Language & Communication 93 (2023) 155–171

Contents lists available at ScienceDirect

Language & Communication

journal homepage: www.elsevier.com/locate/langcom

Comprehending stories in pantomime. A pilot study with typically developing children and its implications for the narrative origin of language

Ines Adornetti, Alessandra Chiera, Valentina Deriu, Daniela Altavilla, Francesco Ferretti*

Cosmic Lab, Department of Philosophy, Communication and Performing Arts, Roma Tre University, Via Ostiense 234-236, 00146, Rome, Italy

A R T I C L E I N F O

Article history:

Keywords:
Language evolution
Narrative processing
Pantomime
Storytelling
Theory of mind
Working memory

A B S T R A C T

This paper presents a pilot study aimed at investigating the comprehension of pantomimic stories and its possible cognitive underpinnings in typically developing children. A group of twenty-two Italian-speaking children aged between 8.02 and 10.11 years were included in the study. Participants watched short videos in which professional actors performed pantomime narratives; then answered a comprehension question and retold the stories. Analyses revealed positive correlations between the comprehension of pantomimes and age, theory of mind, and working memory. The implications of these results for a narrative model of language origin are discussed against the background of an eco-evo-devo perspective.

1. Introduction

1.1. Theoretical background

We present a study aimed at exploring the cognitive underpinnings of pantomimic storytelling in children with typical development, with the broader aim of looking for the evolutionary prerequisites of human communication in the context of a narrative hypothesis of language origin. This study is set against the background of the eco-evo-devo approach, which considers evolution as driven by multiple sources – i.e., developmental, environmental, and genetic – that complement with each other in a process of mutual co-construction (Sultan, 2021). This idea is strictly related to the concept of niche construction, which posits that organisms constantly modify environmental states, exerting some influence over their own evolution, and thus creating opportunities for coevolutionary scenarios (e.g., Laland et al., 2000, 2014).

The eco-evo-devo perspective has been applied also to the study of language and cognition (e.g., Bertossa, 2011; Spencer et al., 2009). Of particular interest for the present investigation is a specific tenet of this perspective, which exploits the niche construction hypothesis to raise concerns about the issue of domain specificity applied to language. Starting from the thesis of the modularity of the mind proposed by Fodor (1983) and further corroborated in several areas, many scholars proposed to consider the acquisition and use of language as constrained by domain-specific mechanisms, that is, evolutionary devices

* Corresponding author.
E-mail address: francesco.ferretti@uniroma3.it (F. Ferretti).

https://doi.org/10.1016/j.langcom.2023.10.001
0271-5309/

dedicated for specific purposes, like the processing of grammar (e.g., Pinker, 1997; Spelke and Kinzler, 2007). However, the existence of similar specific constraints is challenged by many studies, mainly placed in the context of cultural evolution investigations (e.g., Chater et al., 2009; Culbertson and Kirby, 2016), which emphasize the role of non-language capacities, such as sharing and copying, in fostering the evolution of language features. Against this background, a proposal of the eco-evo-devo approach is to connect the requirements for language emergence to a complex multifactorial collection of cognitive capacities emerged for environmental and social pressures and only later exploited to configure the language-ready brain, that set the stage for language ontogeny and phylogeny (e.g., Boeckx and Benítez-Burraco, 2014; Oller et al., 2016; Segovia-Martín & Balari, 2020).

Accordingly, we present a pilot study aiming at exploring the relationship between certain cognitive abilities and narrative communication, intended as pantomimic storytelling – which has been claimed to have represented an important stage in the evolution of human communication (e.g., Boyd, 2018; Corballis, 2017; Ferretti, 2021; Ferretti et al., 2022; McBride, 2014; Zlatev et al., 2020) – to propose an account for language origin and evolution that rules out the need of involving from the beginning language-related biological devices. Before presenting our experimental investigation, a general introduction to the narrative model of language origins underlying the study is required.

1.2. The functional role of narrative

According to the narrative model of language origins, storytelling is the distinctive feature of human language, i.e., the feature characterizing language with respect to other forms of animal communication (Boyd, 2018; Corballis, 2017; Ferretti, 2021; Ferretti et al., 2017; Ferretti et al., 2022; McBride, 2014). From our perspective, the adherence to this model is linked to a more general way of defining communication and its functional role, namely in terms of influence of others' behaviors to make them act in a certain way (e.g., Carazo and Font, 2010; Dawkins and Krebs, 1978; Owren et al., 2010; Rendall et al., 2009; Scarantino, 2013; Seyfarth et al., 2010). Studies on animal rhetoric (Hawhee, 2011; Parrish, 2014, 2021), pointing to the adaptive character of communicative behaviors aiming at exerting some influence over other individuals, strongly corroborate this view. Overall, they allow to define a path of functional continuity between animal and human communication, which rests on the view that communication, in all its forms, is a matter of persuasion.

Although human language and animal communication share the same functional role, our claim is that the human species developed a *specific* way of influencing and modifying others' behavior: in the transition from animal communication to language, humans evolved more efficient persuasive tools governed by the emergence of the ability to tell stories (Ferretti and Adornetti, 2021; Ferretti, 2022). Narrative, conceived as "a primary resource for configuring circumstances and events into more or less coherent scenarios involving the experience of persons" (Herman, 2013, p. 74), has been proved to be a powerful tool of persuasion (Gustafson et al., 2020; Green and Brook, 2000; Hoeken and Sinkeldam, 2014; Igartua and Barrios, 2012; Mazzocco et al., 2010; Schreiner et al., 2018). This would depend on its extraordinary capacity to exert a force on the individual by making her *cognitively transported* into the storyworld and emotionally engaged with the character through a process of *identification* (e.g., Bilandzic and Busselle, 2013; Gustafson et al., 2020; Green and Brock, 2000; Mazzocco et al., 2010). Transportation refers to a state of intense cognitive and emotional focus on the story (Green and Brock, 2000) that can lead to identification with story's protagonist, i.e., to an experience which leads the receiver to adopt the perspective of a character. In doing so, the receiver sees the story events through the character's eyes and thus might be prone to be influenced by his/her beliefs and attitudes (de Graaf et al., 2012).

From this view, investigating the origin of language means exploring the emergence of narrative forms of communication. Various models have been proposed in this regard (e.g., Bietti et al., 2019; Boyd 2018; McBride 2014; Ferretti, 2022; Ferretti et al., 2022). In this paper, we focus on two specific issues characterizing the debate: the material conditions – *semiotic systems* – and the structural constraints – *cognitive devices* – which are required to develop a narrative form of communication. Our investigation rests on a methodological assumption shared by many cognitive models of language origin (e.g., Corballis, 2018; Sperber and Origgi, 2010; Scott-Phillips, 2014): the idea that the systems and cognitive skills responsible for language processing as we know it today are also involved in its phylogenetic origin. From this point of view, examining how language works is a way to shed light on how language possibly evolved.[1] Against this background, we report a pilot study about the comprehension of narrative pantomime and its possible cognitive underpinnings that, shedding light on the mechanisms underlying story processing, might provide some insights on how our hominin ancestors developed a narrative communication – i.e., it might contribute to outline the complex picture of the cognitive systems necessary for narrative language to evolve.

[1] Scott-Phillips and Heintz (2023) suggested that the field of language evolution research consists of three main areas of investigation: "1. The biological evolution of whatever cognitive capacities are necessary to generate, acquire, and use languages. 2. The transition from very simple systems, with few if any of the characteristic features of languages (e.g., no or very little syntax), into a system that is characteristically linguistic. 3. The change from one characteristically linguistic system to another." (Scott-Phillips and Heintz, 2023, p. 95). Our study, focusing on the cognitive prerequisites necessary to use language, is concerned with point 1.

1.3. Narrative pantomime

As for the issue concerning the material conditions that allowed the emergence of storytelling, we posit that the early semiotic system able to convey the defining elements of a story – i.e., coherently connected sequences of events involving the experience of persons – is pantomime. On this view, pantomime was a precursor to human language – a means to tell stories before the emergence of a fully-fledged language (see also Boyd, 2018; Corballis, 2017; McBride, 2014). A starting point for clarifying the relation between the pantomimic origin of language and the ability to tell stories is the thesis proposed by Donald (1991), and further refined by Zlatev (e.g., 2014; Zlatev et al., 2020), which considers *bodily mimesis* (of which pantomime is a specific case) as an intermediate stage between the episodic (i.e., limited to the here and now) communication of great apes and the symbolic culture of *Homo sapiens*. Mimesis is seen as “an embodied, analogue and primordial mode of representation” (Donald, 2012, p. 189) resting “on the ability to produce conscious, self-initiated, representational acts that are intentional but not linguistic” (Donald, 1991, p. 168). Both Donald (1991) and Zlatev (2014) identify the primary adaptive function of bodily mimesis in toolmaking. However, since a mimetic act is by its nature public and has the intrinsic potential to communicate, it would have naturally been *exapted* for other functions, such as intentional communication (Zlatev, 2014; Gärdenfors, 2017; 2021).

Relevant to our proposal is the notion of pantomime growing out of bodily mimesis proposed by Zywiczyński et al. (2018, p. 308) who, stressing the communicative power of pantomime, characterize it as mimetic (volitional and representational); non-conventional and motivated; multimodal but primarily visual; improvised; using the whole body and the surrounding space rather than exclusively manual and stationary; holistic and non-segmental; communicatively complex and self-sufficient; semantically complex; displaced, open ended and universal.

For a narrative account of pantomimic communication, it appears especially relevant the holistic nature of pantomime, i.e., the fact that pantomime can refer to “whole events or sequences of events in a holistic ‘continuous strand’, with no self-apparent onsets and terminations in the stream of movement, which does not naturally decompose into easily isolable component parts” (Zywiczyński et al., 2018, p. 314), along with the fact that it is a form of enactment involving the whole body (Brown et al., 2019; Ferretti, 2021; Ferretti et al., 2022).[2] Maintaining that pantomime is a process involving the whole body that can refer to whole events in a holistic fashion means adopting a “broad” definition of pantomime (Adornetti et al., 2019), which distinguishes it from iconic gesturing, generally considered to be only manual (e.g., Arbib, 2012; Armstrong and Wilcox, 2007; Tomasello, 2008). While hand gestures can be very effective to pantomime single actions and objects (see Brown et al., 2019) – e.g., using fingers to represent scissors cutting – they might be less successful to represent broader events – e.g., representing a tennis player serving the ball. As narrative consists of sequences of events of this latter type – e.g., a tennis player serving the ball and celebrating the point –, a broad notion of pantomime implying a *body-to-body mapping* is required. Brown and colleagues (2019, p. 3) describe this mode of pantomiming as egocentric type, in which “a person performs an empty-handed transitive action in the first person with an imaginary object”.

1.4. Cognitive underpinnings of narrative

The second step of our argument for a narrative account of language origins concerns the structural constraints – the cognitive systems – that allowed our ancestors to tell stories through pantomime before the emergence of verbal language. In this regard, we endorse a “narrative first hypothesis” (Ferretti, 2021), which considers the possibility to express narrative contents through pantomime as secondary to the possibility of mentally representing those contents: narrative is primarily a modality of thought which predates its expression through a semiotic system (Ferretti, 2016; Ferretti et al., 2017). In other words, adhering to the narrative first hypothesis means claiming that semiotic systems do not have in their own the potential to convey a narrative content without underlying appropriate cognitive structures for ascribing meaning to a certain expressive performance. Against this cognitive background, the possibility to exapt pantomime for storytelling depends on narrative being both mentally represented by the individuals who generate it and understood by an audience.

The narrative first hypothesis is corroborated by research attesting that narrative does not depend on language but relies on the proper functioning of a cognitive architecture not specific for linguistic processing. Interesting indications come from neurodevelopmental disorders, such as autism spectrum disorders (ASD). A significant number of investigations has provided evidence that autistic persons have impairments in narrative production (e.g., Adornetti et al., 2023; Diehl et al., 2006; Ferretti et al., 2018; King et al., 2013) and comprehension (e.g., Jolliffe and Baron-Cohen, 2000; Minshew et al., 1995; Nuske and Bavin, 2015). For example, autistic children show difficulties in coherently connecting the sequences of events constituting a

[2] The narrative potential of pantomime is also advanced by McNeill (2005) who defines pantomime as a “gesture or sequence of gestures conveying a narrative line, with a story to tell, produced without speech”. According to McNeill, the production in absence of speech makes pantomime a dead-end in evolutionary terms. In his view, indeed, from the very beginning language had to rely on an integrated system of gesture and speech (McNeill, 2012). Lacking in the speech system, pantomime was not a precursor of human language.

narrative (Diehl et al., 2006; Ferretti et al., 2018) as well as in comprehending the goals and motivations underlying the actions of the stories' characters (e.g., Happé, 1994; Jolliffe and Baron-Cohen, 1999). Relevant for our purposes is that these difficulties have been interpreted as reflecting impairments in cognitive systems and processes not specific for language. Among them, *Central Coherence* (CC; Jolliffe and Baron-Cohen, 2000; Nuske and Bavin, 2015), *Theory of Mind* (ToM; Baron-Cohen et al., 1986; Happé, 1994; Tager-Flusberg and Sullivan, 1995), *Episodic Future Thinking* (EFT; Ferretti et al., 2018; Marini et al., 2019), and *working memory* (WM; Kuijper et al., 2017). CC has been suggested to be responsible for constructing an overall *representation of the story plot* integrating the single elements of an event into a wider global context at both the conceptual (i.e., semantic) and perceptual (i.e., visual) level (e.g., Happé et al., 2001; Lopez et al., 2008; Plaisted, 2001). ToM allows the understanding of the *psychological/motivational causes of characters' actions* (Gerrig, 2010; Oatley, 1999), contributing to give meaning to those actions. EFT is involved in the processing of the temporal axis of a narrative discourse, allowing to envision the *temporal dimension of the characters' actions* (Ferretti et al., 2018). WM is an important predictor of children narrative development (e.g., Dodwell and Bavin, 2008; Veraksa et al., 2020; Ward et al., 2016). It is one of the main components of executive functions and allows to process, store and update information in real time to accomplish a task (e.g., Fuster, 2008; Miyake et al., 2000; Rosenthal et al., 2006). It has been connected to the process of events representation (e.g., Radvansky and Zacks, 2014) since, when people represent a single event, they must keep track of the various aspects involved in that event as well as to integrate those aspects with information coming from both the environment and their world knowledge.

This cognitive model of narrative processing has been further corroborated by recent evidence showing that the narrative impairments of autistic persons are not restricted to the linguistic code, but also extend to the processing of visual stories (Adornetti et al., 2020; Coderre et al., 2018). Overall, these indications strengthen the view that narrative processing relies on a broad cognitive architecture independent from the expressive semiotic system. This is an important indication that can inform language evolution research. Supporting the more general hypothesis that the cognitive architecture underpinning story processing does not rely on systems specific to language, it suggests that such architecture might work as a basis for a communicative/narrative exaptation.

1.5. The present study

In spite of theoretical considerations suggesting that pantomime can support narrative, to the best of our knowledge, there are no neuro-cognitive studies explicitly exploring whether pantomime may be used to convey narrative contents. Some indications by Hogrefe et al. (2013) show that people with acquired aphasia use sequences of pantomimes to convey stories, which are judged as comprehensible by healthy speakers. But it should be stressed that this study did not aim systematically at exploring the narrative potential of pantomimic communication, neither its cognitive prerequisites. To fill this gap, the present research aimed at investigating the comprehension of stories conveyed through pantomime by a group of typically developmental participants belonging to middle childhood. Specifically, the research question underlying this study was whether pantomimes, involving the whole body and representing sequences of events causally and temporally connected each other's to convey a story, are judged as comprehensible by children. Developmental research on pantomime recognition showed that children begin to understand pantomimic acts around 5 years of age (Bigham et al., 2007; O'Reilly, 1995) and that this ability is still developing across childhood (Fabbri-Destro et al., 2019; Wurm et al., 2017). As for story comprehension, studies found that important qualitative improvements in key elements of narrative understanding occurs in middle childhood (Burris and Brown, 2014). Putting together the results of these two lines of research, we expected children to comprehend pantomime stories and recognition rates to increase with age.

In addition to a narrative pantomime comprehension task, we administered tests to evaluate cognitive abilities such as CC, ToM, EFT, and WM that, as mentioned, have been claimed to contribute to the processing of specific aspects of story contents, such as those related to plot and character. Basing on the results of previous research, we predicted to find positive correlations between measures relating to these cognitive abilities and measures of narrative comprehension.

2. Materials and methods

2.1. Participants

Twenty-two Italian-speaking children with typical development aged between 8.02 and 10.11 years were included in this pilot study. They had IQ level in the normal range. The group included twelve females and ten males (Table 1).

Children were recruited in local schools. Before the administration of the tasks, teachers reported that the participants had normal cognitive development, as well as average school performance. Moreover, according to parents' reports, none of them had a known history of psychiatric or neurological disorders, learning disabilities, hearing, or visual loss. All children had normal or corrected-to-normal vision.

The study was approved by the ethical committee of Roma Tre University. Parents signed the consent form for the participation of their children to the study and for the treatment of the data.

Table 1
General data of the participants.

	Typically Developing Children ($n = 22$) M (SD) [range]
Age	9.46 (0.74) [8.02–10.11]
Education	3rd – 5th grade
Gender distribution	Males = 10 (46%) Females = 12 (54 %)
IQ level	102.27 (14.45) [80–130]

Data are expressed as mean (M), standard deviation (SD), and range.

2.2. Procedure

Children were tested individually at school. The administration of the research protocol took two days. On the first day, children were administered the *Raven's Progressive Matrices* to assess their IQ level (Raven, 1938; Italian standardization: Belacchi et al., 2008) and the *digit span memory task* aimed at evaluating their working memory abilities (Wechsler, 1993). On the following day, participants were administered three tasks aimed at assessing their abilities of CC (through the *Picture Puzzles* taken from Korkman et al., 2007; Italian standardization: Urgesi et al., 2011), EFT (through the *Picture Book task*, Adornetti et al., 2021; adapted from Atance and Meltzoff, 2005), and ToM (through the *Theory of Mind-part II* taken from Korkman et al., 2007; Italian standardization: Urgesi et al., 2011). Finally, participants were administered a task to evaluate the comprehension of pantomimed stories through a test specifically developed for this study.

2.2.1. Digit span memory task

To assess children' ability of verbal WM, the *Digit span forward and backward* subtests of the Wechsler Scales III for children (Wechsler, 1993; Italian standardization: Orsini and Picone, 2006) were used. In the digit span forward task, participants were required to repeat a sequence of numbers in the same order pronounced by the experimenter. The sequences consisted of a minimum of 2 to a maximum of 9 digits: for each item of a specific length, two different lists of digits were presented (e.g., 3-8-6; 6-1-2). The children obtained a score of 1 for each list correctly repeated. The task ended when children got both sequences of an item wrong. The digit span forward score coincided with the total of exact repetitions, for a maximum of 16 points. In the digit span backward subtest, participants were asked to repeat each list of digits in the reverse order of which pronounced by the experimenter. The items had the same structure as the digit span forward task, but they had 8 digits at most. The final score was obtained counting the number of lists correctly repeated by participant. The maximum score for the digit span backward was 14. The sum of the scores resulting from these two tasks was the digit span composite score (Digit span total score; Table 2) (maximum 30 points). The mean score of the digit span total score was 11.68 (standard deviation: 2.36), which is within the normal ranges of the Italian Standardization of the Wechsler Scales III for children (Orsini and Picone, 2006).

2.2.2. Picture Puzzles

CC, namely the ability to visually discriminate the constituent parts of a picture recognizing the parts-whole relationship, was evaluated using the *Picture Puzzles* subtest from the NEPSY-II (Korkman et al., 2007; Urgesi et al., 2011). Participants were shown a series of large pictures sectioned by a grid and four smaller pictures, identified by letters (A-B-C-D), belonging to the larger picture. They were asked to indicate the corresponding location of each small picture as a part of the larger picture, i.e., the experimenter told participants "Look at each small picture and show me which frame in the large picture it coincides to". Children had 45 s to complete an item. They obtained a score of 1 if the location of the four small pictures in the grid was correctly identified within 45 s. The response time was always recorded (CC response time), even when the task was completed beyond the given time (i.e., when the score was 0). The test was organized by age. All participants were presented with a first item as a trial. The CC score was obtained by calculating the percentage of the correct answers in relation to the number of items (varying according to age), and by normalizing the response time. Children reported a mean percentage of 75.96 (standard deviation: 30.02) of items correctly identified, which is within the normal ranges of the Italian Standardization of the NEPSY- II (Urgesi et al., 2011).

2.2.3. Picture Book task

EFT, i.e., children's ability to imaginatively pre-experience possible personal future states, was assessed by administering The *Picture Book Trip task* (Adornetti et al., 2021), adapted from Atance and Meltzoff (2005). The task included six colored illustrations of scenarios depicting the same number of possible trip destinations (e.g., snowy mountains, a road in the desert, a waterfall, a riverside, etc.). The scenarios were shown one at time, and always in the same order. Participants were first asked to imagine themselves visiting the depicted places in a future time. Then, for each scenario (e.g., snowy mountains), the examiner presented three photographs of objects that could be respectively: (1) useful in the target place (i.e., a winter coat); (2) semantically related to the scenario (i.e., ice-cubes); and (3) not related in any way with the target place (i.e., a bathrobe). The task required selecting the item that children would *need* to bring with themselves in the target destination. Specifically, the experimenter asked: “Which of these objects will you need to take with you on a trip on snowy mountains?”. For each correct answer, a score of 1 was assigned (Identification Score, IS). After the choice, irrespective of it was right or not, she/he was required to motivate her/his answer (“Why do you need to bring that object with you?”). The motivations were evaluated with 1 point when they included a mention to a future internal state (e.g., cold, thirst, etc.). The total number of correct motivations represented the Motivation Score (MS). A composite score of EFT was obtained by summing up the IS and the MS, for a maximum of 12. Children reported a mean total composite score of 9.45 (standard deviation: 1.71). There are no normative data for this task. However, the present results are in line with those of a previous study in which the same task was administered to a large sample (96 participants) of Italian children (Adornetti et al., 2021).

2.2.4. Theory of mind-part II

The Theory of Mind-part II subtest from the NEPSY-II (Korkman et al., 2007; Urgesi et al., 2011) was used to evaluate children’s ability to understand others’ emotions or feelings in specific social contexts. Participants were shown 9 numbered pictures (the first was a trail item) depicting a series of social situations in which a target individual, i.e., a young girl named Julia, was involved (e.g., playing with cats, riding a roller coaster, etc.). The target individual was always portrayed from the back, so that her face was not shown. For each context, children were asked to indicate from four different options the appropriate photograph corresponding to the emotional state of the young girl, i.e., how Julia feels in that social context. The experimenter assigned a score of 1 for each correct answer, for a total of 8 scores (Table 2). Children reported a mean score of 6.36 (standard deviation: 1), which is within the normal ranges of the Italian Standardization of the NEPSY- II (Urgesi et al., 2011).

2.2.5. Narrative pantomime comprehension task

The narrative pantomime comprehension task was specifically designed for the present study to evaluate children’s ability to understand stories conveyed through pantomime. Participants were asked to watch six video clips displayed on a 14inch PC monitor, showing a series of shorts stories enacted by one actress/actor. The first story was used as a trial to allow children to get acquainted with the test. Thus, five stories were considered for the analyses. To ensure the quality of the pantomime performance, we recruited two professional actors, a boy and a girl, from the eminent Silvio D’Amico Art Academy of Rome. Pantomimes were performed through the whole-body from a character viewpoint, i.e., in an egocentric mode (Brown et al., 2019), and did not include any type of verbal communication so that audio was excluded. All the videos were shot in the same location, i.e., a quiet and empty classroom, with a Canon Eos M100 video camera.

All the stories were 1 min long and had the same narrative structure: a beginning, a sequence of related events involving the actions of a character, the occurrence of a problematic situation, and an open ending showing the actress/actor just taking one target physical object to address the conflictual event. Since the identification of the target object was crucial for understanding the problematic situation as well as the character’s motivation driving the open ending, the presence of a real physical object was methodologically desirable to avoid any disturbance to the comprehension task. The focus of the present study, in fact, was not merely exploring participants’ understanding of pantomimed objects or single events but their ability to reconstruct the plot line by integrating the final event with the beginning and the middle of the narrative. Therefore, following the broad definition of pantomime above discussed, all the stories actions were mimed by the actress/actor just using the whole body in the absence of any corresponding object; only in the final frame the actress/actor took the physical object. However, it is important to stress that no action was performed using this target object: the video stopped before the actress/actor could take an action with it, and before the instrumental goal was revealed. The choice to leave open the final event is motivated by both methodological and theoretical considerations. Several lines of investigation do indeed emphasize the relevance that the conclusion has for understanding the overall meaning of a story: the ending is the point of convergence of all the elements of a narrative which gives unity and direction to the story by making sense of events connecting with the beginning and the middle, thus representing a valuable factor for evaluating if the overall story meaning has been fully comprehended. Figs. 1 and 2 illustrate the critical frames of two stories of the task.

Participants were asked to carefully watch the video on the PC monitor, and then, for each story they were administered two comprehension tasks, corresponding to two comprehension indexes: a first index relating to the children’s understanding of the character’s motivations; a second index assessing the degree of comprehension of the plot line. First, participants were asked to answer to a *character’s motivation question*, i.e., “*Why* did the girl/boy take the *target object*?” (e.g., “*Why* did the boy take the guitar?”). For example, for the guitar story (Fig. 1), the correct answer is that the boy took the guitar to earn some money in order to buy the ice-cream; for the cat food story (Fig. 2), the right answer is that the girl took the pet food to attract the cat pushing him to get down from the tree. These answers obtained a score of 1. Therefore, as five stories were used for the analysis, the total comprehension score consisted of a maximum of 5 points. Since for each question only one right answer was possible, children’s responses were rated by only one coder (the first author).

Successively, children were administered a *retelling task*. Specifically, the retelling task elicited the construction of a representation of the whole narrative, which could be more or less coherent. To build a coherent narrative representation, children had to recognize not only the motivations underlying the character’s actions, but also how the individual pantomimic events constituting the stories were causally and temporally linked each other’s. For that, *retelling task* is suitable to provide more information than the comprehension questions alone on how children processed the story-plot. In fact, in the literature, retelling has been explicitly related to children's ability "to use extended amounts of language, to recall details and to summarize information into an intelligible whole (...) (so as to focus) the listener's attention on restructuring information in a holistic fashion" (John et al., 2003, p. 93). In this vein, the process involved in retelling might be indicative of a "deep level" of comprehension in which an understanding of characters' feelings and thoughts is part of a wider process of building a rich situation model.

After watching the video clip and answering the comprehension question, whether that was correct or incorrect, participants were required to retell the story (i.e., the examiner told "And now tell me the story"). Each story was tape-recorded and transcribed verbatim later in time. The transcriptions included the pauses, false starts, phonological fillers, and, eventually, extraneous elements. Subsequently, referring to coding schemes used in the literature on narrative processing (e.g., for comprehension assessment: Paris and Paris, 2003; for production assessment: Reese et al., 2011; King et al., 2014), retelling was scored according to a scale from 0 to 3 points specifically developed for the present study. This scale was designed to evaluate to what extent children were able to coherently report the stories they saw by integrating the events line, i.e., the beginning, the middle/conflictual event, and the resolution/ending, with the character's motivation. Performance received 0 point when the child did not carry out the task; transcriptions received 1 point when the story was incoherent, i.e., when neither the causal and temporal sequence of events nor the motivations of the character's actions were correct; 2 points were assigned when children correctly described the story events without identifying the motivation behind the final action; finally, 3 points were assigned when the sequence of events was correctly retold and the final motivation was provided. Examples of the speech samples for each point of the scale are reported in the Appendix. The final score of retelling was obtained by summing up the score of each story, for a maximum of 15 points (Pantomime retelling score).

Transcriptions' evaluation was carried out independently by two coders (the third and the fourth author). Inter-reliability was calculated ($r = .95$; $p < .001$). Any discrepancies were resolved by discussion.

Table 2
Descriptive analyses of the children's performance on the tasks administered. Data are expressed as means, standard deviations, and ranges.

	Group (n = 22) M (SD) [range]
Digit span forward score	7.36 (1.26) [5–11]
Digit span backward score	4.32 (1.62) [2–8]
Digit span total score	11.68 (2.36) [8–17]
Central coherence score	75.96 (30.02) [0–100]
Central coherence score response time	169.36 (57.32) [94–270]
Episodic future thinking – identification score	5.59 (.73) [3–6]
Episodic future thinking – motivation score	3.86 (1.32) [2–6]
Episodic future thinking – total score	9.45 (1.71) [5–12]
Theory of mind score	6.36 (1) [5–8]
Pantomime character's motivation comprehension score	3.45 (1.05) [1–5]
Pantomime retelling score	12.09 (2.99) [1–15]

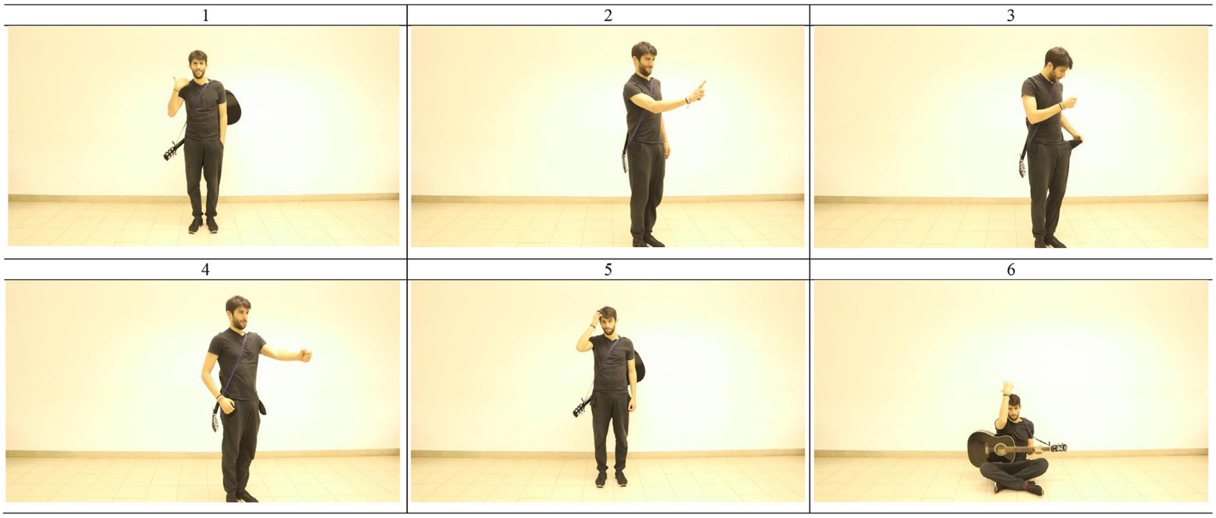

Fig. 1. Critical frames of the guitar story. (1) A young boy is walking with a guitar (i.e., the physical target object) on his back; he is very flushed; therefore, he stops buying an ice-cream; (2) he chooses the ice-cream flavors, but just as he is about to eat it, he realizes he does not have any money left. (3) After searching repeatedly his pants pockets, (4) he gives back the ice-cream, and sadly keeps walking. (5) While reflecting on a possible solution, he suddenly has an idea: (6) he gets his guitar, sits on the street and he places his hat in front of him.

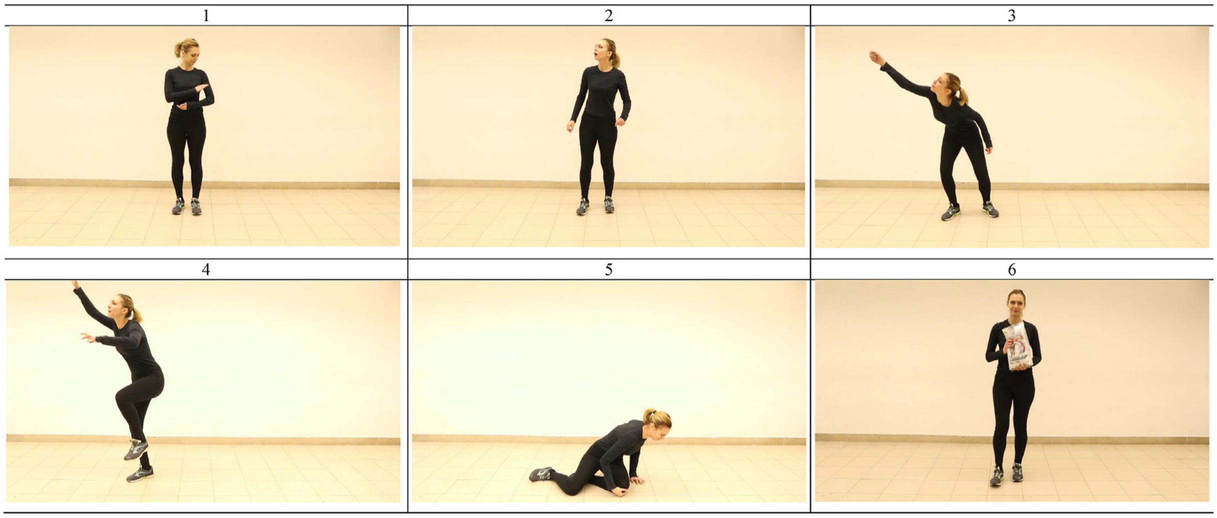

Fig. 2. Critical frames of the cat food story. (1) A young girl is petting her cat on her arms. Then she accompanies her cat on the ground, but unexpectedly the cat runs away and climbs on a tree (2) with the girl watching at the pet. (3) The girl tries moving the cat down: (4) she is trying to climb the tree herself, when accidently (5) she falls on the ground and hurts her knee. Therefore, she looks for another solution and has an idea: with satisfaction, (6) she goes to get a box of cat food (i.e., the physical target object).

3. Statistical analysis

Correlation analysis (Pearson's *r*) between narrative comprehension scores (pantomime character's motivation comprehension score and pantomime retelling score), age and the cognitive abilities scores (IQ, theory of mind, central coherence, episodic future thinking, and working memory) was performed. Subsequently, multiple regression analysis was performed on significant correlations, with the age and cognitive variables as predictors and the narrative comprehension scores as dependent variables.

4. Results

Correlation analysis showed that the pantomime character's motivation comprehension score was positively associated with age ($r = .55$; $p = .007$), digit span backward score ($r = .59$; $p = .004$) and total digit span score ($r = .55$; $p = .008$), while the pantomime retelling score was positively associated with age ($r = .42$; $p = .049$), digit span forward score ($r = .42$; $p = .050$, at the limit) and total digit span score ($r = .51$; $p = .016$) and theory of mind score ($r = .47$, $p = .027$) (Table 3).

Multiple regression analysis with age, digit span backward and total score as predictor variables and pantomime character's motivation comprehension score as dependent variable showed the significant regression model [$R = .65$; $R^2 = .43$; $R^2_{adj} = .33$; $F(3,18) = 4.46$; $p = .016$. Age: $\beta = .34$; $SE = .23$; $t_{(18)} = 1.471$; $p = .158$; digit span backward: $\beta = .13$; $SE = .37$; $t_{(18)} = 0.353$; $p = .728$; total digit span: $\beta = .29$; $SE = .32$; $t_{(18)} = 0.923$; $p = .368$].

At second step, removing age, the multiple regression analysis with digit span backward and total score as predictor variables and pantomime character's motivation comprehension score as dependent variable showed the significant regression model [$R = .60$; $R^2 = .36$; $R^2_{adj} = .29$; $F(2,19) = 5.29$; $p = .015$. Digit span backward: $\beta = .41$; $SE = .32$; $t_{(19)} = 1.629$; $p = .220$; total digit span: $\beta = .22$; $SE = .32$; $t(19) = 0.671$; $p = .510$].

Multiple regression analysis with age, digit span total score and theory of mind score as predictor variables and pantomime retelling score as dependent variable showed the significant regression model at limit [$R = .58$; $R^2 = .34$; $R^2_{adj} = .23$; $F(3,18) = 3.11$; $p = .052$. Age: $\beta = .13$; $SE = .25$; $t_{(18)} = 0.513$; $p = .615$; digit span total: $\beta = .34$; $SE = .22$; $t_{(18)} = 1.557$; $p = .137$; theory of mind: $\beta = .24$; $SE = .71$; $t_{(18)} = 0.981$; $p = .339$].

At second step, removing age, the multiple regression analysis with digit span total score and theory of mind score as predictor variables and pantomime retelling score as dependent variable showed the significant regression model [$R = .58$; $R^2 = .33$; $R^2_{adj} = .26$; $F(2,19) = 4.71$; $p = .022$. Digit span total: $\beta = .37$; $SE = .21$; $t_{(19)} = 1.774$; $p = .092$; theory of mind: $\beta = .31$; $SE = .21$; $t_{(19)} = 1.461$; $p = .160$] (Table 4).

Table 3
Correlation analysis (Pearson's *r*) between narrative comprehension scores (character's motivation comprehension score and pantomime retelling score) and age, IQ, working memory (forward, backward, and total digit span), central coherence, episodic future thinking (identification, motivation, and total) and theory of mind scores.

	Narrative comprehension	
	Pantomime character's motivation comprehension score	Pantomime Retelling score
Age	**r = .55; p = .007**	**r = .42; p = .049**
IQ score	r = .00; p = .990	r = .03; p = .888
Digit span forward score	r = .33; p = .138	r = .42; p = .050
Digit span backward score	**r = .59; p = .004**	r = .41; p = .056
Digit span total score	**r = .55; p = .008**	**r = .51; p = .016**
Central coherence score	r = .22; p = .324	r = .04; p = .855
Episodic future thinking – identification score	r = .00; p = 1.00	r = .20; p = .376
Episodic future thinking – motivation score	r = −.27; p = .231	r = .09; p = .688
Episodic future thinking – total score	r = −.20; p = .375	r = .16; p = .480
Theory of mind score	r = .32; p = .150	**r = .47; p = .027**

Table 4
Multiple regression analyses results.

		Pantomime character's motivation comprehension		Pantomime retelling score
***Step 1* Multiple regression model**		**$R = .65; R^2 = .43; R^2_{adj} = .33$ $F(3,18) = 4.46; p = .016$**		$R = .58; R^2 = .34; R^2_{adj} = .23$ $F(3,18) = 3.11; p = .052$
Predictors	*Age*	$\beta = .34; SE = .23$ $t_{(18)} = 1.471; p = .158$	*Age*	$\beta = .13; SE = .25$ $t_{(18)} = 0.513; p = .615$
	Digit span backward score	$\beta = .13; SE = .37$ $t_{(18)} = 0.353; p = .728$	*Digit span total score*	$\beta = .34; SE = .22$ $t_{(18)} = 1.557; p = .137$
	Digit span total score	$\beta = .29; SE = .32$ $t_{(18)} = 0.923; p = .368$	*Theory of mind*	$\beta = .24; SE = .71$ $t_{(18)} = 0.981; p = .339$
***Step 2* Multiple regression model**		**$R = .60; R^2 = .36; R^2_{adj} = .29$ $F(2,19) = 5.29; p = .015$**		**$R = .58; R^2 = .33; R^2_{adj} = .26$ $F(2,19) = 4.71; p = .022$**
Predictors	*Digit span backward score*	$\beta = .41; SE = .32$ $t_{(19)} = 1.629; p = .220$	*Digit span total score*	$\beta = .37; SE = .21$ $t_{(19)} = 1.774; p = .092$
	Digit span total score	$\beta = .22; SE = .32$ $t_{(19)} = 0.671; p = .510$	*Theory of mind*	$\beta = .31; SE = .21$ $t_{(19)} = 1.461; p = .160$

5. Discussion

This study aimed to explore the narrative potential of pantomimic communication by investigating the comprehension of short pantomime stories and its possible cognitive underpinnings in children with typical development. Analyses confirmed our prediction about the effect of age on narrative pantomime comprehension. In line with expectations, comprehension improved with age: the more the age increased, the more the children were able to reconstruct the story plot by grasping the motivations underlying character's final action (pantomime character's motivation comprehension score) and correctly telling the events constituting the narratives (pantomime retelling score). As for the relationship between children's comprehension performances and the cognitive systems, only two predictions were confirmed: positive correlations were found between comprehension scores (character's motivation comprehension score as well as retelling score) and measures of verbal WM and ToM; CC and EFT turned out to be not involved in narrative pantomime comprehension task. The regression models (with and without age as a predictor) were significant, but individual predictors (WM and ToM) were not. Although the present investigation is a pilot study conducted on a small group of participants, its results offer some stimulating points for discussion of both the ontogenetic and phylogenetic development of narrative pantomime.

5.1. Ontogenetic implications

To the best of our knowledge, this is the first study that investigated the comprehension of narrative pantomime in children with typical development. Most of previous research (both on adults and children) adopted a "narrow" interpretation of pantomime, i.e., "pantomimes that are based on the execution of a relevant motor sequence in the absence of an instrumental goal or of its object for transitive actions" (Adornetti et al., 2019, p. 3), and focused on pantomimic acts produced by hand gestures only (e.g., Dick et al., 2005; Lennox et al., 1988; O'Reilly, 1995; van Nispen et al., 2017). Against this background, O'Reilly (1995) examined both the comprehension and the production of the "body-part-as-object" (BPO) pantomime (e.g., using a finger as a toothbrush) *vs* the "imaginary object" (IO) pantomime (e.g., pretending to hold the toothbrush in hand) in 3- and 5-year-old children and in adults. In line with the more general premise of a developmental progression of representational ability characterized by a gradual distancing of symbols from their referents (Bigham and Bourchier-Sutton, 2007; Werner and Kaplan, 1963), the hypothesis was that BPO pantomimes would have been easier for children to identify than IO pantomimes. Results confirmed the hypothesis: youngest participants had difficulties in comprehending and producing imaginary object representations and obtained better performance when asked to comprehend and produce pantomimes with a body part representation. Overall, these results, showing children's "increasing independence from concrete environmental support in their knowledge about actions" (O'Reilly, 1995, p. 999), highlight a developmental improvement of pantomime comprehension across the preschool years (see also Lennox et al., 1988). Our study might contribute to expand these observations to middle childhood. In our stimuli, the actions enacted to depict the objects were IO pantomimes, such as the boy who holds in his hand an imaginary ice cream (Fig. 1, frame 3) or the girl who pets an imaginary cat in her arms (Fig. 2, frame 1). Although our narrative comprehension task did not directly assess the understanding of this specific aspect pantomime, it is likely that part of the progression observed in the ability to interpret narrative pantomime was tied to a developmental advance of children's symbolic representation ability.

That said, being our pantomime comprehension test based on a *narrative* task, the developmental progress we found can be also explained in terms of a development of narrative comprehension and production abilities over childhood. As for story comprehension, research showed that between 5 and 9 years of age an important qualitative improvement in key elements of narrative understanding occurs (Burris and Brown, 2014). Around age 5, children begin to produce more goal-directed mental representations, i.e., representations of character's desires motivating actions (Trabasso et al., 1992; Berman and Slobin, 1994; Kendeou et al., 2008). By the age of 6 children are more sensitive to causal structures (Lynch et al., 2008) and between 8 and 9 years of age they also appear to be more sensitive to goal structures and inferences (van den Broek et al., 2003; Trabasso et al., 1992). As for story production, by the age of 6 children begin to develop strategies for generating coherent texts (Nicolopoulou, 2008; Peterson and McCabe, 1991). Around age 8, they make efforts to conform their tales to the episodic structure. i.e., causally related, goal-based, problem-resolution episodes with reference to characters' internal states (Stein, 1988; Botvin and Sutton-Smith, 1977). Between 9 and 12 ages, the ability to produce stories with complex plots embedded in multiple episodes becomes mastered (Hudson and Shapiro, 1991). In line with these investigations, our results confirmed the predictions and showed that also the comprehension of stories represented through pantomime follows a developmental improvement during childhood: the more the age increased, the more the children grasped the motivations underlying the character's actions and correctly retold the stories, demonstrating to be sensitive to their causal and goal structures.

A second finding emerging from our analyses concerns the positive correlations between measures of verbal WM and the two narrative scores, i.e., pantomime comprehension question and retelling score, and between ToM and retelling score. Having found these correlations, we therefore explored a cause-effect relationship between the cognitive and narrative variables. To this aim, multiple regression analyses were performed by inserting as predictors the cognitive variables that resulted significantly correlated to the narrative variables. The results showed that the regression models (with and without age as a predictor) were significant, but individual predictors were not. This might be due to the strong inter-relationship between predictors or the small sample size. Overall, putting together the positive correlations and the significant regression models, these results point to the existence of a strong link between the comprehension of narrative pantomime on the one hand and WM and ToM on the other hand.

The positive correlations between measures of verbal WM and the two narrative scores seem confirming previous literature showing that WM is connected to narrative production and comprehension, i.e., to the construction of situation models (Radvansky and Copeland, 2001). Situation models (van Dijk and Kintsch, 1983; Zwaan and Radvansky, 1998), or mental models (Johnson-Laird, 1983), are mental representations simulating the events described in a text. Their importance for narrative processing relies on the fact that they contain crucial aspects of events in the world, such as space, time, causality, and so forth. According to Radvansky and Copeland (2001, p. 1074), the recruitment of WM in the construction of a situation model might be linked to updating processes "in that updating requires that a large amount of information be kept available to allow a person to shift from one situation to the next". Specifically, WM must contain information about the relevant components of a situation, such as the spatial-temporal framework, the entities involved, their goals, motives, and properties, and the causal relations among events. In line with these considerations, previous research attested the crucial role of verbal WM in the development of children's narrative abilities (e.g., Kormos and Trebits, 2011; Montgomery et al., 2009; Veraksa et al., 2020). Our results indicate that the involvement of verbal WM in narrative processing is not restricted to stories processed verbally, as already suggested by research on visual narrative comprehension (e.g., Cohn, 2020; Loschky et al., 2020). Overall, these considerations allow to point to the existence of a cross modal network of cognitive processes and systems sustaining the representation of narrative contents irrespectively of the semiotic systems used to convey stories.

This latter interpretation is further corroborated by the positive correlation between ToM and retelling score: the more the children understood others' emotions or feelings, the more they coherently retold the sequence of story events, i.e., causal and temporal links between the events were properly identified and reported, and correctly described the character's motivation necessary to give meaning to the final action. As stressed by Kim et al. (2021), ToM "acts as an interpretive mechanism in making connections among various perspectives, thoughts, and emotions represented in texts, and hence it plays a critical role in establishing an accurate and rich situation model" (p., 2). In their study aimed at exploring the relations among ToM, mental state talk, and discourse comprehension in a group of 10 years old children, Kim et al. (2021) evaluated two genres of discourses: narrative texts and informational texts. Participants heard short narratives and short informational texts and then were invited to recall discourses and answer to some open-ended comprehension questions. Results showed that ToM predicted the extent of mental state talk in both narrative texts and informational texts and that mental state talk in narrative texts was strongly related to narrative comprehension. Other investigations revealed a development in children's narrative processing, both oral and written, that goes hand in hand with the development of mentalizing abilities across childhood (e.g., Dore et al., 2018; Guajardo and Watson, 2002; Kim, 2020; Pelletier and Beatty, 2015).

These behavioural data are further corroborated by neuroscientific investigations (e.g., Ferstl et al., 2008; Lin et al., 2018; Mar, 2011, Mason and Just, 2009). Relevant to our study is the experiment by Yuan et al. (2018), who used fMRI to explore the brain systems recruited in the generation of narratives. Participants were asked to read short stories describing an event and then represent it, either through a verbal description, a gestural pantomime, and a drawing on a tablet. Results showed the existence of a cross-modal "narrative hub" transcending the systems recruited to convey story content: the three semiotic systems employed to produce the stories activated a common set of cognitive operations in the mentalizing network. According to the authors, "one possible interpretation of the results is that people assume a mentalistic stance as their default mode of processing stories, oriented toward the characters in the stories" (Yuan et al., 2018, p. 1310). In other words, ToM contributes to process a key aspect of narrative – the character-based dimension – independently of the semiotic systems employed to convey stories. Our finding supports such an interpretation: when children had to tell the observed pantomimed stories, they appeared to process the sequences of events with a special focus on the protagonist's motives and feelings. Extending the findings by Yuan and collaborators (2018), our analyses show that the mentalistic stance applies not only to the production of pantomimic stories, but also to their comprehension. Overall, it is our claim that these considerations may provide support to the "narrative first hypothesis", i.e., the view that story processing strongly relies on the proper functioning of a multiple cognitive network not specific for linguistic processing. Before examining the phylogenetic implications of these findings, some last issues emerging from our analyses are worth to be mentioned.

A first issue concerns the finding of differential relations of ToM to the two narrative measures adopted in the present study. While a positive correlation between ToM and retelling score was observed, ToM did not significantly correlate with the comprehension question. This result suggests that our two narrative measures somehow reflect two distinct processes of narrative comprehension. Specifically, retelling may have benefited from ToM skill, encouraging children to make inferences about the characters' goals, beliefs, emotions, and intentions not explicitly present in the story, thus providing a more detailed estimation of pantomimic story comprehension. Conversely, the absence of correlation between ToM and the comprehension question might prove the latter to be of a different nature, in that it may elicit just a portion of information.

Finally, contrary to our predictions, no significant correlations were found between the narrative measures and the score on task of CC. Several studies have highlighted the role of CC in understanding and memory of global story structure, as CC would support the construction of an integrated representation of the story plot (e.g., Happé et al., 2001; Lopez et al., 2008; Norbury and Bishop, 2002). In our study, the absence of correlation between CC and narrative comprehension might be related to methodological issues. Indeed, along with differences among individuals in the processing style, research has also shown that the creation of a coherent representation of the narrative may rely on both local processing and global processing – involving the ability to focus on either the parts, the whole pattern, or both – depending on task and stimulus conditions (see Booth, 2006).

A similar consideration can apply also to a last finding of this study: contrary to our predictions, we did not find correlations between the narrative scores and measures of EFT. In previous investigations, EFT has been found to be involved in the processing of the temporal links between the sequences of story events when participants had to imagine the missing events of a narrative discourse by envisioning past or future episodes (Ferretti et al., 2018; Marini et al., 2019) whereas its contribution was not significant when the narrative stimuli included visual events that were all visible to the participants (Adornetti et al., 2020). Again, it is possible that an influence of EFT in narrative processing is contingent on specific aspects of the narrative.

5.2. Evolutionary implications

The results of this investigation may offer some indications about the narrative origin of human language. At a general level, they show that pantomime represents a suitable means for conveying narrative contents: children understood quite well the narrative plot conveyed through whole-body pantomime and their comprehension grew up with age in a way that seems mirroring the developmental progression of linguistic narrative processing. The fact that pantomime turns out to be a suitable system for storytelling—a system allowing the representation of two crucial elements of a story, such as plot and character (see also Sibierska, 2017)—opens the way to the possibility of considering it a precursor to human language, i.e., a way to tell "proto-stories" before the emergence of a fully-fledged language. That said, in adhering to the "narrative first hypothesis" we consider the potential of pantomime to convey stories as subject to the possibility, for both modern humans and ancient ancestors, to be endowed with a set of cognitive systems enabling narrative representations. In this regard, our investigation highlights that at least two systems are required to comprehend pantomimic storytelling: WM and ToM. It can be assumed that our ancestors' ability to narrate through pantomime rested on the possibility for them to be endowed with these systems. In other words, if our hypothesis on the pantomimic narrative origin of language is correct, then WM and ToM do not merely support the proper functioning of story processing, but they were also involved in the selective pressures that have driven the transition from animal communication to human language.

As for WM, a great body of research has tried to unveil its evolutionary origins (e.g., Coolidge and Wynn, 2020; Haidle, 2010; Nowell, 2010; Read et al., 2022). Overall, this research points to the view that, even if all primates (possibly, all mammals) have WM, with the emergence of *Homo ergaster/erectus* there was a crucial development of this capacity and that such development parallels complexity increases in stone artifacts. Specifically, Coolidge and Wynn (2019) described Acheulean handaxe manufacture typical of *Homo ergaster/erectus* as the first cognitive archaeological Rubicon that seems to have required an increase in WM skills. From this view, the expansion of WM during human phylogeny predated the origin of fully-fledged language: such expansion was originally driven by selective pressures related to toolmaking and tool-use (Stout et al., 2015) and only later exploited for other aims, including communicative purposes supporting pantomimic storytelling.

Research on ToM in non-human primates also indicates that the advent of this cognitive capacity preceded the dawn of language. Experiments showed that chimpanzees, bonobos, and orangutans can pass several false-belief tests (e.g., Krupenye et al., 2016; Buttelmann et al., 2017; Kano et al., 2019), suggesting that these apes have, to some degree, rudimentary capacities to attribute mental states to others. These findings provide evidence that also our hominin ancestors possessed the cognitive equipment necessary to understand how and what others thought. Also in this case, it can be assumed that this ability originally evolved for functions not related to language – to interpret other's behaviors – and was later exploited for pantomimic communication allowing our ancestors to develop increasingly sophisticated narrative forms of communication. An important consideration is that the strict relationship between comprehension of pantomimic storytelling and mentalizing abilities contributes to support the view that pantomimic proto-stories might fulfill a persuasive aim. The mentalizing system is, in fact, among the cognitive devices making possible one of the processes underlying narrative persuasion, i.e., identification with the story characters (Ferretti et al., 2022), which implies taking over the protagonists' goals or plans and experiencing different emotions depending on whether these plans work out or fail (Oatley, 1999). As suggested by Bilandzic and Busselle (2013, p. 213), this form of perspective taking "should increase a message's effectiveness as people care for the characters and internalize outcome expectancies". On this view, the development of proto-stories conveyed through pantomime can be considered as an enhancement of persuasive abilities already present in other forms of animal communication.

Along with being a means of persuasion, pantomimic storytelling has also modified environments of our ancestors creating a new ecological niche, i.e., a cultural environment made of symbols (e.g., rituals, traditions, religions, etc.). As highlighted within the niche-construction perspective, culture is not only a way to respond to environmental pressures but also a source of new challenges to the individuals who inhabit it: cultural changes, when modifying environments, become powerful forces of evolutionary changes (Laland et al., 2000). Against this background, it is plausible hypothesizing a co-evolutionary scenario in which pantomimic storytelling emerged through the exaptation of cognitive systems such as ToM and WM for the purpose of making persuasion more efficient. This would have created a *feedback loop* favoring the emergence of more structured and complex expressive resources in the service of more effective communicative exchanges on the persuasive level (Benítez-Burraco, Ferretti, and Progovac, 2021). From this perspective, the selective pressures toward more effective forms of persuasion would have triggered the development "of a complex grammar and articulated forms of speech in order to provide arguments aimed at both supporting and defending one's own point of view" (Ferretti and Adornetti, 2021, p. 4; Benítez-Burraco, Ferretti, and Progovac, 2021). In fact, narrative is not the only means of persuasion: since the rise of classical rhetoric, argumentation has been considered the persuasive strategy par excellence (e.g., Perelman and Olbrechts-Tyteca, 1958). Argumentation is a product of reasoning, i.e., a form of inference which involves attending to the reasons for accepting a conclusion. The point to stress is that this inferential reasoning relies on propositional representations (Sperber and Wilson, 1986) and, therefore, requires a sophisticated expressive system at the grammatical level, i.e., a system able to express the constituent structure of a sentence necessary to convey propositional contents (Ferretti et al., 2022). In an evolutionary perspective, the selective pressures towards more effective forms of persuasion fostered the transition from pantomime to grammatically sophisticated codes. More elaborate grammars provide better tools for persuasion (Benítez-Burraco, Ferretti, and Progovac, 2021) that, in turn, enhanced argumentative skills as well as narrative skills making it possible "to express fully-fledged stories presenting more complex features which characterize modern-day storytelling" (Ferretti et al., 2022, p. 11).

5.3. Limitations and indications for future studies

The present research was a pilot study and, for that, had several limitations. First, the investigation was conducted on a small group of children. Therefore, though interesting, our results need to be corroborated in a larger sample. This could be particularly important for the multiple regression analyses. As mentioned, while the regression models were significant, individual predictors were not. The small sample size probably affected this result. Second, the inclusion of tasks aimed at providing a description of the linguistic profile (e.g., grammatical and semantic competencies) of the children would have offered a more comprehensive view of their retelling skills. Third, from a methodological point of view, it cannot be excluded that the choice to administer the two comprehension tasks to the same group of participants could have affected the performance. For that, we believe that a future study aiming at replicating the present pilot should rely on an independent samples design, administering the two comprehension tasks to two different groups of participants.[3] Moreover, another narrative pantomime condition could be added. As said, the stories were mimed by the actress/actor just using the whole body in the absence of any corresponding object, but in the last frame the actress/actor took a physical object, without

[3] We thank one anonymous reviewer for this suggestion.

performing action using this object. This was done for the above explained methodological and theoretical reasons. However, in future studies it could be interesting adding a control condition in which the actress/actor does not take the physical object, but just mimes that object.[4]

Finally, our results concerning the involvement of ToM and WM in the comprehension of pantomimic storytelling highlight only some aspects of narrative processing. Since storytelling is a multifaceted ability, there is no doubt that other cognitive systems are involved in its processing. As we mentioned, previous research showed that among other cognitive abilities, both CC and EFT seem to be involved in a different way in the processing of the global meaning of a story. Future research should take these points into consideration and try to clarify the potential association of temporal projection and central coherence with the processing of specific aspects of pantomimic storytelling.

6. Conclusion

The present pilot study investigated the comprehension of stories narrated via pantomime and its possible cognitive underpinnings in a group of children with typical development. Our results, although somehow limited in their potential generation, suggest that understanding of narrative pantomime increases with age and that two cognitive abilities are linked to children's comprehension performances: working memory and theory of mind. These results might offer interesting indications for the view that human language originated from narrative forms of communication. Specifically, our results suggest that pantomime is a suitable means for conveying narrative contents, thus supporting accounts which argue that pantomime could have acted as system "to tell" stories before the emergence of vocal language. Moreover, our findings highlight the involvement of working memory and theory of mind in the processing of pantomime narrative. As it is reasonable to think that the systems and cognitive skills responsible for language processing as we know it today were also involved in its origin, we can speculate that working memory and theory of mind were part of a complex multifactorial collection of cognitive systems not specific for language that, during phylogeny, were exapted for communicative purposes to configure the language-ready brain.

Author contributions

IA contributed to plan the study, supervised the recruitment of the participants and the administration of the task, contributed to the interpretation of the results, wrote the paper. AC contributed to plan the study, supervised the administration of the task, contributed to the interpretation of the results and to the writing of the Introduction and Discussion. VD prepared the materials, administered the tasks, evaluated the transcriptions, contributed to the interpretation of the results and to the writing of the Materials & Methods' section. DA administered the tasks, evaluated the transcriptions, processed the data, contributed to the interpretation of the results, and wrote Results' section. FF planned the study, supervised the recruitment of the participants and the administration of the tasks, contributed to the interpretation of the results and to the writing of the Introduction and Discussion.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The current study was approved by the ethical committee of Roma Tre University. Parents signed the consent form for the participation of their children to the study and for the treatment of the data.

Declaration of competing interest

The authors declare that they have no conflict of interest.

Acknowledgments

We would like to thank the parents of the children involved in this study and the teachers of the "Istituto Comprensivo Corrado Melone - Plessi Odescalchi e Fumaroli" (Ladispoli) for their cooperation in recruiting the participants. We also thank Michael Arbib, Nathalie Gontier, Sławomir Wacewicz, Przemysław Żywiczyński and Jordan Zlatev for stimulating discussions during the preparation of this study. We are very grateful to Roberta Azzarone and Lorenzo Parrotto for their pantomimic performances.

[4] We thank a second anonymous reviewer for the comment that allowed us to think about this new condition.

Appendix. Retelling task scale

Scale 0–3 points	Narrative samples from the "guitar story" (Fig. 1)
0 points: The child did not carry out the task.	Non ho capito/*I didn't understand.*
1 point: The story produced is incoherent, i.e., when neither the causal and temporal sequence of events nor the motivations of the character's actions are correct.	Lui passeggiava e aveva caldo e non aveva niente nelle tasche, e non l'avevo capito che cosa e poi si era girato che faceva così ma non l'avevo capito bene./*He was walking and he was too warm and he had nothing in his pockets and I didn't understand what and then he turned around that he was doing this but I didn't understand it well.*
2 points: The story events are correctly described but the motivation behind the final action is missing or not explicitly stated.	Ho visto che un signore aveva caldo … poi ha cominciato a pensare e poi è andato in una gelateria e gli ha detto quale gelato voleva indicando e … gliel'ha dato poi … ha cominciato a leccare solo che il signore gli ha detto "aspetta, devi pagare" a allora ha toccato prima la tasca … non c'era … i soldi … e nell'altra tasca non c'erano i soldi e … ha cominciato a suonare la chitarra e ha messo il cappello/*I saw that a man was hot … Then he started thinking and went to an ice-cream parlor and ordered the ice-cream indicating the flavors … the he started licking it but the gentlemen told him "wait, you have to pay for the ice-cream". So, he searched his pocket … there was nothing … in the other pocket there was no money. In the end, he took the guitar and put down his hat.*
3 points: The sequence of events was correctly retold and the final motivation was provided.	Questo ragazzo ha molto caldo allora ha visto un signore che vendeva gelati o qualcosa di fresco allora voleva comprarlo no perché sentiva molto caldo però si è si è accorto che non aveva più i soldi allora glielo ha ridato. E allora poi an un certo punto gli è venuta questa idea di mettersi per terra poggiare il cappello così gli davano un po' di soldi così aveva la possibilità di comprarlo./*This boy is very flushed so he saw a gentleman who was selling ice creams or something fresh, so he wanted to buy it because he felt very hot but he realized that he had no longer money, so he gave it back to him. Then at a certain point he came up with this idea to get down on the ground and put his hat down so they'd give him some money so he could buy it.*

References

Adornetti, I., Chiera, A., Deriu, V., Altavilla, D., Lucentini, S., Marini, A., et al., 2020. An investigation of visual narrative comprehension in children with autism spectrum disorders. Cognit. Process. 21 (3), 435–447. https://doi.org/10.1007/s10339-020-00976-6.

Adornetti, I., Chiera, A., Altavilla, D., Deriu, V., Marini, A., Gobbo, M., et al., 2023. Defining the characteristics of story production of autistic children: A multilevel analysis. J. Autism Dev. Disord., 1–18. https://doi.org/10.1007/s10803-023-06096-2.

Adornetti, I., Chiera, A., Altavilla, D., Deriu, V., Marini, A., Valeri, G., et al., 2021. Self-projection in middle childhood: a study on the relationship between theory of mind and episodic future thinking. Cognit. Process. 22, 321–332.

Adornetti, I., Ferretti, F., Chiera, A., Wacewicz, S., Żywiczyński, P., Deriu, V., et al., 2019. Do children with autism spectrum disorders understand pantomimic events? Front. Psychol. 10, 1382 https://doi.org/10.3389/fpsyg.2019.01382.

Arbib, M., 2012. How the Brain Got Language. Towards a New Road Map. Oxford University Press, Oxford. https://doi.org/10.1075/bct.112.

Armstrong, D.F., Wilcox, S.E., 2007. The Gestural Origin of Language. Oxford University Press, Oxford. https://doi.org/10.1093/acprof:oso/9780195163483.001.0001.

Atance, C.M., Meltzoff, A.N., 2005. My future self: young children's ability to anticipate and explain future states. Cognit. Dev. 20 (3), 341–361. https://doi.org/10.1016/j.cogdev.2005.05.001.

Baron-Cohen, S., Leslie, A.M., Frith, U., 1986. Mechanical, behavioural and intentional understanding of picture stories in autistic children. Br. J. Dev. Psychol. 4 (2), 113–125. https://doi.org/10.1111/j.2044-835X.1986.tb01003.x.

Belacchi, C., Scalisi, T.G., Cannoni, E., Cornoldi, C., 2008. Manuale CPM Coloured Progressive Matrices: Standardizzazione Italiana. GiuntiO.S. Organizzazioni Speciali, Firenze.

Benítez-Burraco, A., Ferretti, F., Progovac, L., 2021. Human self-domestication and the evolution of pragmatics. Cognit. Sci. 45 (6), e12987.

Berman, R.A., Slobin, D.I., 1994. Relating Events in Narrative: A Crosslinguistic Developmental Study. Lawrence Erlbaum Associates, Hillsdale.

Bertossa, R.C., 2011. Morphology and behaviour: functional links in development and evolution. Phil. Trans. Biol. Sci. 366 (1574), 2056–2068. https://doi.org/10.1098/rstb.2011.0035.

Bigham, S.A., Bourchier-Sutton, A., 2007. The decontextualization of form and function in the development of pretence. Br. J. Dev. Psychol. 25 (3), 335–351. https://doi.org/10.1348/026151006X153154.

Bilandzic, H., Busselle, R., 2013. Narrative persuasion. In: Dillard, J.P., Shen, L. (Eds.), The Sage Handbook of Persuasion: Developments in Theory and Practice, vol. 2, pp. 200–219. https://doi.org/10.4135/9781452218410.

Boeckx, C.A., Benítez-Burraco, A., 2014. The shape of the human language-ready brain. Front. Psychol. 5, 282. https://doi.org/10.3389/fpsyg.2014.00282.

Booth, R., 2006. Local–Global Processing and Cognitive Style in Autism Spectrum Disorders and Typical Development. Institute of Psychiatry, King's College London, London.

Botvin, G.J., Sutton-Smith, B., 1977. The development of structural complexity in children's fantasy narratives. Dev. Psychol. 13 (4), 377–388. https://doi.org/10.1037/0012-1649.13.4.377.

Boyd, B., 2018. The evolution of stories: from mimesis to language, from fact to fiction. Wiley Interdisciplinary Rev. Cognit. Sci. 9 (1), e1444. https://doi.org/10.1002/wcs.1444.

Brown, S., Mittermaier, E., Kher, T., Arnold, P., 2019. How pantomime works: implications for theories of language origin. Front. Commun. 4, 9. https://doi.org/10.3389/fcomm.2019.00009.

Burris, S.E., Brown, D.D., 2014. When all children comprehend: increasing the external validity of narrative comprehension development research. Front. Psychol. 5, 168. https://doi.org/10.3389/fpsyg.2014.00168.

Buttelmann, D., Buttelmann, F., Carpenter, M., Call, J., Tomasello, M., 2017. Great apes distinguish true from false beliefs in an interactive helping task. PLoS One 12 (4), e0173793. https://doi.org/10.1371/journal.pone.0173793.

Carazo, P., Font, E., 2010. Putting information back into biological communication. J. Evol. Biol. 23 (4), 661–669. https://doi.org/10.1111/j.1420-9101.2010.01944.x.

Chater, N., Reali, F., Christiansen, M.H., 2009. Restrictions on biological adaptation in language evolution. Proc. Natl. Acad. Sci. USA 106 (4), 1015–1020. https://doi.org/10.1073/pnas.0807191106.

Coderre, E.L., Cohn, N., Slipher, S.K., Chernenok, M., Ledoux, K., Gordon, B., 2018. Visual and linguistic narrative comprehension in autism spectrum disorders: neural evidence for modality-independent impairments. Brain Lang. 186, 44–59. https://doi.org/10.1016/j.bandl.2018.09.001.

Cohn, N., 2020. Your brain on comics: a cognitive model of visual narrative comprehension. Topics Cognit. Sci. 12 (1), 352–386. https://doi.org/10.1111/tops.12421.

Coolidge, F.L., Wynn, T., 2019. The second cognitive Rubicon in stone-knapping: late Acheulean handaxes. In: Conference "Retuning Cognition with a Pair of Rocks: Culture, Evolution, Technology". Center for Philosophy of Science, Cathedral of Learning, University of Pittsburgh, Pittsburg.

Coolidge, F.L., Wynn, T., 2020. The evolution of working memory. Année Psychol. 120 (2), 103–134. https://doi.org/10.3917/anpsy1.202.0103.

Corballis, M.C., 2017. The Truth about Language: what it Is and where it Came from. University of Chicago Press, Chicago. https://doi.org/10.1080/01434632.2019.1653426.

Corballis, M.C., 2018. Precursors to language. Topoi 37, 297–305. https://doi.org/10.1007/s11245-016-9418-8.

Culbertson, J., Kirby, S., 2016. Simplicity and specificity in language: domain-general biases have domain-specific effects. Front. Psychol. 6, 1964. https://doi.org/10.3389/fpsyg.2015.01964.

Dawkins, R., Krebs, J.R., 1978. Animal signals: information or manipulation. In: Krebs, J.R., Davies, N.B. (Eds.), Behavioural Ecology: an Evolutionary Approach. Blackwell Scientific, Oxford, pp. 282–309.

De Graaf, A., Hoeken, H., Sanders, J., Beentjes, J.W., 2012. Identification as a mechanism of narrative persuasion. Commun. Res. 39 (6), 802–823. https://doi.org/10.1177/0093650211408594.

Dick, A.S., Overton, W.F., Kovacs, S.L., 2005. The development of symbolic coordination: representation of imagined objects, executive function, and theory of mind. J. Cognit. Dev. 6 (1), 133–161. https://doi.org/10.1207/s15327647jcd0601_8.

Diehl, J.J., Bennetto, L., Young, E.C., 2006. Story recall and narrative coherence of high-functioning children with autism spectrum disorders. J. Abnorm. Child Psychol. 34 (1), 83–98. https://doi.org/10.1007/s10802-005-9003-x.

Dodwell, K., Bavin, E.L., 2008. Children with specific language impairment: an investigation of their narratives and memory. Int. J. Lang. Commun. Disord 43 (2), 201–218. https://doi.org/10.1080/13682820701366147.

Donald, M., 1991. Origins of the Modern Mind: Three Stages in the Evolution of Human Culture. Harvard University Press, Cambridge.

Donald, M., 2012. The mimetic origins of language. In: Gibson, K.R., Tallerman, M. (Eds.), The Oxford Handbook of Language Evolution. Oxford University Press, Oxford. https://doi.org/10.1093/oxfordhb/9780199541119.013.0017.

Dore, R.A., Amendum, S.J., Golinkoff, R.M., Hirsh-Pasek, K., 2018. Theory of mind: a hidden factor in reading comprehension? Educ. Psychol. Rev. 30 (3), 1067–1089 https://doi.org/10.1007/s10648-018-9443-9.

Fabbri-Destro, M., Gizzonio, V., Bazzini, M.C., Cevallos, C., Cheron, G., Avanzini, P., 2019. The relationship between pantomime execution and recognition across typically developing and autistic children. Research in Autism Spectrum Disorders 61, 22–32. https://doi.org/10.1016/j.rasd.2019.01.008.

Ferretti, F., 2022. L'istinto persuasivo. Come e perché gli umani hanno iniziato a raccontare storie. Carocci editore, Roma.

Ferretti, F., 2021. The narrative origins of language. In: Lock, A., Sinha, C., Gontier, N. (Eds.), Oxford Handbook on Human Symbolic Evolution. Oxford University Press, Oxford, UK. https://doi.org/10.1093/oxfordhb/9780198813781.013.33.

Ferretti, F., 2016. The social brain is not enough: on the importance of the ecological brain for the origin of language. Front. Psychol. 7, 1138. https://doi.org/10.3389/fpsyg.2016.01138.

Ferretti, F., Adornetti, I., 2021. Persuasive conversation as a new form of communication in Homo sapiens. Philosophical Transactions of the Royal Society B 376 (1824), 20200196. https://doi.org/10.1098/rstb.2020.0196.

Ferretti, F., Adornetti, I., Chiera, A., 2022. Narrative pantomime: a protolanguage for persuasive communication. Lingua 271, 103247. https://doi.org/10.1016/j.lingua.2022.103247.

Ferretti, F., Adornetti, I., Chiera, A., Nicchiarelli, S., Valeri, G., Magni, R., et al., 2018. Time and narrative: an investigation of storytelling abilities in children with autism spectrum disorder. Front. Psychol. 9, 944. https://doi.org/10.3389/fpsyg.2018.00944.

Ferretti, F., Adornetti, I., Chiera, A., Nicchiarelli, S., Magni, R., Valeri, G., Marini, A., 2017. Mental Time Travel and language evolution: a narrative account of the origins of human communication. Lang. Sci. 63, 105–118. https://doi.org/10.1016/j.langsci.2017.01.002.

Ferstl, E.C., Neumann, J., Bogler, C., von Cramon, D.Y., 2008. The extended language network: a meta-analysis of neuroimaging studies on text comprehension. Hum. Brain Mapp. 29 (5), 581–593. https://doi.org/10.1002/hbm.20422.

Fodor, J.A., 1983. The Modularity of Mind. The MIT Press, Cambridge.

Fuster, J., 2008. The Prefrontal Cortex, fourth ed. Academic Press, London.

Gärdenfors, P., 2017. Demonstration and pantomime in the evolution of teaching. Front. Psychol. 8, 415. https://doi.org/10.3389/fpsyg.2017.00415.

Gärdenfors, P., 2021. Demonstration and pantomime in the evolution of teaching and communication. Lang. Commun. 80, 71–79. https://doi.org/10.1016/j.langcom.2021.06.001.

Gerrig, R.J., 2010. Readers' experiences of narrative gaps. Storyworlds J. Narrat. Stud. 2 (1), 19–37. https://www.jstor.org/stable/10.5250/storyworlds.2.1.19.

Green, M.C., Brock, T.C., 2000. The role of transportation in the persuasiveness of public narratives. J. Pers. Soc. Psychol. 79 (5), 701. https://doi.org/10.1037/0022-3514.79.5.701.

Guajardo, N.R., Watson, A.C., 2002. Narrative discourse and theory of mind development. J. Genet. Psychol. 163 (3), 305–325. https://doi.org/10.1080/00221320209598686.

Gustafson, A., Ballew, M.T., Goldberg, M.H., Cutler, M.J., Rosenthal, S.A., Leiserowitz, A., 2020. Personal stories can shift climate change beliefs and risk perceptions: the mediating role of emotion. Commun. Rep. 33 (3), 121–135. https://doi.org/10.1080/08934215.2020.1799049.

Haidle, M.N., 2010. Working-memory capacity and the evolution of modern cognitive potential: implications from animal and early human tool use. Curr. Anthropol. 51 (S1), S149–S166.

Happé, F.G., 1994. An advanced test of theory of mind: understanding of story characters' thoughts and feelings by able autistic, mentally handicapped, and normal children and adults. J. Autism Dev. Disord. 24 (2), 129–154. https://doi.org/10.1007/BF02172093.

Happé, F., Frith, U., Briskman, J., 2001. Exploring the cognitive phenotype of autism: weak "central coherence" in parents and siblings of children with autism: I. Experimental tests. J. Child Psychol. Psychiatry Allied Discip. 42 (3), 299–307. https://doi.org/10.1017/S0021963001006916.

Hawhee, D., 2011. Toward a bestial rhetoric. Philos. Rhetor. 44 (1), 81–87. https://doi.org/10.1353/par.2011.0007.

Herman, D., 2013. Storytelling and the Sciences of Mind. MIT Press, Cambridge. https://doi.org/10.7551/mitpress/9547.001.0001.

Hoeken, H., Sinkeldam, J., 2014. The role of identification and perception of just outcome in evoking emotions in narrative persuasion. J. Commun. 64 (5), 935–955. https://doi.org/10.1111/jcom.12114.

Hogrefe, K., Ziegler, W., Wiesmayer, S., Weidinger, N., Goldenberg, G., 2013. The actual and potential use of gestures for communication in aphasia. Aphasiology 27 (9), 1070–1089. https://doi.org/10.1080/02687038.2013.803515.

Hudson, J.A., Shapiro, L.R., 1991. From knowing to telling: the development of children's scripts, stories, and personal narratives. In: McCabe, A., Peterson, C. (Eds.), Developing Narrative Structure. Lawrence Erlbaum Associates, Hillsdale, pp. 89–136.

Igartua, J.J., Barrios, I., 2012. Changing real-world beliefs with controversial movies: processes and mechanisms of narrative persuasion. J. Commun. 62 (3), 514–531. https://doi.org/10.1111/j.1460-2466.2012.01640.x.

John, S.F., Lui, M., Tannock, R., 2003. Children's story retelling and comprehension using a new narrative resource. Can. J. Sch. Psychol. 18 (1–2), 91–113. https://doi.org/10.1177/082957350301800105.

Johnson-Laird, P.N., 1983. Mental Models: towards a Cognitive Science of Language, Inference, and Consciousness 6. Harvard University Press, Cambridge.

Jolliffe, T., Baron-Cohen, S., 1999. The strange stories test: a replication with high-functioning adults with autism or Asperger syndrome. J. Autism Dev. Disord. 29 (5), 395–406. https://doi.org/10.1023/A:1023082928366.

Jolliffe, T., Baron-Cohen, S., 2000. Linguistic processing in high-functioning adults with autism or Asperger's syndrome. Is global coherence impaired? Psychol. Med. 30 (5), 1169–1187 https://doi.org/10.1017/S003329179900241X.
Kano, F., Krupenye, C., Hirata, S., Tomonaga, M., Call, J., 2019. Great apes use self-experience to anticipate an agent's action in a false-belief test. Proc. Natl. Acad. Sci. USA 116 (42), 20904–20909. https://doi.org/10.1073/pnas.1910095116.
Kendeou, P., Bohn-Gettler, C., White, M.J., Van Den Broek, P., 2008. Children's inference generation across different media. J. Res. Read. 31 (3), 259–272. https://doi.org/10.1111/j.1467-9817.2008.00370.x.
Kim, Y.S.G., 2020. Theory of mind mediates the relations of language and domain-general cognitions to discourse comprehension. J. Exp. Child Psychol. 194, 104813. https://doi.org/10.1016/j.jecp.2020.104813.
Kim, Y.S.G., Dore, R., Cho, M., Golinkoff, R., Amendum, S.J., 2021. Theory of mind, mental state talk, and discourse comprehension: theory of mind process is more important for narrative comprehension than for informational text comprehension. J. Exp. Child Psychol. 209, 105181. https://doi.org/10.1016/j.jecp.2021.105181.
King, D., Dockrell, J.E., Stuart, M., 2013. Event narratives in 11–14 year olds with autistic spectrum disorder. Int. J. Lang. Commun. Disord 48 (5), 522–533. https://doi.org/10.1111/1460-6984.12025.
King, D., Dockrell, J., Stuart, M., 2014. Constructing fictional stories: a study of story narratives by children with autistic spectrum disorder. Res. Dev. Disabil. 35 (10), 2438–2449. https://doi.org/10.1016/j.ridd.2014.06.015.
Korkman, M., Kirk, U., Kemp, S., 2007. Nepsy-II. Pearson, San Antonio.
Kormos, J., Trebits, A., 2011. Working memory capacity and narrative task performance. In: Robinson, P. (Ed.), Second Language Task Complexity: Researching the Cognition Hypothesis of Language Learning and Performance. Benjamins, Amsterdam, pp. 267–285. https://doi.org/10.1075/tblt.2.17ch10.
Krupenye, C., Kano, F., Hirata, S., Call, J., Tomasello, M., 2016. Great apes anticipate that other individuals will act according to false beliefs. Science 354 (6308), 110–114. https://doi.org/10.1126/science.aaf8110.
Kuijper, S.J., Hartman, C.A., Bogaerds-Hazenberg, S., Hendriks, P., 2017. Narrative production in children with autism spectrum disorder (ASD) and children with attention-deficit/hyperactivity disorder (ADHD): similarities and differences. J. Abnorm. Psychol. 126 (1), 63. https://doi.org/10.1037/abn0000231.
Laland, K.N., Odling-Smee, J., Feldman, M.W., 2000. Niche construction, biological evolution, and cultural change. Behav. Brain Sci. 23 (1), 131–146. https://doi.org/10.1017/S0140525X00002417.
Laland, K.N., Boogert, N., Evans, C., 2014. Niche construction, innovation and complexity. Environ. Innov. Soc. Transit. 11, 71–86. https://doi.org/10.1016/j.eist.2013.08.003.
Lennox, L., Cermak, S.A., Koomar, J., 1988. Praxis and gesture comprehension in 4-, 5-, and 6-year-olds. Am. J. Occup. Ther. 42 (2), 99–104. https://doi.org/10.5014/ajot.42.2.99.
Lin, N., Yang, X., Li, J., Wang, S., Hua, H., Ma, Y., Li, X., 2018. Neural correlates of three cognitive processes involved in theory of mind and discourse comprehension. Cognit. Affect Behav. Neurosci. 18 (2), 273–283. https://doi.org/10.3758/s13415-018-0568-6.
Lopez, B., Leekam, S.R., Arts, G.R., 2008. How central is central coherence? Preliminary evidence on the link between conceptual and perceptual processing in children with autism. Autism 12 (2), 159–171. https://doi.org/10.1177/1362361307086662.
Loschky, L.C., Larson, A.M., Smith, T.J., Magliano, J.P., 2020. The scene perception & event comprehension theory (SPECT) applied to visual narratives. Topics in cognitive science 12 (1), 311–351. https://doi.org/10.1111/tops.12455.
Lynch, J.S., Van Den Broek, P., Kremer, K.E., Kendeou, P., White, M.J., Lorch, E.P., 2008. The development of narrative comprehension and its relation to other early reading skills. Read. Psychol. 29 (4), 327–365. https://doi.org/10.1080/02702710802165416.
Mar, R.A., 2011. The neural bases of social cognition and story comprehension. Annu. Rev. Psychol. 62 (1), 103–134. https://doi.org/10.1146/annurev-psych-120709-145406.
Marini, A., Ferretti, F., Chiera, A., Magni, R., Adornetti, I., Nicchiarelli, S., Vicari, S., Valeri, G., 2019. Episodic future thinking and narrative discourse generation in children with Autism Spectrum Disorders. J. Neurolinguistics 49, 178–188. https://doi.org/10.1016/j.jneuroling.2018.07.003.
Mason, R.A., Just, M.A., 2009. The role of the theory of mind cortical network in the comprehension of narratives. Lang. Linguist. Compass 3 (1), 157–174. https://doi.org/10.1111/j.1749-818X.2008.00122.x.
Mazzocco, P.J., Green, M.C., Sasota, J.A., Jones, N.W., 2010. This story is not for everyone: transportability and narrative persuasion. Soc. Psychol. Personal. Sci. 1 (4), 361–368. https://doi.org/10.1177/1948550610376600.
McBride, G., 2014. Storytelling, behavior planning, and language evolution in context. Front. Psychol. 5, 1131. https://doi.org/10.3389/fpsyg.2014.01131.
McNeill, D., 2005. Introduction. In: McNeill, D. (Ed.), Language and Gesture. Cambridge University Press, Cambridge, pp. 1–12.
McNeill, D., 2012. How Language Began: Gesture and Speech in Human Evolution. Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9781139108669.
Minshew, N.J., Goldstein, G., Siegel, D.J., 1995. Speech and language in high-functioning autistic individuals. Neuropsychology 9 (2), 255–261. https://doi.org/10.1037/0894-4105.9.2.255.
Miyake, A., Friedman, N.P., Emerson, M.J., Witzki, A.H., Howerter, A., Wager, T.D., 2000. The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: a latent variable analysis. Cognit. Psychol. 41 (1), 49–100. https://doi.org/10.1006/cogp.1999.0734.
Montgomery, J.W., Polunenko, A., Marinellie, S.A., 2009. Role of working memory in children's understanding spoken narrative: a preliminary investigation. Appl. Psycholinguist. 30 (3), 485–509. https://doi.org/10.1017/S0142716409090249.
Nicolopoulou, A., 2008. The elementary forms of narrative coherence in young children's storytelling. Narrat. Inq. 18 (2), 299–325. https://doi.org/10.1075/ni.18.2.07nic.
Norbury, C.F., Bishop, D.V., 2002. Inferential processing and story recall in children with communication problems: a comparison of specific language impairment, pragmatic language impairment and high-functioning autism. Int. J. Lang. Commun. Disord 37 (3), 227–251. https://doi.org/10.1080/13682820210136269.
Nowell, A., 2010. Working memory and the speed of life. Curr. Anthropol. 51 (S1), S121–S133.
Nuske, H.J., Bavin, E.L., 2015. Narrative comprehension in 4–7-year-old children with autism: testing the Weak Central Coherence account. Int. J. Lang. Commun. Disord 46, 108–119. https://doi.org/10.3109/13682822.2010.484847.
Oatley, K., 1999. Meeting of minds: dialogue, sympathy, and identification in reading fiction. Poetics 28 (5–6), 439–454. https://doi.org/10.1016/S0304-422X(99)00011-X.
Oller, D.K., Dale, R., Griebel, U., 2016. New frontiers in language evolution and development. Topics Cognit. Sci. 8 (2), 353–360. https://doi.org/10.1111/tops.12204.
O'Reilly, A.W., 1995. Using representations: comprehension and production of actions with imagined objects. Child Dev. 66 (4), 999–1010. https://doi.org/10.1111/j.1467-8624.1995.tb00918.x.
Orsini, A., Picone, L., 2006. WISC-III. Contributo Alla Taratura Italiana. Giunti Organizzazioni Speciali, Firenze.
Owren, M.J., Rendall, D., Ryan, M.J., 2010. Redefining animal signaling: influence versus information in communication. Biol. Philos. 25 (5), 755–780. https://doi.org/10.1007/s10539-010-9224-4.
Paris, A.H., Paris, S.G., 2003. Assessing narrative comprehension in young children. Read. Res. Q. 38 (1), 36–76. https://doi.org/10.1598/RRQ.38.1.3.
Parrish, A.C., 2014. Adaptive Rhetoric. Evolution, Culture, and the Art of Persuasion. Routledge, New York. https://doi.org/10.4324/9781315852218.
Parrish, A.C., 2021. The sensory modes of animal rhetorics. A Hoot in the Light. Palgrave Macmillan, London. https://doi.org/10.1007/978-3-030-76712-9.
Pelletier, J., Beatty, R., 2015. Children's understanding of Aesop's fables: relations to reading comprehension and theory of mind. Front. Psychol. 6, 1448. https://doi.org/10.3389/fpsyg.2015.01448.
Peterson, C., McCabe, A., 1991. Linking children's connective use and narrative macrostructure. In: McCabe, A., Peterson, C. (Eds.), Developing Narrative Structure. Lawrence Erlbaum Associates, Hillsdale, pp. 29–53.

Pinker, S., 1997. How the Mind Works. Norton, New York.
Perelman, C., Olbrechts-Tyteca, L., 1958. Classicisme et romantisme dans l'argumentation. In: Revue internationale de philosophie, vols. 47–57. https://www.jstor.org/stable/23940182.
Plaisted, K., 2001. Reduced generalization in autism: an alternative to weak central coherence. In: Burack, J., Charman, T., Yirmiya, N., Zelazo, P. (Eds.), The Development of Autism: Perspectives from Theory and Research. Erlbaum, Mahwah.
Radvansky, G.A., Copeland, D.E., 2001. Working memory and situation model updating. Mem. Cognit. 29 (8), 1073–1080. https://doi.org/10.3758/BF03206375.
Radvansky, G.A., Zacks, J.M., 2014. Event Cognition. Oxford University Press, Oxford. https://doi.org/10.1093/acprof:oso/9780199898138.001.0001.
Raven, J.C., 1938. Progressive Matrices: a Perceptual Test of Intelligence. H.K. Lewis, London.
Read, D.W., Manrique, H.M., Walker, M.J., 2022. On the working memory of humans and great apes: strikingly similar or remarkably different? Neurosci. Biobehav. Rev. 134, 104496 https://doi.org/10.1016/j.neubiorev.2021.12.019.
Reese, E., Haden, C.A., Baker-Ward, L., Bauer, P., Fivush, R., Ornstein, P.A., 2011. Coherence of personal narratives across the lifespan: a multidimensional model and coding method. J. Cognit. Dev. 12 (4), 424–462. https://doi.org/10.1080/15248372.2011.587854.
Rendall, D., Owren, M.J., Ryan, M.J., 2009. What do animal signals mean? Anim. Behav. 78 (2), 233–240 https://doi.org/10.1016/j.anbehav.2009.06.007.
Rosenthal, E.N., Riccio, C.A., Gsanger, K.M., Jarratt, K.P., 2006. Digit Span components as predictors of attention problems and executive functioning in children. Arch. Clin. Neuropsychol. 21 (2), 131–139. https://doi.org/10.1016/j.acn.2005.08.004.
Scarantino, A., 2013. Animal communication as influence-mediated influence. In: Stegmann, U. (Ed.), Animal Communication Theory: Information and Influence. Cambridge University Press, New York, pp. 63–87.
Schreiner, C., Appel, M., Isberner, M.B., Richter, T., 2018. Argument strength and the persuasiveness of stories. Discourse Process 55 (4), 371–386. https://doi.org/10.1080/0163853X.2016.1257406.
Scott-Phillips, T., 2014. Speaking Our Minds: Why Human Communication Is Different, and How Language Evolved to Make it Special. Palgrave Macmillan, New York, NY.
Scott-Phillips, T., Heintz, C., 2023. Animal communication in linguistic and cognitive perspective. Annu. Rev. Linguist. 9, 93–111. https://doi.org/10.1146/annurev-linguistics-030421-061233.
Segovia-Martin, J., Balari, S., 2020. Eco-evo-devo and iterated learning: towards an integrated approach in the light of niche construction. Biol. Philos. 35 (4), 1–23. https://doi.org/10.1007/s10539-020-09761-3.
Seyfarth, R.M., Cheney, D.L., Bergman, T., Fischer, J., Zuberbühler, K., Hammerschmidt, K., 2010. The central importance of information in studies of animal communication. Anim. Behav. 80 (1), 3–8. https://doi.org/10.1016/j.anbehav.2010.04.012.
Sibierska, M., 2017. Storytelling without telling: the non-linguistic nature of narratives from evolutionary and narratological perspectives. Lang. Commun. 54, 47–55. https://doi.org/10.1016/j.langcom.2016.10.005.
Spelke, E.S., Kinzler, K.D., 2007. Core knowledge. Dev. Sci. 10 (1), 89–96. https://doi.org/10.1111/j.1467-7687.2007.00569.x.
Spencer, J.P., Blumberg, M.S., McMurray, B., Robinson, S.R., Samuelson, L.K., Tomblin, J.B., 2009. Short arms and talking eggs: why we should no longer abide the nativist–empiricist debate. Child Dev. Perspect. 3 (2), 79–87. https://doi.org/10.1111/j.1750-8606.2009.00081.x.
Sperber, D., Origgi, G., 2010. A pragmatic account of the origin of language. In: Larson, R.K., Déprez, V., Yamakido, H. (Eds.), The Evolution of Human Language: Biolinguistic Perspectives. Cambridge Univ. Press, Cambridge, UK, pp. 124–131.
Sperber, D., Wilson, D., 1986. Relevance: Communication and Cognition. Harvard University Press, Cambridge.
Stein, N.L., 1988. The development of children's storytelling skill. In: Franklin, M.B., Barten, S. (Eds.), Child Language: A Reader. Oxford University Press, New York.
Stout, D., Hecht, E., Khreisheh, N., Bradley, B., Chaminade, T., 2015. Cognitive demands of lower paleolithic toolmaking. PLoS One 10 (4), e0121804. https://doi.org/10.1371/journal.pone.0121804.
Sultan, S.E., 2021. Eco-evo-devo. In: Nuño de la Rosa, L., Müller, G.B. (Eds.), Evolutionary Developmental Biology. Springer, Cham. https://doi.org/10.1007/978-3-319-32979-6_42.
Tager-Flusberg, H., Sullivan, K., 1995. Attributing mental states to story characters: a comparison of narratives produced by autistic and mentally retarded individuals. Appl. Psycholinguist. 16 (3), 241–256. https://doi.org/10.1017/S0142716400007281.
Tomasello, M., 2008. Origins of Human Communication. MIT Press, Cambridge. https://doi.org/10.7551/mitpress/7551.001.0001.
Trabasso, T., Stein, N.L., Rodkin, P.C., Munger, M.P., Baughn, C.R., 1992. Knowledge of goals and plans in the on-line narration of events. Cognit. Dev. 7 (2), 133–170. https://doi.org/10.1016/0885-2014(92)90009-G.
Urgesi, C., Campanella, F., Fabbro, F., 2011. NEPSY-II (Italian Standardization). Giunti, Firenze.
van den Broek, P., Lynch, J.S., Naslund, J., Ievers-Landis, C.E., Verduin, K., 2003. The development of comprehension of main ideas in narratives: evidence from the selection of titles. J. Educ. Psychol. 95 (4), 707–718. https://doi.org/10.1037/0022-0663.95.4.707.
Van Dijk, T.A., Kintsch, W., 1983. Strategies of Discourse Comprehension. Academic Press, New York.
van Nispen, K., van de Sandt-Koenderman, W.M., Krahmer, E., 2017. Production and comprehension of pantomimes used to depict objects. Front. Psychol. 8, 1095. https://doi.org/10.3389/fpsyg.2017.01095.
Veraksa, A., Bukhalenkova, D., Kartushina, N., Oshchepkova, E., 2020. The relationship between executive functions and language production in 5–6-year-old children: insights from working memory and storytelling. Behav. Sci. 10 (2), 52. https://doi.org/10.3390/bs10020052.
Ward, C.M., Rogers, C.S., Van Engen, K.J., Peelle, J.E., 2016. Effects of age, acoustic challenge, and verbal working memory on recall of narrative speech. Exp. Aging Res. 42 (1), 97–111. https://doi.org/10.1080/0361073X.2016.1108785.
Wechsler, D., 1993. Manual for the Wechsler Intelligence Scale for Children-III. Psychological Corporation, San Antonio.
Werner, H., Kaplan, B., 1963. Symbol Formation. Wiley, New Jersey.
Wurm, M.F., Artemenko, C., Giuliani, D., Schubotz, R.I., 2017. Action at its place: contextual settings enhance action recognition in 4- to 8-year-old children. Dev. Psychol. 53 (4), 662–670. https://doi.org/10.1037/dev0000273.
Yuan, Y., Major-Girardin, J., Brown, S., 2018. Storytelling is intrinsically mentalistic: a functional magnetic resonance imaging study of narrative production across modalities. J. Cognit. Neurosci. 30 (9), 1298–1314. https://doi.org/10.1162/jocn_a_01294.
Zlatev, J., 2014. Human uniqueness, bodily mimesis and the evolution of language. Humana Mente. J. Philos. Stud. 27 (7), 197–219.
Zlatev, J., Zywiczyński, P., Wacewicz, S., 2020. Pantomime as the original human-specific communicative system. J. Lang. Evolution 5 (2), 156–174. https://doi.org/10.1093/jole/lzaa006.
Zwaan, R.A., Radvansky, G.A., 1998. Situation models in language comprehension and memory. Psychol. Bull. 123 (2), 162. https://doi.org/10.1037/0033-2909.123.2.162.
Zywiczyński, P., Wacewicz, S., Sibierska, M., 2018. Defining pantomime for language evolution research. Topoi 37 (2), 307–318. https://doi.org/10.1007/s11245-016-9425-9.