

Constraints on communicating the order of events in stories through pantomime

Marta Sibierska^{1,2}, Przemysław Żywicznyński¹, Jordan Zlatev²,

Joost van de Weijer³, Monika Boruta-Żywicznyńska¹

¹ Centre for Language Evolution Studies, Nicolaus Copernicus University in Toruń, Poland,

address: Collegium Maius, Room 26,

ul. Fosa Staromiejska 3, 87-100 Toruń, Poland

² Division for Cognitive Semiotics, Lund University, Sweden,

address: Helgonabacken 12, 221 00 Lund, Sweden

³ Humanities Lab, Lund University, Sweden,

address: Helgonabacken 12, 221 00 Lund, Sweden

Corresponding author: Marta Sibierska, sibier@umk.pl

Declarations of interest: none.

Abstract

Pantomime is a means of bodily-visual communication that is based on iconic gestures that are not fully conventional. It has become a key element in many models of language evolution and a strong candidate for the original human-specific communicative system (Zlatev et al. 2020). Although pantomime affords successful communication in many contexts, it has some semiotic limitations. In this study, we looked at one of them, connected with communicating the order of events in stories. We assumed that pantomime is well-suited for communicating simple stories, where events are arranged in a chronological order, and less so for communicating complex stories, where events are arranged in a non-chronological order. To test this assumption, we designed a semiotic game in which participants took turns as directors and matchers. The task of the directors was to mime a story in one of two conditions (chronological or non-chronological); the task of the matchers was to interpret what was mimed. The results showed that the chronological condition was easier for the participants. In the non-chronological condition, we observed that initially poor communicative success improved as the participants started to use various markers of event order. The results of our study provide an insight into the early stages of conventionalisation in bodily-visual communication, a potential first step towards protolanguage, possibly propelled by the need to convey chronologically complex stories.

Keywords: stories, gesture, pantomime, mimesis, iconicity, order of events, semiotic game, language evolution

1. Introduction

In recent years, pantomime has often been proposed as a likely candidate for “the original human-specific communicative system” (Zlatev et al., 2020): a stage in the evolution of human cognition and communication that depended on iconic (i.e. resemblance-based) gestures expressed with hands, arms, and the whole body, as well as other semiotic resources like vocalisations (cf. Żywiczyński et al., 2018). There are three lines of thought arguing for pantomime as a precursor to language that have become particularly influential. One is Donald’s theory of mimesis (1991; 2001; later e.g. Gärdenfors, 2017; Zlatev, 2014; Zlatev et al., 2020). A second is Arbib’s Mirror System Hypothesis (Arbib, 2005, 2012, 2016; Arbib et al., 2018), and a third is Tomasello’s (2008) proposal that language was bootstrapped by two types of “natural human gesture”: pointing and pantomiming. There are important differences between these positions, for example regarding the question of whether pantomime was accompanied by vocalisation (Zlatev et al., 2017; Zlatev et al. 2020) or not (Arbib, 2012, 2013). To some degree, it is possible to elicit a consensual understanding of pantomime, whereby it is dominated by non-vocal, mimetic and not fully conventionalised means of communication (cf. Arbib’s notion of *ad hoc pantomime*, 2012), which is executed by coordinated movements of the body.¹ Semiotically, individual pantomimes are iconic representations of actions or events which may be displaced from the here and now (cf. Gärdenfors’s notion of detachment, 2003; Żywiczyński et al., 2018). In contrast to non-human animal communication, pantomime is topically unconstrained; however, it is constrained in some other respects, including the complexity of the information that is to be communicated (Itti & Arbib, 2006; Żywiczyński et al., 2021).

¹ Some definitions stress the point that pantomime tends to involve the movement of the whole body (e.g. Żywiczyński et al., 2018), on which the above definition is largely based on (but see Żywiczyński et al., 2021 for a more nuanced position), while others (notably, Arbib, 2012; Arbib, submitted) reject this requirement.

This view is supported with evidence from communication games (e.g. Zlatev et al., 2017), where participants use pantomime to show actions and changes of state, predominantly by means of “acting as if”, or the “enacting mode” (Müller, 2014; see Fig. 1).



Figure 1. An example of the action of running enacted by means of whole-body movements. The stills come from the video recordings collected in the present study.

In such studies, participants used pantomime to communicate events involving an Agent and a Patient (Zlatev et al., 2017; Żywicznyński et al., 2021; for a more general discussion of this capacity of pantomime, see Gärdenfors et al., 2018). For example, in a study by Zlatev and colleagues (2017), pantomime was used to communicate four transitive actions: “kissing”, “pushing”, “slapping”, and “waving”. In similar studies based on communication games (Galantucci & Garrod, 2011), typically, the repertoire of events communicated is contextually constrained by a closed meaning matrix. For instance, Żywicznyński and colleagues (2021) used a set of images out of which participants had to choose the one that had been mimed by an actor. As these studies show, pantomime can be successfully used to communicate not only single events, but also sequences of events that are causally connected (see Fig. 2; see also Ferretti, 2021; Gärdenfors, 2021).



Figure 2. An example of an event communicated by means of pantomime: a woman (the first tile) is eating a sandwich (the second tile), a monkey (the middle tile) steals the sandwich (the fourth tile), and the woman screams and waves her hand at the monkey (the fifth tile). The stills come from the video recordings collected in the present study.

Given that pantomime is based on iconic gestures, as stated at the onset, its comprehension does not rely on semiotic conventions, but on the resemblance between an expression and what it represents (see Fig. 3). This resemblance may reside in shared qualities (such as shape) as well as shared relations (such as positioning in space), corresponding to imagic (or imagistic) and diagrammatic iconicity, respectively (Jakobson, 1965; Peirce, 1974). A classic example of diagrammatic iconicity that has to do with linguistic temporality is that of “veni, vidi, vici”, where the order of the verbs reflects the natural order of the events. Thus, we interpret the famous sentence to mean: first, he came; second, he saw; third, he conquered (Simone, 1995; for a discussion of diagrammatic iconicity in connection with distance, see Devylder, 2018). Similar examples can be found in bodily-visual communication, for instance in signed languages (see e.g. Pietrandrea & Russo, 2007; Sallandre & Cuxac, 2001). Since pantomime is strongly based on iconicity, the order in which a sequence of events are shown can be expected to match the so-called *ordo naturalis*, so that if a person mimes a woman eating a sandwich, then a monkey stealing the sandwich, then the woman screaming at the monkey in anger (cf. Fig. 2), we would not assume that screaming happened before eating.

Pantomime is also prototypically a “performance”, a form of face-to-face interaction. As such, it unfolds in real time, one movement after another. It is thus often assumed (e.g. Kuhn & Schmid, 2013) that as long as pantomime is not, for instance, video-recorded and edited, it does not easily allow for doing away with the constraints of (diagrammatic) iconicity (Ryan, 2012; Żywicznyński et al., 2018: 311).



Figure 3. An example of an iconic hand gesture: the index finger and the middle finger are positioned to resemble the shape of a pair of scissors. As the resemblance is apparent, the gesture can be seen as based more on primary than on secondary iconicity. This still comes from the video recordings collected in the present study.

The temporally iconic character of bodily-visual communication is taken for granted to the extent that it is scarcely discussed in gesture studies. Instead, in the context of communication about temporal relations, attention is paid to gesture-speech correspondence for time metaphors and to the use of space for time references (see e.g. Burns et al., 2019). We know from these studies that in bodily-visual communication, it is possible to refer to different temporal planes, at least “the past”, “the present”, and “the future”, by means of meaning-making mechanisms other than iconicity itself. For instance, deixis (e.g. pointing), which is used, “to reference locations, items, or people in the world” (see e.g. Novack & Goldin-Meadow, 2017), offers some possibilities for referencing past or future events, regardless of the sequence of events shown. Deictic gestures can call for knowledge of cultural conventions connected with mapping time onto space, e.g. ordering events on a lateral axis (left to right, see e.g. Rodriguez, 2019: 7 for an example of a gesture used by a speaker of English to refer to a canonical ordering of events, with the past shown to the utmost left, the present in the middle, and the future shown to the utmost right) or a sagittal axis (back to front, see e.g. Núñez & Sweetser, 2006: 437 for an example of a gesture,

pointing forward, used by a speaker of Spanish to refer to the future; for a detailed analysis of the phenomenon see e.g. Casasanto & Jasmin, 2012; Cooperrider, Núñez & Sweetser, 2014). In principle it should be possible to incorporate the same or similar strategies for ordering and reordering events in pantomime.

There is at least one communicative context in which the ability to represent events in different orders is crucial: storytelling. At least since antiquity, the order of events has been discussed as an essential (e.g. Abbott, 2011) aspect of storytelling, with much emphasis put on its manipulations. For instance, Horace in his *Ars Poetica*, advised authors to begin stories “in the middle of things” (*in media res*) rather than start “from the egg” (*ab ovo*) (see e.g. Richardson, 2002: 1). Much later, narratologists such as Genette (2002) claimed that the most common way to tell a story is starting in the middle and then introducing some elucidatory analepses (i.e. explanatory flashbacks). The claim about anachrony of stories can also be identified, in different wording, in the works of other, both classical and cognitive, narratologists (see e.g. discussions on “dechronolisation” in Bremond, 1966; Greimas, 1966; “fictional time” in Ronen, 1994; “order” in Friedemann, 1910; Schmid, 2010; see also Herman, 2009; Sternberg, 2001). Importantly, distortions of a chronological order of events can be observed both in written or “regularised” oral stories (such as myths and folktales, whose contents and structures are to an extent fixed), as well as in casual, conversational storytelling, which is characterised by multiple “false starts” and “corrections” (see e.g. Norrick, 2007).

Storytelling is an essential component in all human cultures (see e.g. Boyd, 2009; Gottschall, 2012), and must have played a key role in the evolution of language, e.g. in the transition from mimetic to mythic culture, as per the theory of Donald (1991). But that does not exclude the emergence of “mimetic preverbal narratives” (Boyd, 2017: 2) even prior to the evolution of (proto)language. The question is about their complexity, and in particular their chronological complexity. Could stories expressed in pantomime, for example, start “in the middle of things”, reporting events in a non-chronological order? Or does this imply the

need to go beyond pantomime and introduce conventional (i.e. agreed upon, explicitly or implicitly) signs: symbols, and thus at least protolanguage (cf. Zlatev et al., submitted)?

To address these questions, we looked more closely at the constraints of pantomime on communicating events in a sequence in the context of storytelling. Based on the considerations outlined above, we assumed that pantomime would be suitable for communicating simple stories in which events are arranged chronologically. However, it would be less successful when people need to represent events in a non-chronological order, which is characteristic of more complex stories (Boyd, 2017; Zlatev et al., submitted). To test this hypothesis, we designed a study based on “semiotic games” (see e.g. Krauss & Winheimer, 1966; Fay et al., 2010; cf. Fay et al., 2013, 2014). Specifically, we adapted a referential communication task paradigm, where the participants are asked to communicate with each other in a specific medium (e.g. drawings, gestures, vocalisations), but without the use of spoken or written language. In a number of interactions, often referred to as “games” and/or “rounds”, the participants create novel conventions in order to communicate successfully (see e.g. Galantucci & Garrod, 2011). We invited participants to play a charades-like game, in which they had to use pantomime to communicate short stories to one another in two conditions: chronological and non-chronological. We expected that communicative success would be greater in the chronological condition than in the non-chronological condition (hypothesis 1). Further, we predicted that the participants would develop strategies to communicate a disruption of chronology, which would lead to increasing success in communication across successive games in the non-chronological condition (hypothesis 2). However, such strategies would involve introducing conventionalised signs, and thus transcending the borders of pantomime into protolanguage.

2. Study

2.1. Stimulus and procedure

52 participants (female = 35), whose mean age was 25.48 (SD = 6), were recruited from students and employees of Nicolaus Copernicus University in Toruń, Poland. They took part

in the experiment for course credit or remuneration in kind. The participants signed informed consents and GDPR statements and agreed to be video-recorded for the purposes of the study. They worked in 26 pre-formed pairs, in which they arranged themselves according to their preference. The experiment was conducted with the use of E-Prime 3.0 (Psychology Software Tools, 2016) stimulus presentation software, paired with two DELL screens, with resolution 1920 x 1080, placed on opposite sides of the experiment space. An experiment session consisted of four games, 12 rounds each. In each round, the two participants were positioned on opposite sides of the experiment space (see Fig. 4).

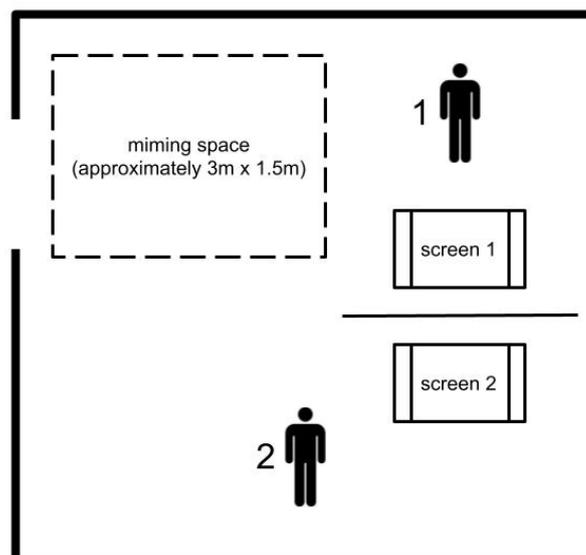


Figure 4. The initial position of the director is marked with number (1). After studying the input displayed on screen 1, the director moved into the miming space, which was marked out on the floor. The position of the matcher is marked with number (2). After watching the director, the matcher was shown possible answers to choose from on screen 2. The director and the matcher could not see each other's screens during the rounds.

One of the participants took on the role of the director, while the other one was the matcher.

First, the director was shown a verbal representation of a story in Polish on screen 1 (see Fig. 4) taken from the pool of 24 stories shown in Table 1. Each story consisted of three events. Half of the stories had a woman as the main character while the other half had a man as the main character. 12 stories contained transitive actions in the first event (e.g. eating, lifting, reading) and 12 stories contained intransitive actions in the first event (e.g.

jogging, swimming, walking). The contents of the stories differed: nine stories had only one character while the remaining 15 stories had two. Six stories included an animal (e.g. a bear, a monkey, a shark) and 16 stories included a prop (e.g. a bottle, a razor, a stone).

Table 1

The pool of all stories used in the study, here translated from Polish into English.

story ID	event 1	event 2	event 3
bear	A man opened a door.	He saw a bear.	He ran away
newspaper	A man was reading a newspaper.	He saw some shocking news.	He screamed in surprise.
pin	A man put a pin on a chair.	A woman sat down on the chair.	She jumped off the chair, screaming.
rope	A man was pulling a rope.	A woman cut the rope with scissors.	The man fell back.
roof	A man was climbing a ladder.	Wind blew away the ladder.	He was left hanging from the roof.
weights	A man was lifting weights.	A butterfly sat on the bar.	He was crushed by the bar.
fish	A man was fishing.	A fish pulled the fishing rod very hard.	He fell into the water.
apple	A man reached for an apple on a tree.	The apple was bad.	The man was sad.
stumble	A man was jogging.	A woman waved at him.	He stumbled.
shave	A man was shaving.	He cut his neck with the razor.	He put a sticking plaster on his neck.
hammer	A man was hammering.	He smashed his fingers.	He screamed.
sleep	A man was sleeping.	A woman cried.	He woke up with a start.
ball	A woman kicked a ball.	The ball hit a man.	He shouted in pain.
sandwich	A woman was eating a sandwich.	A monkey stole her sandwich.	She was angry.
balloon	A woman was blowing a balloon.	A man pierced the balloon with a needle.	She shouted with anger.
axe	A woman was chopping wood.	A log fell on her foot.	She screamed.
stone	A woman threw a stone.	The stone broke a window.	She hid behind a tree.
potato	A woman was peeling a potato.	The potato slipped from her hand.	The woman cut her hand.
sneeze	A woman was walking in the park.	She picked up and smelt a flower.	She sneezed.
shark	A woman was swimming.	She saw a shark.	She jumped out of the water screaming.

drink	A woman was drinking from a bottle.	A man patted her on the shoulder.	She choked up.
purse	A woman was walking with her purse.	A thief snatched the purse.	She shouted and waved her fist.
wet	A woman was walking down the street.	A man poured water out of the window.	She got all wet.
car	A woman was driving.	She saw a bear on the road.	She braked the car hard.

In the chronological condition, the story was arranged into two or three separate sentences, with the third event expressed at the end. In the non-chronological condition, the story started with the third event, and then a subordinate clause including the Polish equivalent of the word “because” (“ponieważ”) introduced events one and two (see Table 2).

Table 2

An example of the same story represented verbally in the two conditions.

chronological condition		non-chronological condition	
event 1	A man reached for an apple on a tree.	event 3	A man was sad
event 2	The apple was bad.	event 1	because when he reached for an apple on a tree,
event 3	The man was sad.	event 2	he found out that the apple was bad.

In each game, there were six stories in the chronological condition and another six in the non-chronological condition. The stories as well as their order were randomly selected by the software for each game. The same story could not appear twice in the same game, but it could re-appear in successive games. After reading the story, the director was to communicate it to the matcher in a pre-specified space, where they were visible to the matcher on the opposite side of the room (see Fig. 4), and, at the same time, video-recorded with a Panasonic HC-V700 camera mounted on a tripod. The director was instructed to use whole-body movement and not to use speech or non-verbal vocalisations (though some participants spontaneously deviated from the instructions and produced various sounds).

After watching the director, the matcher was presented with four comic strips displayed on screen 2 (see Fig. 4). The strips were placed from top to bottom and read from left to right. One of the strips matched the story from the director's input in the same order. One of the other three corresponded to the story that was being communicated, but in the opposite order, and two corresponded to one of the other stories in two different orders (see Fig. 5), randomly selected for each round by the software. The order in which the comic strips were displayed to the matcher was also randomised.



Figure 5. An example of the matcher's input. Strip 1 corresponds to story ID "balloon" in the chronological condition; strip 2 corresponds to story ID "apple" in the non-chronological condition; strip 3 corresponds to story ID "apple" in the chronological condition; and strip 4 corresponds to story ID "balloon" in the non-chronological condition (for stories ID, see Table 1).

The task of the matcher was to choose the alternative that corresponded to the story that was being communicated by the director through pantomime. After the matcher made their choice, both participants saw a smiling face for a correct match or a sad face for an incorrect match. The visual feedback was supported with verbal feedback from the experimenter ("correct answer" or "incorrect answer"). Then, the participants switched roles, moving on to

the next round. At the end of each game, they also got verbal feedback from the experimenter on their total score for this game. Communicative success was operationalised as the accuracy of the matchers' responses. We recorded 1248 of responses in total: 624 in the chronological condition and 624 in the non-chronological condition, which translates into 156 responses in each of the games in each of the conditions.

2.2. Coding

As stated at the end of Section 1, we hypothesised that in an interactive setting, the participants would start to communicate a disruption in chronology by e.g. inventing markers of event order (for a more detailed discussion of these, see Zlatev et. al., submitted). Based on a viewing of a random selection of ten video recordings, we developed a list of such markers. For example, the director could simply enact the events in a non-chronological order, where “enacting” means mapping the director’s body onto the body of a character from the story and acting as if they were the character (see Müller, 2014; Zlatev et al., 2020). The director could also use a metaphorical gesture or a series of gestures to refer to the past in the space behind them; to enumerate the conditions or to enumerate the events; or to attract the matcher’s attention (see Fig. 6 A–C).



Figure 6. A. A model example of a marker used to refer to order of events on a sagittal axis and show the metaphorical past in the space behind the director.



Figure 6. B. A model example of a marker used to enumerate the events from the story, from 1 to 3.



Figure 6. C. A model example of a marker used to draw the matcher's attention by hand waving.

We employed two expert coders, independent of the main researchers involved in the study, to code the presence or absence of markers of event order in all 1248 video recordings.

First, the coders worked independently and, then, compared the results of their work. There was a substantial agreement between the coders, kappa = 0.77 (95% CI, 0.73 to 0.81), $p = 0.000$. The final version of the coding was created on the basis of consensus. There was no unsettled disagreement between the coders.

3. Results

Table 3 shows accuracy counts and proportions as well as counts and proportions of marker use by the participants. Overall, the accuracy in the chronological condition was very high. Accuracy in the non-chronological condition, on the contrary, was very low in the first game but improved gradually across the subsequent three games. The table also shows a similar pattern in the use of event order markers by the participants. In the chronological condition, the frequencies of event order marker use were comparatively low across the four games. The corresponding frequencies in the non-chronological condition were higher already at the first game and continued to increase after that. Together, these patterns suggest a positive association between the use of the markers of event order and the success with which the directors were able to communicate the content of the stories to the matchers. That is, the correct identification of stories that were presented in a non-chronological order improved if the event order was marked by the director, but for the stories presented in chronological order the markers did not have any effect.

Table 3

Distributions (counts and proportions) of correct matches and event order marker use.

	condition	game 1	game 2	game 3	game 4	total
accuracy	chronological	150 (.96)	138 (.88)	150 (.96)	146 (.94)	584 (.94)
	non-chronological	13 (.08)	28 (.18)	71 (.46)	99 (.63)	211 (.34)
	total	163 (.52)	166 (.53)	221 (.71)	245 (.79)	795 (.64)
event order markers	chronological	17 (.11)	25 (.16)	28 (.18)	26 (.17)	96 (.15)
	non-chronological	47 (.30)	69 (.44)	95 (.61)	114 (.73)	325 (.52)
	total	64 (.21)	94 (.30)	123 (.39)	140 (.45)	421 (.34)

We analysed the data with the use of R Statistical Software (version 4.1.1; RStudio Team 2019) and the lme4 package (Bates et al., 2015). We ran a series of mixed effects logistic regression models to test the effects of “condition”, “game”, and “marker” on

response accuracy. Pairs of participants were included as a random effect. A series of nested models of increasing complexity was created. The simplest of these included only an intercept. After that, the predictors were added one by one to subsequent models, first as main effects, then as two-way interactions. The most complex model that was significantly better than its predecessor (likelihood ratio test, $\chi^2 = 34.06$, $df = 1$, $p = 0.000$) contained the three main effects and two two-way interactions between game and marker and between condition and marker.

Figure 7 shows the predicted proportions with 95% confidence intervals from this model. The figure adds to the observations that were made on the basis of the values in Table 3. Overall, the proportions of correct answers to chronological stories were much higher (near ceiling) than those to non-chronological stories. However, when the order of the events was marked by the directors in non-chronological stories performance was better already during the first game and continued to improve over the next three games.

Given the significance of the two-way interactions we compared the effects of order marker within each game in the chronological condition and in the non-chronological condition. The comparisons were done using the multcomp R-package (Hothorn, Bretz and Westfall, 2008). The p -values reported below have been adjusted for multiple comparisons. Within the chronological condition, the effect of marker was significant for game 1 ($B = 1.763$, $SE = 0.549$, $z = 3.209$, $p = 0.010$), but not for games 2 ($B = 0.442$, $SE = 0.506$, $z = 0.874$, $p = 0.928$), 3 ($B = 0.009$, $SE = 0.592$, $z = 0.015$, $p = 1.000$) or 4 ($B = -0.474$, $SE = 0.615$, $z = -0.770$, $p = 0.957$). Within the non-chronological condition, the difference was significant for games 1 ($B = -1.774$, $SE = 0.474$, $z = -3.742$, $p = 0.001$), 2 ($B = -3.095$, $SE = 0.477$, $z = -6.491$, $p = 0.000$), 3 ($B = -3.528$, $SE = 0.468$, $z = -7.541$, $p = 0.000$), and 4 ($B = -4.010$, $SE = 0.510$, $z = -7.864$, $p = 0.000$).

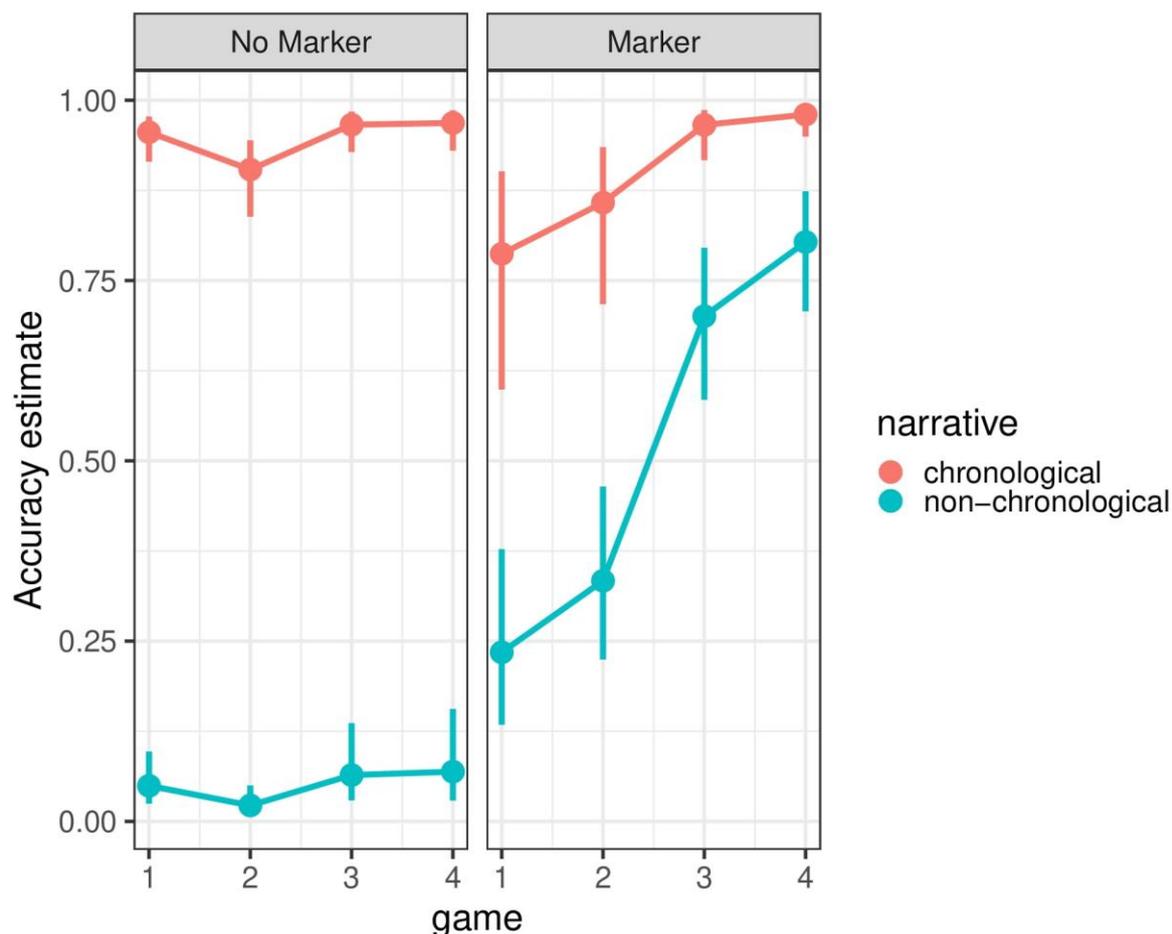


Figure 7. Predicted proportions of correct matches.

4. Discussion

The results supported both hypotheses. First, pantomimes of chronologically ordered events had a much higher communicative success (near ceiling) than pantomimes of non-chronologically ordered events. This result presents what is possibly the first empirical support for the assumption about the constraint for temporally iconic event representation in stories expressed through pantomime (see Section 1). This implies that pantomime is an effective means of communicating simple stories and is less suitable for complex ones (see Zlatev et al., submitted).

As for the second hypothesis, the analysis of pantomimes in the non-chronological condition showed a significant increase in accuracy of the matchers' responses in the course of the experiment session. The communicative success of pantomimes in the non-chronological condition that contained markers of event order was significantly higher in the

first game than that of the pantomimes in the non-chronological condition that did not contain them. When markers of event order were used, accuracy increased significantly across the four games. In contrast, the accuracy of interpreting pantomimes in the non-chronological condition that did not contain such markers stayed low throughout the four games.

We also observed an interesting pattern in the chronological condition, depending on whether they contained markers of event order or not: the communicative success of pantomimes without markers remained at a ceiling level across the games, while that of pantomimes with markers in the first game was significantly lower than the success of the corresponding pantomimes that did not make use of markers. When event order markers were present, the result improved in the second game and increased significantly in the third game, reaching the ceiling level. This observation suggests that when we add information (in the form of a marker of event order) about the chronological order of events in the chronological condition, this may lead to confusing the chronological and non-chronological conditions and creating noise (see “semantic noise” in Jandt, 2017: 82–83; cf. “internal noise” in Shannon & Weaver, 1949; Hockett, 1952).

To sum up, the interplay between the order in which events are mimed and the use of markers of event order indicates that for the participants of this study, the optimal strategies for successful communication in the two conditions were in opposition to one another: in the chronological condition not to use markers, and in the non-chronological condition to use markers of event order. The way in which markers of event order were used by the participants of the present study ties in with findings from research on the emergence of conventionalised signs in bodily-visual communication. Both experimental studies on improvised gestural communication (e.g. Motamedi et al., 2019; Motamedi et al., 2021) as well as research on emerging signed languages and homesign (e.g. Goldin-Meadow, 2003; Goldin-Meadow et al., 2014; Senghas et al., 2004) suggest that such symbolic (i.e. conventionalised) signs emerge gradually, in the course of horizontal and vertical transmission. In our study, we could observe an introduction of a symbolic sign at a very early stage, when a specific use of movement for communicative purposes (a marker of

event order) stabilised (cf. “usualisation” in Schmid, 2015) in at least one of the participants and was successfully understood by their partner. This can be interpreted as a first step in successful transmission that leads to the emergence of language-like structures (e.g. Motamedi et al., 2019) or protolanguage (Zlatev et al., submitted).

Further, the results of our study can be interpreted in the context of the early stages of compositionality in a communicative system. Compositionality allows for arranging simple units into more complex ones, whereby the meaning of the whole depends on the meaning of its parts. In signed languages, compositionality has to do with combining the parameters of movements (e.g. the positioning of a body part) as well as combining movements as units (see e.g. Pleyer et al., 2022). Silent gestures and signs of signed languages at an early stage tend to be more holistic and become more and more compositional in later generations of participants (e.g. Kirby et al., 2022) or cohorts of signers (e.g. Senghas et al., 2004; Clay et al., 2014).² Pantomime is not compositional in the above sense, but more holistic. Its units (if there are any) are for the most part not discernible: many articulators are used at the same time, in a stream-like fashion, so that it is difficult to say where one movement terminates and another starts (see e.g. Żywicznyński et al., 2018). Thus, the meaning-making processes in pantomime depend more on producing and understanding the whole pattern rather than its parts.

In our study, the way of enacting events themselves did not change across conditions; it retained the typical transitive structure with an agent, a patient, and an action (Gärdenfors, 2014; Warglien et al., 2012), represented mostly in the stream-of-movement fashion that is characteristic of pantomime (Żywicznyński et al., 2018). Some pantomimes, however, were supplemented with markers, used before enacting an event and in between events; the same markers were also reused for different events and/or repeated. Thus, to an

² Senghas et al. argue that the simultaneous strategy is more characteristic of co-speech gestures, while in emerging signed languages (here, NSL), even in the earliest cohorts of signers, signs are already subject to segmentation, which then further leads to increasing compositionality in the following cohorts (2004: 1780).

extent, they functioned similarly to the so-called dedicated gestures in signed languages: the movements of different body parts that have a grammatical function (e.g. raising brows to turn a statement into a question, see Zeshan, 2004). Evidence from emerging signed languages (Al-Sayyid Bedouin Sign Language in Sandler, 2012; Israeli Sign Language in Meir & Sandler, 2008) shows that such dedicated gestures are added to existing signs by new cohorts of signers to add on meaning. At first, they appear spontaneously, do not have a clearly determined structure and are not strictly synchronised with the production of the sign they are “added to”. In later cohorts of signers, dedicated gestures tend to become more and more systematic: the position of the articulators becomes fixed and the production of the gesture becomes more closely aligned to the timing of the accompanying signs (Sandler, 2012).

It is important to note that the markers of event order that were observed in our study relied on prior cultural conventions to a great extent: enumerating events with the fingers, organising the miming spaces into frames of a comic strips or a timeline, and using a metaphorical backwards gesture to refer to the past. Interestingly, the latter can be observed in signed languages, in which past and future are referred to alongside backward and forward movements (see e.g. Jacobowitz & Stokoe, 1988 for American Sign Language; Łozińska, 2012 for Polish Sign Language). For instance, the sign “now” in American Sign Language and Polish Sign Language make use of the space directly in front of the signer (see Fig. 8A). In turn, the sign “tomorrow” in American Sign Language and Polish Sign Language involves a forward movement of the hands, whereas the sign “yesterday” involves a backward movement (see Fig. 8B). The use of similar signs in our study conforms with the assumption about inter-group variation and cultural specificity in pantomime (e.g. Zlatev & Andrén, 2009; Żywicznyński et al., 2021), and this applies even more to the proto-linguistic markers that emerged in the non-chronological condition due to conventionalisation.



Figure 8. A. "Now" in American Sign Language (on the left) and "now" ("teraz") in Polish Sign Language (on the right).



Figure 8. B. "Tomorrow" in American Sign Language and Polish Sign Language (on the left) and "yesterday" ("wczoraj") in Polish Sign Language (on the right).

In sum, the results of our study suggest both that pantomime as a communicative system has its limitations with respect to representation of non-chronological order of events and that these limitations can be overcome through the introduction of compositional, proto-linguistic elements. This lends further support for the claim that pantomime was the original sign-based (as opposed to signal-based) communicative system in human evolution (Zlatev et al., 2020). These conclusions tie with the research on the role of pantomime in the

emergence of early signs in new signed languages (Mineiro et al., 2021). At the same time, this study opens up the discussion about one possible factor that could have driven the evolution of pantomime into a more language-like system: the need to convey more chronologically complex stories.

However, we need to be careful in drawing comparisons between the findings of our experimental study and natural communication for at least two reasons. First, the study incorporated a closed “meaning space”. The directors were instructed to enact standardised stories with three events and no more than two characters (see Section 2.1). They interpreted the stories in different ways (e.g. sometimes, they omitted one or two of the three events), but, still, the information passed to the matcher was to a large extent controlled. Following a forced-choice paradigm, the matchers were instructed to give an answer with reference to the four comic strips, which further determined what information the directors had to include in their pantomimes in order for them to be correctly interpreted in two respects: (1) the story had to be distinguished from a different, randomly selected story (see Section 2.1); (2) the sequence of events had to be marked as chronological or non-chronological. Although the closed meaning space provided the communicative context crucial for pantomime (Żywicznyński et al., 2021: 7), it casts doubt on the ecological validity of the design, a problem not uncommon in similar experimental studies (e.g. Żywicznyński et al., 2021: 8).

Second, the design determined the way in which the directors mimed the stories: in the non-chronological condition, the third event was expected to be shown at the beginning. In a natural interaction, this is not the only disruption of chronology that occurs in the process of sharing stories: for instance, the beginning is sometimes recounted a couple of times (see “false starts” in Norrick, 2007); the end is not recounted at all (see failed attempts at humour in co-narration in Norrick, 2004); or events are reported in a “mosaic-like” fashion, where some are omitted and then supplemented not by the main storyteller, but by other interlocutors (Norrick, 2018). Notably, even though the design put a constraint on the directors to show the third event first, reordering events also appeared spontaneously in

ways which we did not anticipate. For example, one participant mimed the story with ID “bear” (see Table 1) in the following way: first, he showed there was a bear behind a door (event 2); then, he mimed opening the door (event 1) and running away (event 3). Such a sequence did not stem from the directors’ input, nor from the concern for making the matcher’s task easier. This suggests that pantomime may to some extent express stories in a non-chronological way even if there are communicative constraints in this respect. Thus, the second hypothesis is not as unambiguously supported as suggested above (see Zlatev et al., submitted)

The extent of this tendency could be explored in a different experimental setting, possibly based on the iterated learning paradigm (see e.g. Kirby et al., 2014), where a story would be passed on from one generation of participants to another, with no constraints on choosing strategies and the focus put, for instance, on its tellability, that is how salient a story is when compared to other stories. Salience can be achieved by a “break in expectations” (see e.g. Norrick, 2004), which can concern the way in which events are reported. In an experimental setting based on such a paradigm, we could see whether disruptions of chronology would occur spontaneously (i.e. with no direct pressure to order events in a story in a specific way); whether such disruptions would lead to a higher tellability; and whether they would prompt the participants to start to develop conventionalised (symbolic) signs for marking the order of events.

5. Conclusion

Pantomime has been argued to be a strong candidate for being the first human-unique communicative system, allowing our ancestors to express an open-ended number of messages (Arbib, 2012; Zlatev et al., 2020). It even has the potential for communicating simple stories (Boyd, 2017). However, it also has its semiotic limitations (see e.g. Żywiczyński et al., 2021), and these need to be further explored. In this study, we focused on constraints concerning communicating the order of events in stories consisting of three events. Given the temporal diagrammatic iconicity of pantomime (of the “veni, vidi, vici”

type), we assume that pantomime will be well-suited for conveying simple stories, where events are arranged in a chronological sequence, but less so for expressing events in a non-chronological order, characteristic of more complex stories. This assumption, which was not tested in an experimental setting before, was corroborated in our study. Our findings showed that not only was the chronological condition easier for the participants but that communicative success was at a ceiling level. In the non-chronological condition, in turn, we could observe a learning effect, where communicative success increased with each game, and that this increase was connected with the introduction of markers of event order. The results of our study provide an insight into the early stages of conventionalisation in bodily-visual communication, a potential first step towards protolanguage, possibly propelled by the need to convey more chronologically complex stories.

Acknowledgments

This research was supported by the Polish National Science Centre (NCN) under the agreement UMO-2017/27/B/HS2/00642. Marta Sibierska was supported by the Polish National Agency for Academic Exchange (NAWA) under the agreement PPN/BEK/2020/1/00319/U/00001. The equipment and the software used in this research was provided by the Lund University Humanities Lab.

References

- Abbott, H. P. (2011). Narrativity. In: Hühn, P. et al. (Eds.) *The Living Handbook of Narratology*. Hamburg: Hamburg University. <http://www.lhn.uni-hamburg.de>, DOA: 1 Oct 2022.
- Arbib, M.A. (submitted). Pantomime within and beyond the evolution of language. In: Żywiczyński, P., Wacewicz, S., Boruta-Żywiczyńska, M., Blomberg, J. (Eds.) *Perspectives on pantomime: evolution, development, interaction*. Philadelphia–Amsterdam: John Benjamins.
- Arbib, M. A., Aboitiz, F., Burkart, J. M., Corballis, M., Coudé, G., Hecht, E., ... & Wilson, B. (2018). The comparative neuroprimatology 2018 (CNP-2018) road map for research on How the Brain Got Language. *Interaction Studies* 19(1–2), 370–387.
- Arbib, M.A. (2016). Towards language-ready brain: biological evolution and primate comparisons. *Psychonomic Bulletin & Review*, PMID 27368635, <https://doi.org/10.3758/s13423-016-1098-2>.
- Arbib, M.A. (2013). Complex imitation and the language-ready brain. *Language and Cognition* 5, pp. 273–312, <https://doi.org/10.1515/langcog-2013-0020>.
- Arbib, M.A. (2012). *How the brain got language*. Oxford: Oxford University Press.
- Arbib, M.A. (2005). From monkey-like action recognition to human language: an evolutionary framework for neurolinguistics. *Behavioral and Brain Sciences* 28, pp. 105–168.
- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using {lme4}. *Journal of Statistical Software* 67 (1), 1–48.
- Boyd, B. (2017). The evolution of stories: From mimesis to language, from fact to fiction. *WIREs Cognitive Science* 9(1), 1444, <https://doi.org/10.1002/wcs.1444>.
- Boyd, B. (2009). *On the Origin of Stories: Evolution, Cognition, and Fiction*. Cambridge, MA–London: The Belknap Press of Harvard University Press.
- Bremond, C. ([1966] 1980). “The Logic of Narrative Possibilities.” *New Literary History* 11, 387–411.

- Burns, P., McCormack, T., Jaroslawska, A. J., O'Connor, P. A., & Caruso, E. M. (2019). Time points: a gestural study of the development of space–time mappings. *Cognitive science* 43(12), e12801.
- Casasanto, D. and Jasmin, K. (2012). The Hands of Time: Temporal Gestures in English Speakers. *Cognitive Linguistics* 23(4), 643–674.
- Clay, Z., Pople, S., Hood, B., Kita, S. (2014). Young children make their gestural communication systems more language-like: Segmentation and linearization of semantic elements in motion events. *Psychological science* 25(8), pp. 1518–1525.
- Cooperrider, K., Núñez, R. and Sweetser, E. (2014). The Conceptualisation of Time in Gesture. In: C. Müller et al. (Eds.) *Body–Language–Communication*. Berlin–Boston: De Gruyter Mouton, pp. 1781–1788.
- Currie, M. (2007). *About time: narrative, fiction, and the philosophy of time*. Edinburgh: Edinburgh University Press.
- Devyllder, S. (2018). Diagrammatic iconicity explains asymmetries in Paamese possessive constructions. *Cognitive Linguistics* 29(2), pp. 313–348, <https://doi.org/10.1515/cog-2017-0058>.
- Donald, M. (2001). *A mind so rare: The evolution of human consciousness*. New York: W. W. Norton.
- Donald, M. (1991). *Origins of the modern mind. Three stages in the evolution of mind and cognition*. New York: Harvard University Press.
- Fay, N., Lister, C. J. , Ellison, T. M., Goldin-Meadow, S. (2014). Creating a communication system from scratch: gesture beats vocalization hands down. *Frontiers in Psychology* 5, 354, <https://doi.org/10.3389/fpsyg.2014.00354>.
- Fay, N., Arbib, M.A., Garrod, S. (2013). How to bootstrap a human communication system. *Cognitive Science* 37, pp. 1356–1367, <https://doi.org/10.1111/cogs.12048>.
- Fay, N., Garrod, S., Roberts, L., Swoboda, N. (2010). The interactive evolution of human communication systems. *Cognitive Science* 34(3), pp. 351–386.

- Ferretti, F. (2021). The narrative origins of language. In: Gontier, N. et al. (Eds.) *The Oxford Handbook of Human Symbolic Evolution*. Oxford–New York: OUP, <https://doi.org/10.1093/oxfordhb/9780198813781.013.33>.
- Friedemann, K. ([1910] 1969). *Die Rolle des Erzählers in der Epik*. Darmstadt: WBG.
- Galantucci, B. and Garrod, S. (2011). Experimental semiotics: a review. *Frontiers in Human Neurosciences* 5, <https://doi.org/10.3389/fnhum.2011.00011>.
- Gärdenfors, P. (2021). Demonstration and pantomime in the evolution of teaching and communication. *Language & Communication* 80, 71–79.
- Gärdenfors, P., Jost, J., Warglien, M. (2018). From actions to effects: three constraints on event mapping. *Frontiers in Psychology* 9, 1391, <https://doi.org/10.3389/fpsyg.2018.01391>.
- Gärdenfors, P. (2017). Demonstration and Pantomime in the Evolution of Teaching. *Frontiers in Psychology* 8, 415.
- Gärdenfors, P. (2014). *The Geometry of Meaning: Semantics Based on Conceptual Spaces*. Cambridge, MA: MIT Press.
- Gärdenfors, P. (2003). *How homo became sapiens: on the evolution of thinking*. New York: Oxford University Press.
- Genette, G. (2002). Order, duration, and frequency. In: Richardson, B. (Ed.), *Narrative Dynamics: Essays on Time, Plot, Closure, and Frames*. Columbus: Ohio State University, 25–34.
- Goldin-Meadow, S., Levine, S.C., Hedges, L.V., Huttenlocher, J., Raudenbush, S.W., Small, S.L. (2014). New evidence about language and cognitive development based on a longitudinal study: hypotheses for intervention. *Am. Psychol.* 69(6), pp. 588–599, <https://doi.org/10.1037/a0036886>.
- Goldin-Meadow, S. (2003). *Hearing gesture: How our hands help us think*. Cambridge, MA–London: Belknap Press of Harvard University Press.
- Gottschall, J. (2012). *The Storytelling Animal: How Stories Make Us Human*. Boston–New York: Mariner Books.

- Greimas, A. J. ([1966] 1983). *Structural Semantics. An Attempt at a Method*. Lincoln: University of Nebraska Press.
- Herman, D. (2009). *Basic Elements of Narrative*. Malden, MA: Wiley-Blackwell.
- Hockett, C. (1952). An Approach to the Quantification of Semantic Noise. *Philosophy of Science* 19(4), 257–260.
- Hothorn, T., Bretz, F., Westfall, P. (2008). Simultaneous Inference in General Parametric Models. *Biometrical Journal* 50(3), 346–363
- Itti, L. and Arbib, M.A. (2006). Attention and the minimal subscene. In: Arbib, M.A. (Ed.) *From action to language via the Mirror Neuron System*. Cambridge: Cambridge University Press, pp. 289–346, <https://doi.org/10.1017/CBO9780511541599.010>.
- Jacobowitz, E. L., Stokoe, W. C. (1988). Signs of tense in ASL verbs. *Sign Language Studies* 60, pp. 331–340.
- Jakobson, R. (1965). Quest for the essence of language. *Diogenes* 13(51), pp. 21–37, <https://doi.org/10.1177/039219216501305103>.
- Jandt, F. E. (2017). *An Introduction to Intercultural Communication: Identities in a Global Community*. Thousand Oaks–London–Delhi: SAGE Publications.
- Kirby, S., Motamedi, Y., Wolters, L., Smith, K. (2022). Compositionality arises from iterated learning despite a preference for holistic signals: An experimental model of sign language emergence. In: Ravnani, A. et al. (Eds.) *The Evolution of Language: Proceedings of the Joint Conference on Language Evolution (JCoLE)*. Nijmegen: Joint Conference on Language Evolution, pp. 402–404.
- Kirby, S., Griffiths, T., Smith, K. (2014). Iterated learning and evolution of language. *Current Opinion in Neurobiology* 28, 108–114.
- Krauss, R.M. and Winheimer, S. (1966). Concurrent feedback, confirmation and the encoding of referents in verbal communication. *Journal of Personality and Social Psychology* 4, pp. 343–346.

- Kuhn, M., Schmidt, J. N. (2013). Narration in film. In: P. Hühn et al. (Eds.), *The Living Handbook of Narratology*. Hamburg: Hamburg University. <http://www.lhn.uni-hamburg.de>, DOA: 1 Oct 2021.
- Łozińska, S. (2012). Gramatyczne funkcje ruchu w polskim języku migowym (PJM). In: Lisczyk-Kubina, K. and Maciołek, M. (Eds.) *Ruch w języku, język w ruchu*. Katowice: Uniwersytet Śląski w Katowicach, pp. 89–97.
- Meir, I. and Sandler, W. (2008). *A language in space: the story of Israeli Sign Language*. New York: Lawrence Erlbaum Associates.
- Mineiro, A., Báez-Montero, I. C., Moita, M., Galhano-Rodrigues, I., & Castro-Caldas, A. (2021). Disentangling pantomime from early sign in a new sign language: window into language evolution research. *Frontiers in Psychology* 12, 640057.
- Mineiro, A., Carmo, P., Carocha, C., Moita, M., Carvalho, S., Paço, J., & Zaky, A. (2017). Emerging linguistic features of sao tome and principe sign language. *Sign Language & Linguistics* 20(1), 109–128.
- Motamedi, Y., Smith, K., Schouwstra, M., Culbertson, J., Kirby, S. (2021). The emergence of systematic argument distinctions in artificial sign languages. *Journal of Language Evolution* 6(2), 77–98.
- Motamedi, Y., Schouwstra, M., Smith, K., Culbertson, J., Kirby, S. (2019). Evolving artificial sign languages in the lab: from improvised gesture to systematic sign. *Cognition* 192, 103964.
- Müller, C. (2014). Gestural modes of representation as techniques of depiction. In: C. Müller et al. (Eds.) *Body–Language Communication: An International Handbook on Multimodality in Human Interaction*. Berlin–Boston: De Gruyter Mouton, pp. 1687–1701.
- Norricks, N. R. (2018). Collaborative remembering in conversational narration. *Topics in Cognitive Science* 11(4), 733–751.
- Norricks, N. R. (2007). Conversational storytelling. In: D. Herman (Ed.) *The Cambridge Companion to Narrative*. Cambridge: CUP, pp. 127–141.

- Norrick, N. R. (2004). Humor, tellability, and conarration in conversational storytelling. *Text & Talk* 24(1), 79–111.
- Novack, M. A. and Goldin-Meadow, S. (2017). Gesture as representation action: A paper about function. *Psychonomic Bulletin & Review* 24, pp. 652–665.
- Núñez, R. E. and Sweetser, E. (2006). With the future behind them: convergent evidence from Aymara language and gesture in the crosslinguistic comparison of spatial construals of time. *Cognitive Science* 30(3), pp. 401–450.
- Peirce, Ch. S. (1974). *Collected papers of Charles Sanders Peirce*. Cambridge, MA: The Belknap Press of Harvard University Press.
- Pietrandrea, P. and Russo, T. (2007). Diagrammatic and imagic hypoicons in signed and verbal languages. In: Pizzuto, E., Pietrandrea, P., Simone, R. (Eds.) *Verbal and signed languages. Comparing structures, constructs and methodologies*. Berlin: De Gruyter Mouton, pp. 35–56.
- Player, M., Lepic, R., Hartmann, S. (2022). Compositionality in different modalities: a view from usage-based linguistics. *International Journal of Primatology*, <https://doi.org/10.1007/s10764-022-00330-x>.
- Psychology Software Tools. (2016). E-Prime 3.0. Pittsburgh, PA.
- Richardson, B. (Ed.) (2002). *Narrative dynamics: essays on time, plot, closure, and frames*. Columbus: Ohio State University.
- Rodriguez, L. (2019). Time is not a line. Temporal gestures in Chol Mayan. *Journal of Pragmatics* 151, 1–17, <https://doi.org/10.1016/j.pragma.2019.07.003>.
- Ronen, Ruth (1994). *Possible Worlds in Literary Theory*. Cambridge: CUP.
- RStudio Team. (2019). RStudio: Integrated Development for R. Rstudio, Inc. Boston, MA. <http://www.rstudio.com/>.
- Ryan, M. L., (2012). Narration in various media. In: P. Hühn et al. (Eds.) *The Living Handbook of Narratology*. Hamburg: Hamburg University. <http://www.lhn.uni-hamburg.de>, DOA: 1 Oct 2022.

- Sallandre, M. A. and Cuxac, Ch. (2001). Iconicity in sign language: A theoretical and methodological point of view. In: Wachsmuth, I. and Sowa, T. (Eds.) *Gesture and sign languages in human-computer*. London: International Gesture Workshop Proceedings, pp. 18–20.
- Sandler, W. (2012). Dedicated gestures and the emergence of sign language. *Gesture* 12(3), pp. 265–307.
- Schmid, H. J. (2015). A blueprint of the Entrenchment-and-Conventionalization Model. *GCLA* 3, 3–15.
- Schmid, W. (2010). *Narratology. An Introduction*. Berlin: De Gruyter Mouton.
- Senghas, A., Kita, S., Ozyürek, A. (2004). Children creating core properties of language: evidence from an emerging sign language in Nicaragua. *Science* 305, 1779, <https://doi.org/10.1126/science.1100199>.
- Shannon, C. E., Weaver, W. (1949). *The Mathematical Theory of Communication*. Urbana: University of Illinois Press.
- Simone, R. (1995) Iconic aspects of syntax. A pragmatic approach. In: Simone, R. (Ed.) *Iconicity in Language*. Amsterdam–Philadelphia: John Benjamins, pp. 153–170.
- Sternberg, M. (2001). How Narrativity Makes a Difference. *Narrative* 9, pp. 115–22.
- Tomasello, M. (2008). *Origins of Human Communication*. Cambridge, MA: MIT Press.
- Warglien, M., Gärdenfors, P., Westera, M. (2012). Event structure, conceptual spaces and the semantics of verbs. *Theoretical Linguistics* 38(3–4), pp. 159–193.
- Zeshan, U. (2004). Interrogative constructions in signed languages: crosslinguistic perspectives. *Language* 80(1), pp. 7–39.
- Zlatev, J., Sibierska, M., Żywiczyński, P., van de Weijer, J., Boruta-Żywiczyńska, M. (submitted). Can pantomime narrate? A cognitive semiotic approach. In: Żywiczyński, P., Wacewicz, S., Boruta-Żywiczyńska, M., Blomberg, J. (Eds.) *Perspectives on pantomime: evolution, development, interaction*. Philadelphia-Amsterdam: John Benjamins.

- Zlatev, J., Żywiczyński, P., Wacewicz, S. (2020). Pantomime as the original human-specific communicative system. *Journal of Language Evolution* 5(2), pp. 156–174, <https://doi.org/10.1093/jole/lzaa006>.
- Zlatev, J., Żywiczyński, P., van de Weijer, J., Wacewicz, S. (2017). Multimodal-first or pantomime-first? Communicating events through pantomime with and without vocalization. *Interaction and Iconicity in the Evolution of Language* 18(3), 465–488, <https://doi.org/10.1075/is.18.3.08zla>.
- Zlatev, J. (2014). Bodily mimesis and the transition to speech. In: M. Pina & N. Gontier (Eds.) *The evolution of social communication in primates*. Berlin: Springer, pp. 165–178.
- Zlatev, J. and Adrén, M. (2009). Stages and transitions in children's semiotic development. In: J. Zlatev et al. (Eds.) *Studies in Language and Cognition*. Cambridge University Press, pp. 380–401.
- Żywiczyński, P., Sibierska, M., Wacewicz, S., van de Weijer, J., Ferretti, F., Adornetti, I., Chiera, A., Deriu, V. (2021). Evolution of conventional communication. A cross-cultural study of pantomimic re-enactments of transitive events. *Language & Communication* 80, pp. 191–203, <https://doi.org/10.1016/j.langcom.2021.07.002>.
- Żywiczyński, P., Wacewicz, S., Sibierska, M. (2018). Defining pantomime for language evolution research. *Topoi* 37, pp. 307–318, <https://doi.org/10.1007/s11245-016-9425-9>.