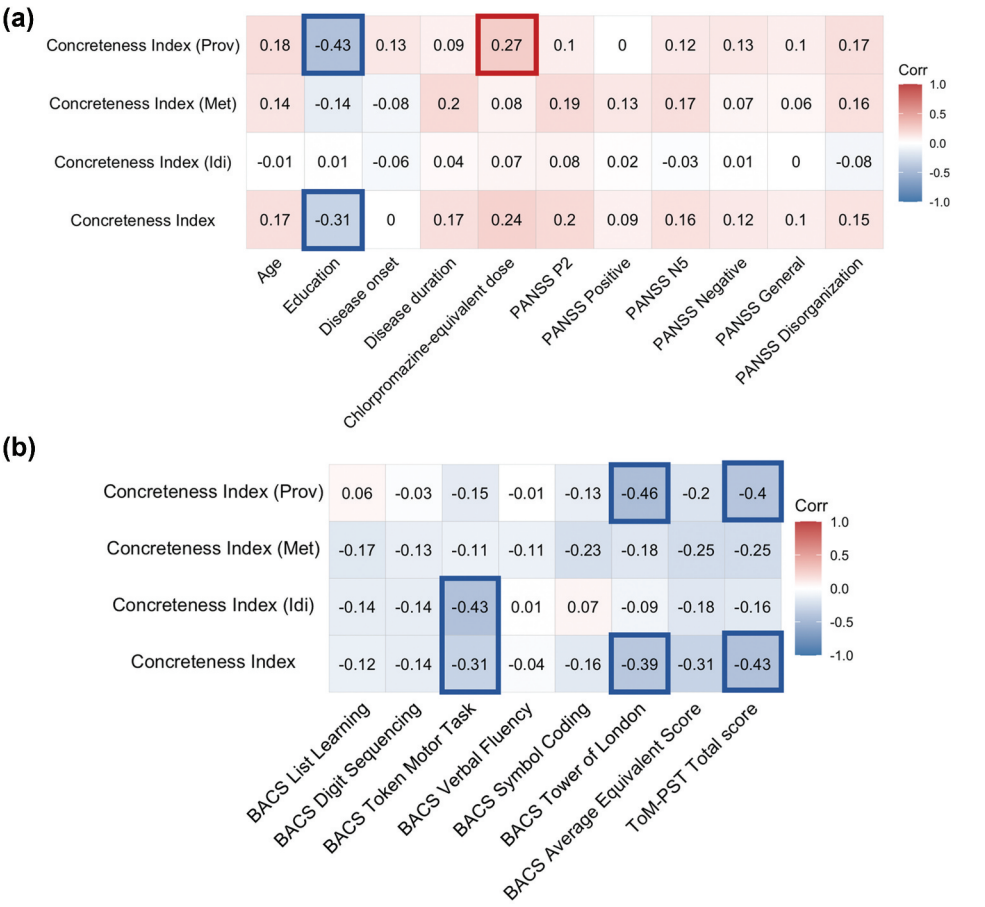

Figure 3. Correlogram between Concreteness Index and individual difference variables in the schizophrenia group. The plots show correlations between Concreteness (global mean value and sub-values for idioms, metaphors, and proverbs) and demographic, clinical, and psychopathological measures (a), and cognitive and sociocognitive measures (b) in the schizophrenia group. The magnitude of associations is depicted by color (highlighted cells indicate significant correlations, with significance level $p < .05$). PANSS = Positive and Negative Syndrome Scale; BACS = Brief Assessment of Cognition in Schizophrenia; ToM-PST = Theory of Mind Picture Sequencing Task.

schizophrenia and healthy controls using an automated pipeline, focusing on word concreteness values. Our results showed that speech samples in the schizophrenia group were characterised by a higher occurrence of concrete words, especially for proverbs, and that greater word concreteness corresponded to lower accuracy in figurative language understanding. The tendency to rely more on concrete vocabulary in explaining figurative expressions was also indicative of participants' global pragmatic abilities. Moreover, in the schizophrenia group, word concreteness was associated with neurocognitive and sociocognitive skills, suggesting that it was a relevant predictor of cognitive functioning in schizophrenia.

These findings advance our knowledge of formal thought disorder in schizophrenia, bridging psychopathology and linguistics via the use of natural language processing. Specifically, the main contribution of this study is to disclose the linguistic roots of concretism, by showing that a bias towards the concrete properties of the semantic representation of words might be associated with the symptom known as concretism. We grounded the hypothesis of a link between concretism and concreteness in the literature on semantic difficulties in schizophrenia, which has been documented as vulnerable across a number of domains (Kuperberg, 2010; Tan et al., 2020), including establishing the relation among words within their semantic networks (Barattieri di San Pietro et al., 2023; Pomarol-Clotet et al., 2008; Spitzer et al., 1993), using words from specific semantic classes (Buck et al., 2015; Minor et al., 2015), as well as the persistence of concrete properties of words (Spitzer, 1993) and difficulties in integrating abstract concepts (Kuperberg et al., 2008). The hypothesis was proved correct, in that higher use of concrete vocabulary in individuals with schizophrenia impacts the understanding of figurative expressions, thus unveiling difficulties in dealing with semantic features linked to perceptual experience and abstracting less concrete meanings from them. Although word concreteness was associated with education as well in the schizophrenia group, the greater tendency to concreteness in this group seems to be genuine and not simply depending on group differences in cultural factors, since it emerged also when the analysis was controlled for participants' education level.

We can further elaborate on our findings by looking at the correlation between concreteness and imageability. Capitalising on evidence of increased imagery vividness in schizophrenia (Oertel et al., 2009; Sack, 2005), we might reason that individuals with schizophrenia remain anchored to concrete aspects of words possibly due to the mental images aroused by them. Complementary with respect to Kuperberg et al. (2008), who argued that abstract concepts are difficult to integrate because they miss imagistic representation compared to concrete ones, we suggest that concrete and imagistic representations themselves might be an obstacle when abstracting from them is required, as in the case of figurative language. Converging evidence comes from neurofunctional studies, where metaphor processing difficulties have been shown to be associated with altered activations not only in semantic-related areas of the language network, such as the right middle/superior temporal gyri and the left inferior frontal gyrus (Della Rosa et al., 2018; Poldrack et al., 1999), but also in the cuneus and precuneus (Kircher et al., 2007; Mashal et al., 2014), which play a relevant role in mental imagery processes (Fletcher et al., 1995). In this view, the bias towards concreteness might be framed within an impairment in integration mechanisms in schizophrenia (Kuperberg et al., 2008), affecting in particular the ability to integrate non-verbal perceptual-based semantic features and amodal linguistic properties

into a unitary conceptual representation during language processing, and belonging to the broader domain of multisensory integration disruption (Gröhn et al., 2022).

Another relevant finding is offered by the correlation analysis, which showed that the bias towards concreteness exhibits a pattern of association that resembles the one observed for general pragmatic impairment. In particular, bias towards concreteness in participants with schizophrenia patterned with lower neurocognitive skills, especially executive functioning, and lower mentalising ability. This mirrors the link between pragmatic impairment and cognitive and sociocognitive deficits extensively documented in schizophrenia for both general pragmatic ability (Bambini et al., 2016; Frau Bischetti et al., 2025; Parola et al., 2018), as observed here as well (see Supplementary Figure S2), and for specific phenomena, such as proverb (Brüne & Bodenstein, 2005; Kiang et al., 2007) and idiom comprehension (Schettino et al., 2010). However, we did not find a direct correlation between the bias towards concreteness and symptomatology, in particular lack of abstract thinking as measured in item N5 of the PANSS. The link with symptomatology emerged at a higher level, i.e. when considering accuracy in figurative language understanding (as indexed in APACS tasks), rather than word concreteness alone. Hence, the bias towards concrete aspects of words documented here seems to capture specifically the pragmatic manifestation of concretism, alongside additional neurocognitive and sociocognitive nuances. However, it is possible that, with more fine-grained measures of psychopathological dimensions and in a sample with different clinical characteristics, the association between word concreteness and concretism as a symptom might change. In particular, different results might emerge when using clinical measures of formal thought disorder, such as the Thought and Language Disorder scale (TALD; Kircher et al., 2014), which explicitly distinguishes between positive and negative dimensions, with concretism included in the latter. Furthermore, we should also notice that this study involved stabilised participants with a long-term course of disease: we might expect that in a sample with more acute symptoms, the relationship between the bias towards concreteness aspects of words and clinical measures of psychopathological symptoms becomes stronger. Interestingly, the correlation analysis revealed also a link between the higher use of concrete vocabulary and higher chlorpromazine daily intake: this finding might either genuinely reflect iatrogenic effects of pharmacologic treatment – in line with other studies linking language deficits to specific antipsychotic drugs (e.g. de Boer et al., 2020) – or might index a global measure of clinical severity impacting also language ability. Future studies are needed to better ground the relationship between semantic/pragmatic dimensions and pharmacological aspects (see Vita et al., 2024).

The question now becomes how general the bias towards concreteness is in schizophrenia, i.e. whether it is a pervasive feature of formal thought disorder. Our findings revealed that figurative language interpretation was more strongly affected by the concrete bias in the case of proverbs, which confirms that these expressions are particularly challenging for individuals with schizophrenia (Bambini et al., 2020; see also Felsenheimer & Rapp, 2023). The explanation for this might be two-fold. On the one hand, proverbs might be especially difficult in terms of abstract meaning representation, possibly due to their moral and social wisdom value (Sperber & Wilson, 1995) or because they highly rely on the literal meaning for deriving the figurative one (Unger, 2019; for other similar cases, see; Carston, 2010b). On the other hand, the absence of significant group differences in concreteness in meaning verbalisation for metaphors and idioms might be spurious and due to the specific characteristics of our stimuli. In particular,

most metaphoric stimuli in our task could be characterised as physical metaphors, i.e. metaphors requiring inferences on physical properties (e.g. *Some voices are trumpets* or *Some handbags are boulders*, see Canal et al., 2022; Lecce et al., 2019), which require concrete vocabulary in their correct explanation. We can speculate that, when mental metaphors, i.e. metaphors conveying psychological properties would be included, the bias towards concreteness would emerge in the schizophrenia group for this type of item as well. Support for this speculation comes from the exploratory item-level analysis, where the only mental metaphor included in our task (*Some memories are thorns*) elicited verbal explanations with higher concrete content in participants with schizophrenia compared to controls (see Supplementary Table S5). Beyond mental metaphors, we might also wonder whether altered semantic processes at the word level might be relevant to other aspects of pragmatic skills known for being impaired in schizophrenia, such as irony and humour (Adamczyk et al., 2024; Parola et al., 2021). In particular, previous studies reported greater difficulty in processing mental jokes (e.g. *My love story ended in tragedy, I married him*) compared to phonological ones (e.g. *There's a bug on the clock, a clockroach*) in people with schizophrenia (Agostoni et al., 2024), which might also be linked to mechanisms hindering the ability to abstract from a concrete vocabulary.

While there is evidence that the bias towards concreteness might extend to other figurative language domains, it does not seem to extend to all language tasks. The analysis of effect generalisability showed that the overuse of concrete words in the schizophrenia group did not generalise to a semi-structured interview on autobiographic topics. This is in line with the growing body of evidence showing that the involvement of specific semantic dimensions, especially those capitalising on sensory-motor experience, varies from task to task, being greater in lexical-semantic tasks rather than grammatical ones (Frau et al., 2025). The limited task generalisability observed for concreteness effects has also strong methodological implications for the application of automated methods to the study language in schizophrenia (Corcoran et al., 2020; Elvevåg et al., 2007). While concreteness seems a promising measure to characterise speech in individuals with schizophrenia, it is possible that its relevance is limited to tasks where individuals are requested to articulate abstract ideas, as in figurative language, or in talking about creativity (see preliminary evidence in Barattieri di San Pietro et al., 2024 on the DAIS corpus, Delgaram-Nejad et al., 2023). Now that the search for the best computational linguistic features to predict clinical models and outcomes is at the centre of the debate (Palaniyappan et al., 2023), our study suggests that – through an adequate speech elicitation task and after further checks for cross-cultural generalisability (Bora et al., 2021) – word concreteness might be useful not only to assess higher-level aspects of communication but also to capture symptoms and cognitive functioning, possibly extending to progress monitoring in integrated treatment programmes (Bechi et al., 2020; Buonocore et al., 2018; Lindenmayer et al., 2013).

The applicability of concreteness feature analysis to monitoring treatment effects brings us to discuss also potential rehabilitative implications of our findings. While treatment of language disturbances in schizophrenia is still a niche (Jimeno, 2024; Joyal et al., 2016), our study suggests that the combination of pragmatic and semantic aspects might be most beneficial to improve treatment outcomes. For instance, approaches based on promoting pragmatic inferences (Bambini, Agostoni, et al., 2022), already shown to be related to quality of life (Agostoni et al., 2021), might be profitably

integrated with activities potentiating semantic processing in the abstract dimension, thus targeting one of the roots of pragmatic impairment. Possibly, the combination of pragmatic and semantic training more broadly, from vocabulary knowledge to semantic categorisation (e.g. De Lorenzo et al., 2020) would be beneficial as well. Although we showed that the greater tendency to rely on concrete words in the clinical compared to the control group is independent of education, which in turn is related to vocabulary (Walker et al., 2009), we cannot rule out that weaknesses in lexical and semantic knowledge (e.g. a poorer vocabulary) may also contribute to concreteness effects. In acknowledging the limitation of our study, which did not include specific measures of vocabulary and semantic skills, we suggest that future studies extend the consideration of the possible lexical and semantic roots of concretism beyond concreteness and capitalise on the findings to shape communication remediation.

To conclude, in this study we unveiled novel aspects of the linguistic profile of schizophrenia, by showing that the pragmatic manifestation of concretism is rooted in word semantics, specifically in the concrete-abstract dimension. These findings highlight the multidimensionality of language difficulties in schizophrenia, stemming from the building blocks of language and extending to the highest level of linguistic representation (Bambini, Frau, et al., 2022; Covington et al., 2005; Moro et al., 2015; Salavera et al., 2013; Tavano et al., 2008), but especially emphasise the centrality of language for untying the knots of formal thought disorder, bridging linguistic and psychopathological categories.

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