Journal of Language Evolution, 2026, **11**, lzag003
https://doi.org/10.1093/jole/lzag003
Published: 7 July 2026
Research article

OXFORD

The career of metaphor in pantomime: a motion-capture study of the conventionalization of metaphor

Marek Placiński [1,2†], **Michael Pleyer** [1,2*,†]

[1]Centre for Language Evolution Studies, Nicolaus Copernicus University in Toruń, ul. Fosa Staromiejska 3 (Room 26), Toruń 87-100, Kujawsko-Pomorskie, Poland
[2]Institute of Advanced Studies, Nicolaus Copernicus University in Toruń, Wileńska 4, Toruń 87-100, Kujawsko-Pomorskie, Poland
*Corresponding author. Centre for Language Evolution Studies, Nicolaus Copernicus University in Toruń, ul. Fosa Staromiejska 3 (Room 26), Toruń 87-100, Kujawsko-Pomorskie, Poland. E-mail: pleyer@umk.pl
[†]Both authors contributed equally to this work.

Human communication is highly adaptable in the sense that, for instance, new words or combinations of words emerge when there is a communicative pressure. However, another way in which humans can communicate about novel experiences is through meaning extensions of words that are already in their lexicon. One of the key driving factors of such polysemic extension is metaphorical conceptual mappings, which first become usualized, and then conventionalized within a community. In this article, we set out to investigate whether this kind of conceptual mapping can be achieved in an experimental semiotic study and whether the usualization trajectories of concrete and metaphorical meanings differ from each other. We do so by engaging participants in a referential game in which dyads of participants have to communicate about concrete and metaphorical meanings. We find that, over the course of the experiment, participants adapt elements of their kinematics from concrete to metaphorical meanings. We also find that the usualization trajectory is different between the two groups of meanings: both meanings initially undergo reduction in terms of movement path. However, concrete meanings continue to change and become more efficient across all rounds, while metaphorical meanings stabilize earlier and do not change significantly after their initial kinematic changes. In contrast to concrete meanings, we find no significant change in terms of speed and volume for metaphorical meanings. The study provides evidence that both concrete and metaphorical meanings can be expressed through pantomime, but their trajectory of change is different.

Keywords metaphor, pantomime, motion capture, language evolution

1. Introduction

Human communication is characterized by open-endedness. When we use language, we can talk about virtually anything, from past events to abstract concepts. In one conversation, we can talk about having coffee later in the afternoon, recount last week's affairs, or discuss such abstract notions as love, friendship, or science. This capacity of language stands in contrast with the communication systems of other animals, which do not share this ability (Hockett 1960; Pleyer et al. 2025).

One way this capacity is achieved is through the ability of the human mind/brain to store a large number of form-meaning pairings, with the estimated size of the mental lexicon ranging from 14,000 to 40,000 words (Goulden et al. 1990; D'Anna et al. 1991; but the exact estimate depends on the definition "word," see Brysbaert et al. 2016). However, no matter how large, a stable lexicon with fixed form-meaning pairings is unable to adapt to the ever-changing conditions in which humans live and communicate. This, of course, begs the question of how fixed form-meaning

© The Author(s) 2026. Published by Oxford University Press.
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (https://creativecommons.org/licenses/by/4.0/), which permits unrestricted reuse, distribution, and reproduction in any medium, provided the original work is properly cited.

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

pairings can be extended to accommodate new meanings.

One answer to this question is that new meanings are acquired through compositionality and combinatoriality, either through coining new words, compounds or new phrases and syntactic expressions (see especially Kirby et al. 2015; Pleyer et al. 2024b). This answer does not represent the full picture and is only partly correct, as it implies that novel form-meaning pairings emerge whenever it is necessary to name something new. That is not always the case. A considerable number of words in the lexicon of different languages are characterized by polysemy, i.e. have many meanings. In this sense, polysemy also accounts for the open-endedness of human language.

In this article, we set out to explore the potential of polysemic extension of the meanings of words. We do so by designing a motion capture experiment in which participants have to communicate pantomimically about a closed set of referents. In the first half of the game, they have to communicate about concrete meanings, and in the second half about metaphorical ones. The concrete and metaphorical meanings make use of conceptual mapping, with the source domain in the concrete meanings. A secondary objective of our study is to explore whether concrete and metaphorical forms have a different usualization pattern by comparing their kinematic parameters, such as signing space and speed.

2. Theoretical background

As mentioned in the Section 1, a common solution found in languages and indeed in language evolution to enable the open-endedness of linguistic meaning is that existing signs take on extended meanings. Such extended meanings are linked to their original meanings via associative connections, leading to polysemy (e.g., Sweetser 1990; Gries 2015; Vicente and Falkum 2017). Polysemy is one of the key mechanisms enabling the open-ended expressivity of language, as it enables the expression of "new ideas not by inventing new words, but by extending existing words beyond their original meanings" (Srinivasan and Rabagliati 2015). In fact, polysemyous meaning extension is an extremely widespread phenomenon in English. For example, for English, there are estimates that up to 84 per cent of words are polysemous to some degree (Floyd and Goldberg 2021), whereas others estimate that virtually every single word in natural languages exhibits polysemy (Vicente and Falkum 2017).

The historical development of polysemy via meaning extension as well as the various factors that influence these processes has been well-documented in historical linguistic research, especially in diachronic semantics (e.g. Allan and Robinson 2012). The key driver of such semantic change that has been highlighted in much of this work is that of metaphorical extension (e.g. Sweetser 1990; Anderson 2017). In metaphor, we experience and understand one kind of thing in terms of another (Lakoff and Johnson 1980). Aspects of a source domain, which most often is a concrete domain (such as space), are "mapped" onto a target domain, which most often is more abstract (such as time). This in turn helps us understand and conceptualize an abstract domain in terms of another domain we have more experience with, often based on our embodied interaction with the world around us. For example, the conceptual metaphor of TIME IS SPACE yields expressions such as "a short time," "a long time," or "I'm looking forward to it." (Lakoff and Johnson 1980; Kövecses 2010). In conceptual metaphor theory, our conceptual system is seen as organized in terms of conceptual metaphors, meaning that such metaphoric expressions are windows into how we conceptualize these domains. So if we use conceptual metaphors such "We're at a crossroads in our relationship," "When we were in our twenties, our relationship was quite a wild ride" or "We've reached the end of our relationship," this shows that we actually understand and conceptualize love in terms of a metaphor LOVE IS A JOURNEY.

The use of metaphor and conceptual metaphorical mappings has been observed in a variety of different modalities, including not only in spoken language but also in gesture (Cienki and Müller 2008), signed languages (Wilcox 2000; Taub 2001; Kaneko and Sutton-Spence 2017) and in graphic representations (Stampoulidis et al. 2019). In fact, many signs in signed languages are motivated by iconicity, metonymy, and metaphor and associative links (Kaneko and Sutton-Spence 2017), with many signed metaphors emerging out of iconic forms.

Diachronically, metaphors represent instances of motivated metaphoric extension, where a more concrete meaning (the source domain) is extended via some associative or conceptual link to a more abstract meaning (the target domain). For example, the more abstract meaning "bright, cheerful, joyous" (OED) for the adjective *sunn*y is historically younger and derived from the literal, concrete sense of "characterized by or full of sunshine" (OED). In this sense, the metaphorical meaning of *sunny* is an instantiation of the conceptual metaphor HAPPINESS IS LIGHT (Anderson 2017).

Importantly, however, in modern English both the metaphorical and the concrete meaning of *sunny* can be found in the dictionary, meaning that both meanings have become conventionalized. In their career of metaphor model, Bowdle and Gentner (2005) propose that novel, "online" metaphoric extensions become conventionalized word senses over time, gradually being viewed as less and less

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

metaphoric and more conventionalized. This however, is a gradual process. In fact, Gentner and King (2024) found that word senses that are historically newer are generally perceived to be more metaphoric than word senses that are older. Overall, this means that there are two key processes in the development of metaphorical meanings: the initial emergence of metaphorical meanings and their subsequent conventionalization.

It is still an open question whether metaphorical extension functions in the same way in laboratory experiments where participants are required to expand their communication systems. Investigating this could provide insights into whether metaphorical extension might contribute to explaining the emergence of polysemous meanings during the evolution and cultural development of language. A limited number of studies so far have investigated the emergence of metaphors and metaphoric extensions experimentally (Verhoef et al. 2016, 2022, 2024; Bowerman and Smith 2022; Smith et al. 2025). The conventionalization of metaphors has so far not been studied experimentally in detail. Such studies on the emergence and use of abstract metaphorical meanings are of high interest, as they can lend support to theories that assign an important role to the process of metaphorical extension in the evolutionary and cultural emergence of language (e.g. Smith and Höfler 2015; Knight and Lewis 2017; Gil and Shen 2021; Ellison and Reinöhl 2022). Here, we address both the emergence and conventionalization of metaphorical meaning in a nonlinguistic medium, that of pantomime. Using this methodology, our study contributes to one of the key questions regarding the evolution of language as formulated by Planer and Sterelny (2021): we must "explain how hominin signaling became readily expandable."

2.1. Metaphor, language evolution, and pantomime

How do communicators convey metaphorical meanings in the absence of a shared language? In this article, we shed light on a specific proposal about the evolution of language, namely that pantomime was "the original human-specific communicative system" (Zlatev et al. 2020) that served as a foundation for the evolution of language. It has been shown that pantomime can be used to successfully communicate the structure of events and referents (Zlatev et al. 2017; Żywiczyński et al. 2021). However, it is less clear whether pantomime can be used to communicate more abstract concepts, such as time (Ryan 2012; Żywiczyński et al. 2018). In order to serve as an open-ended communication system, at some time in its evolutionary and cultural development, pantomime would have needed to become able to also communicate complex, abstract meaning. Here, we investigate how pantomime fares with metaphorical mappings. That is, how do communicators use pantomime to express metaphorical expressions such *to raise prices* (*podnieść ceny*) or *to throw an idea* (*podrzucić pomysł*). Answering the question whether metaphor (1) can be expressed in pantomime, (2) is used as a resource to extend the meaning of symbols and (3) becomes more conventionalized over time in experimental semiotic studies will also yield important evidence for theorizing in conceptual metaphor theory (Lakoff and Johnson 1980; Kövecses 2010, 2020), and Cognitive Linguistics (Geeraerts and Cuyckens 2007; Dąbrowska and Divjak 2015), which assume that metaphor is not only a linguistic, but a general cognitive phenomenon that structures our conceptual system. This is the view held by Conceptual Metaphor Theory (Lakoff and Johnson 1980; Kövecses 2010).

What makes metaphor an important process both from a diachronic perspective and regarding the question of how communication systems become expandable in such a way that they can be used to communicate about everything is that metaphors license semantic extension and the formation of polysemy. As already mentioned in Section 2, the conventionalization of metaphors has important implications for the status of metaphors in the language system. Specifically, one central claim of the career of metaphor hypothesis is that over the course of their diachronic historical development, metaphors gradually shift from being processed as comparisons to being processed via categorization.

The above means that as metaphors become conventionalized, the way they are being processed also changes (Bowdle and Gentner 2005). When a metaphor is understood via comparison, they are understood via the more schematic common relational structure of the two concepts. For example, Polish *being eaten by a bear* (*być zjedzonym przez niedźwiedzia)* and *being eaten by stress* (*być zjedzonym przez stresl)* share the common relational structure of a patient being consumed by an agent. Through frequent repetition, cognitive entrenchment and conventionalization of a metaphor the processing mode then shifts to understanding metaphors as category statements. In the case of being eaten by stress for example, if this metaphor is understood via categorization it is understood "as a member of a superordinate domain-general metaphoric category expressed by the base term eat. That is, eat in this case is understood as a lexicalized "domain-general relational schema" (Bowdle and Gentner 2005). When they are still being processed as novel metaphors, metaphors require active inference and "sense creation" of the intended conceptualization, whereas when they have become conventionalized

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

metaphors they require "sense retrieval" (Giora 1997; Turner and Katz 1997; Bowdle and Gentner 2005) and presumably are less cognitively demanding.

We expect that for expression of metaphoric meanings via pantomime, as our experiment only consists of a few rounds of interaction, processing of metaphoric meanings will differ from the processing of concrete meanings, which will be reflected in differences in the trajectories of how concrete vs metaphoric conceptualizations become usualized and socially coordinated (Pleyer et al. 2024a). Following Schmid (2020), we define the process of conventionalization as comprising the processes of usualization and diffusion. Usualization is the first stage of the conventionalization process, in which patterns of use become locally established and socially coordinated between interactants through repetition. In the process of usualization, patterns of use can become local, tacit norms and ways to achieve recurrent goals of communication shared between interactants. Usualized patterns of use can then diffuse throughout a community of practice, turning them into conventions. As our study, and most other studies of conventionalization of pantomime investigate local interactions and the initial emergence and coordination of patterns of use, and not their subsequent diffusion throughout wider communities, we here use the more precise term usualization to capture this process.

Regarding usualization patterns, we expect that the career of metaphor in pantomime will present a different trajectory of change in its formal expression compared to the "career of concrete meanings." That is, we predict that concrete meanings will show stronger effects in terms of reduction of kinematic parameters than metaphoric meanings, which are markers of social coordination and usualization (Namboodiripad et al. 2016; Placiński et al. 2023). Pressures for communicative efficiency lead to the reduction in kinematic parameters in the process of usualization, making them less costly to produce and process. However, existing research shows that more accessible and less cognitive complex meanings are reduced more than those that are less accessible and more cognitively complex and demanding (Levshina 2022). As metaphors require complex cognitive mappings, and more complex ones than concrete meanings, we expect that this will also be reflected in their usualization patterns. Existing research on sign languages (Taub 2001; Meir 2010) has also shown that trying to map concrete meanings onto metaphorical meanings in the visual–gestural domain is a more cognitively complex and demanding process compared to processing simple concrete mappings, adding to the argument that concrete and metaphorical expressions will differ in their patterns of kinematic parameter reduction (see Section 4).

2.2. Related work

To test our hypotheses (see Section 2.3), we designed an experimental semiotic study. Experimental semiotics is a budding field in experimental linguistics that proscribes participants from using language during the experiment. The participants need to rely on some other communication system instead, often one that they have to build from scratch (see Delliponti et al. 2023; Nölle and Galantucci 2023). Given the task to communicate with each other in an interactive scenario, participants quickly negotiate meaningful symbols to communicate about referents and coordinate their actions (Nölle and Galantucci 2023). The communication systems commonly used in experimental semiotics are vocal (Fay et al. 2014; Erben Johansson et al. 2021), visual (Garrod et al. 2007; Roberts and Clark 2020), gestural (Kirton et al. 2021), or pantomimic (Żywiczyński et al. 2021; Placiński et al. 2023; Sibierska et al. 2023).

Experimental semiotics designs are broadly divided into referential and coordination games (Galantucci et al. 2012). To test our hypotheses (see Section 3), we engage participants in a referential game. Referential games engage participants in a communicative task in which they have to establish a set of forms for a fixed, often closed, meaning space. They can be viewed as an extension of study designs from experimental pragmatics in which participants used natural language to communicate about sets of referents that were regular objects (see e.g. Brennan and Clark 1996) or novel shapes (e.g. Clark and Wilkes-Gibbs 1986). Referential semiotics experiments have shown that participants establish local conventions in order to communicate, but the degree to which they can use the same set of forms to communicate efficiently is still an open question (see Pleyer et al. 2024a). A very limited number of studies have looked at metaphor and semantic extension in an experimental semiotics design. Verhoef et al. (2016, 2022, 2024) found that participants can successfully create a visual–spatial communication system communicating temporal concepts such as *second*, *day*, *year*, as well as *yesterday*, *today* and *tomorrow* that makes use of the conceptual metaphor TIME IS SPACE. Smith and colleagues (Bowerman and Smith 2022; Smith et al. 2025), showed that participants could extend the meaning of graphic symbols to related meanings based on shared salient semantic metonymic and metaphoric associations in domains such as colors, objects, and emotions.

Many experimental semiotic studies that engage the use of silent gesture or pantomime have implemented kinematic measures in order to operationalize usualization and similarity. Among the first of them is the study by Namboodiripad and colleagues (2016), who used Kinect to capture participants' hand movement.

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

Usualization was measured as the amplitude (the difference between the most extreme locations) of hands. A reduction in the amplitude of movement was taken as an increase in usualization. Another motion capture study with a similar design investigated kinematic usualization in pantomimic interactions (Author et al. 2023). Here, usualization was operationalized in terms of path and volume of movements (see Section 3.3 for definitions). Kinematic systematicity and similarity were studied by Pouw and et al. (2021). These two were operationalized respectively as entropy and shape dynamic time warping (see Section 3.3). The results showed that gestures become more systematic, that is, one gesture is more easily distinguished from another gesture (as evidenced by lower entropy levels) and that gestures within one transmission chain are more similar to the gestures from that transmission chain than from a separate chain. These studies show that kinematic parameters can be used as an operationalization of usualization.

Beyond experimental semiotics, motion capture has been used to investigate conventionalization in sign languages. For instance, one study aimed to determine whether kinematic properties can be used to classify movements as gestures or signs of a sign language (Stamp et al. 2024) and found quantitative differences between actual signs and gestures across certain movement components. Another study investigated the size of signing space in Nicaraguan Sign Language in signers from the earliest and later generations of this language (Flaherty et al. 2023). The study found that signing space becomes reduced over generations, a trajectory that resembles findings from experimental semiotics. Another study found that z-axis use is not a prerequisite for the emergence of spatial grammar (Sato et al. 2022).

In our own study (see Section 3), we design a referential experimental semiotics game in which participants have to communicate about a closed meaning space of metaphorical and concrete meanings. We use motion capture to quantify similarity, pantomime space, and speed (see Section 2.3 for specific research questions and hypotheses).

2.3. Research questions and hypotheses

We designed our study to answer the research questions that were highlighted in Section 1 of this article: how can the lexicon be extended and what is the evolutionary trajectory of forms expressing metaphorical meanings compared with concrete meanings. The specific research questions are:

RQ1 can people be primed to make metaphorical mappings in other modalities, similar to what we observe in spoken language?

Hypothesis: Participants will rely on mapping from concrete to metaphorical meanings, as predicted by CMT, after having been primed to do so.

Operationalization: we will compare shape distance time warping values between the subsequent rounds of the game and between concrete and metaphorical meanings (see Section 3.3 for details). The lower shape distance time warping values, the greater the similarity between two actions.

RQ2: do movements representing metaphorical meanings usualize in a similar way to movements representing concrete meanings thereby taking similar paths toward conventionalization?

Hypothesis: In line with the career of metaphor hypothesis we hypothesize that metaphors also become increasingly usualized over multiple rounds, that is they will be subject to the same usualization and conventionalization pressures. These include kinematic reduction in the space and path of movement (see ANONYMOUS 3 or Namboodiripad et al. 2016), as well as increased speed. However, we also predict that concrete meanings will be usualized and reduced faster and to a higher degree, given that cognitively and communicatively metaphors are more demanding and less accessible (see Section 4). That is, we predict reduction in the space of phantomimes/gestures and an increase in their speed, but that this process will take place to a lesser degree than for concrete meanings.

Operationalization: we will compare the space of pantomimes/gestures (see Section 3.3. for details) and their speed between rounds of the game.

RQ3: does communicative efficiency increase over time; if so, is the trajectory similar for both types of meaning?

Hypothesis: Levshina (2022) proposes that communicative efficiency involves balancing between cost and benefit ratio. Our RQ2 addresses the question of costs—we predict that a change in kinematic parameters toward efficiency—RQ3 predicts that this efficiency goes hand-in-hand with achieving communicative success. We predict that communicative success will go hand-in-hand with reduction of kinematic parameters: while at the beginning of the experiment participants will require more time to provide the correct answer, as they progress through the experiment and establish the common ground, they will identify the correct answer faster.

Operationalization: we obtain time to provide the correct answer.

3. Experiment

To evaluate our hypotheses (see Section 2.3), we designed a referential experimental semiotic game. We engaged pairs of participants and tasked them with

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

Table 1 The list of meanings from the experiment.

No.	Concrete meaning	Metaphorical meaning
1	*podrzucić piłkę* (eng. "to throw a ball")	*podrzucić pomysł* ("to throw an idea")
2	*wymknąć się z domu* (eng. "to sneak out of the house")	*wymknąć się spod kontroli* (eng. "to slip (literally—sneak) out of control")
3	*być zjedzonym przez niedźwiedzia* (eng. "to be eaten by a bear")	*być zjedzonym przez stres* (eng. "to be eaten by stress")
4	*najeść się do syta* (eng. "to eat one's fill")	*najeść się strachu* (eng. "to get (literally—eat) the fright of your life"
5	*szlifować blat* (eng. "to polish the desktop")	*szlifować pomysł* (eng. "to polish an idea")
6	*podnieść dziecko* (eng. "to lift up a child")	*podnieść ceny* (eng. "to raise (literally—lift up) prices")
7	*przynieść kapelusz* (eng. "to bring a hat")	*przynieść straty* (eng. "to bring losses")
8	*dać książkę* (eng. "to give a book")	*dać trochę luzu* (eng. "to cut (literally—give) some slack")
9	*złamać gałąź* (eng. "to break a branch")	*złamać kogoś* (eng. "to break someone")
10	*nagiąć kijek* (eng. "to bend a stick")	*nagiąć zasady* (eng. "to bend rules")

grounding a communication system with the use of whole body communication—pantomime.

3.1. Participants

We invited 30 dyads ($N = 60$, 38 females and 22 males) to participate in our study. We discarded data from 3 pairs due to technical problems such as tracking errors or the participants not being able to finish the task within the specified timeframe. Hence, our sample consisted of 27 pairs of participants ($N = 54$, 34 females and 20 males; between 19 and 55 years of age; mean age = 23). All participants were native speakers of Polish.

3.2. Procedure

The participants were to communicate about a closed set of twenty meanings, ten of which were concrete and ten metaphorical, over three rounds. These meanings were blocked so that in each of the three rounds of the game, the participants communicated first about concrete and then afterwards about metaphorical meanings. Although the order of blocks was fixed, the meanings were randomized within the blocks. As such, the first block can be seen as a priming block for the second block. The participants assumed the role of the director and the guesser. The director reenacted all twenty meanings within the round and the guesser was supposed to guess the meaning of the reenactments. The meanings were displayed on a computer screen that the guesser could not see. The guesser could provide any number of answers until they had provided the correct one and was not limited by time. Following the answer, the experimenter informed the participants whether the answer was correct or incorrect. Once all twenty meanings had been reenacted and correctly guessed, the participants switched roles and the guesser—now the director—had to reenact the same meanings. After both participants had completed enacting and guessing, the round ended. Neither the guesser nor the director was informed in advance about what they were to communicate or about the relation between the two blocks of meanings.

The meanings from the concrete and the metaphorical block were related by the verb. See Table 1 for a complete list of meanings used in the experiment. The reason these meanings were related was because we aimed to evaluate whether participants will use motion patterns from concrete meanings in order to express metaphorical meanings (i.e. whether they would perform metaphorical mapping).

The motion data in the experiment was obtained with the use of an inertial measurement-based (IMU-based) motion capture. IMU sensors are composed of three units: an accelerometer, a gyroscope and a magnetometer. Such a setup means that the system estimates acceleration (linear and angular), rotation and position of the sensor (Rekant et al. 2022). In the case of the system used in this study, Rokoko Smartsuit Pro II, there are 18 sensors placed on the whole body. Our participants also wore Rokoko SmartGloves, which means that there were two additional sensors for each palm and for each finger of the participant. The integrated system captures movement at 100 Hz sampling rate. IMU-based systems estimate the position of the sensor as a deviation of that sensor from the central unit, called the hub. The hub is located above the participant's hips. An essential feature of IMU-based systems is that they have to be

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

calibrated before a recording. Calibration can be understood as a process of removing errors of measurement, which naturally accumulate over time (Poddar et al. 2017). We performed calibration every time participants switched roles and when the recording quality was deemed poor, for instance, when there was drift. After each experimental session, the data were exported from each participant individually.

3.3. Operationalizations

3.3.1. Shape dynamic time warping

Shape dynamic time warping (shape DTW) is a method of analysis that allows comparisons between two sequences of data points, called time series (Escudero-Arnanz et al. 2023). Time series are measurements taken over time and sequenced in a chronological and equidistant manner (Esling and Agon 2012). Shape dynamic time warping is an extension of an earlier method of analysis, called dynamic time warping. The original version of the algorithm was implemented in the domain of acoustic analysis as a method of spoken word recognition by matching patterns (Sakoe and Chiba 1978). The aim of the warping function of the algorithm is to eliminate any time differences between two time series so that a maximal coincidence between two sequences can be attained. The drawback of this algorithm is that the comparison between two time series is pointwise, which is prone to error. Shape dynamic time warping mitigates this error by taking into consideration the local structure of the time series a given observation is embedded within (Zhao and Itti 2018). Here, we propose to use shape dynamic time warping as a measure of similarity between two kinematic time series of joint position data, following Pouw and Dixon (2020) who applied shape DTW as a means of analyzing similarity between gesture velocity profiles.

We perform the analysis of movement similarity to address our Research Question 1 (see Section 2.3). For our analysis, we take two actions that share the same verb (e.g. “to polish a table” and “to polish an idea”), that are from the same round and the same participant, and compute the shape DTW between them. We select actions with the same verbs because we expect metaphorical mapping to occur between them.

3.3.2. Usualization: movement space, speed, and path

Operationalizations of usualization or conventionalization that are often used in motion research are movement space, speed, and path (see especially Namboodiripad et al. 2016 or Żywiczyński et al. 2024). All data were passed through a Savitzky-Golay filter (window length: 11, degree: 2) prior to obtaining measures of usualization. To measure movement space, we take bounding box of movement volume:

$$\mathrm{BBMV} = s_x * s_y * s_z,$$

where BBMV stands for bounding box of movement volume, and s for the amplitude of articulators (difference between most extreme points) in a given axis (x, y, and z respectively). BBMV is expressed in cubic units and is, essentially, a cuboid that encloses the participant’s movement. We first obtained BBMV for each joint and then summed up these values in order to obtain the total bounding box of movement volume of the whole body. The bounding box of movement volume corresponds to the total three-dimensional area that the participant has occupied in a trial. BBMV has been used as a measure of exaggeration and usualization in motion capture studies (Żywiczyński et al. 2024; Placiński et al. 2023). Movement path is defined by the following formula:

$$\mathrm{path} = \mathrm{pos}_{i-1} - \mathrm{pos}_i,$$

where pos_i is the position of the joint at an ith point in the sequence of the time series. These values were later summed up for each joint along each axis, and then for the entire body in order to obtain the total movement path of the entire body. Path is one of the classic measures of exaggeration and usualization in motion capture studies (e.g. Namboodiripad et al. 2016) and we use it as an ancillary measure to BBMV. Finally, we used speed defined as:

$$v = \sqrt{}$$

where v_x, v_y, and v_z stands for movement speed in x, y, and z axes, respectively. Three-dimensional speed is the root sum of squares of speed along all axes. We first obtained the total speed for a given joint and then summed up all values to obtain full body 3D speed. Manipulating speed has been found to aid action recognition (Trujillo et al. 2020) and reproducing demonstrated actions (Żywiczyński et al. 2024).

We take these measures as operationalizations of usualization, which is related to our Research Question 2 (see Section 2.3). That is, following previous studies (Namboodiripad et al. 2016; Placiński et al. 2023) we expect participants, notwithstanding the meaning (metaphorical vs concrete) to produce more exaggerated pantomimes at the beginning of the experiment (occupying larger space, traversing larger distances, moving at a slower speed). We expect these measures to change over the course of the experiment, that is, for space and distance to decrease and speed to increase. We expect

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

Table 2 The influence of round on movement similarity.

	Estimate	Std. error	Df	*t* value	*P*
Intercept	−0.001	0.009	57.22	−0.02	0.01
Round 2 – Round 1	−0.35	0.05	1,567	−8.06	0.01
Round 3 – Round 2	−0.09	0.04	1,567	−2.10	0.03

speed to increase because, although at the beginning slower actions may be easier to identify, later on there will be a pressure on efficiency leading participants to speed up their movements. We expect a reduction in the signaling space for the same reason. Second, we predict that there is going to be a different baseline value for the concrete and metaphorical meanings, with the latter occupying larger space and being slower at the outset because they represent cognitively more complex and less immediately accessible meanings. Finally, we hypothesize that the rate of change will be different in these two meaning conditions, with concrete meanings having a faster reduction rate compared with metaphorical meanings.

Finally, for RQ3, we operationalize communicative success as reaction time. Reaction time was measured automatically by the PsychoPy software (Peirce et al. 2019), from the stimulus onset until the guesser provided the correct answer. As above, we expect different rates of reaction time for the metaphorical and concrete meanings: longer for the former than the latter.

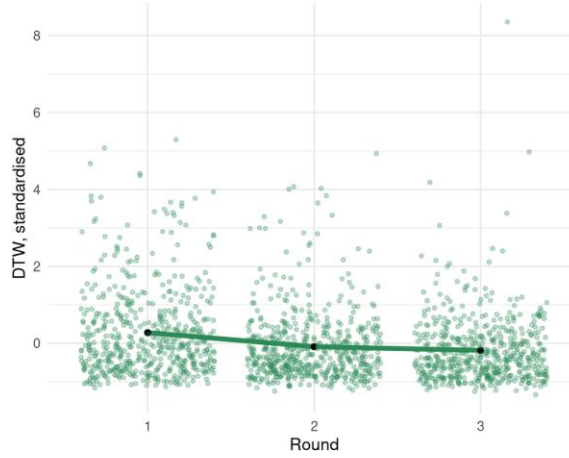

Figure 1 Change in standardized dynamic time warping distance between rounds of the game.

3.4. Results

To answer Research Question 1, that is to estimate whether participants express metaphorical meanings through mappings, we fitted a mixed effects generalized linear regression model to the data. Our modeling procedure followed the principles outlined by Barr and colleagues (2013) in that we attempted to fit a maximal random effects structure justified by the design of the study that the data from our study could support. We rejected models that resulted in a singular fit or that did not converge. The maximal model in our case was one with a random intercept for the participant and one for the meaning that the participants had to communicate. Hence, our model controls for random individual variation across these variables.

We first modeled the influence of round on the similarity of movements between concrete and metaphorical meanings. The similarity was operationalized as shapeDTW distance (see Section 3.3 for a definition), and the lower the distance, the greater the similarity between two pantomimes. The shapeDTW distance values were divided by the total number of tracked joints in order to obtain a normalized value and standardized. We also recoded the round variable using the backward difference coding scheme, which means that the values in the table reflect the difference between subsequent levels of the round variable. Table 2 and Fig. 1 show the change in shapeDTW between rounds and Figs. 2 and 3 illustrate specific DTW plots from the first round and the last round of the game.

The model indicates a negative relationship between distance of concrete and metaphorical pantomimes and the round predictor. The distance decreases between the second and the first round of the game (estimate = −0.35, $P = 0.01$). The same can be observed between the third and the second round of the game (estimate = −0.09, $P = 0.03$).

To answer Research Question 2, related to usualization across the variables mentioned in Section 3.3, we fitted three separate models, with the usualization variable as the outcome variable and round and metaphorical status of the meaning (metaphorical vs nonmetaphorical) as the predictor variables. The outcome variables were standardized. The random effects structure was similar to the shape dynamic time warping models, but with a random

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

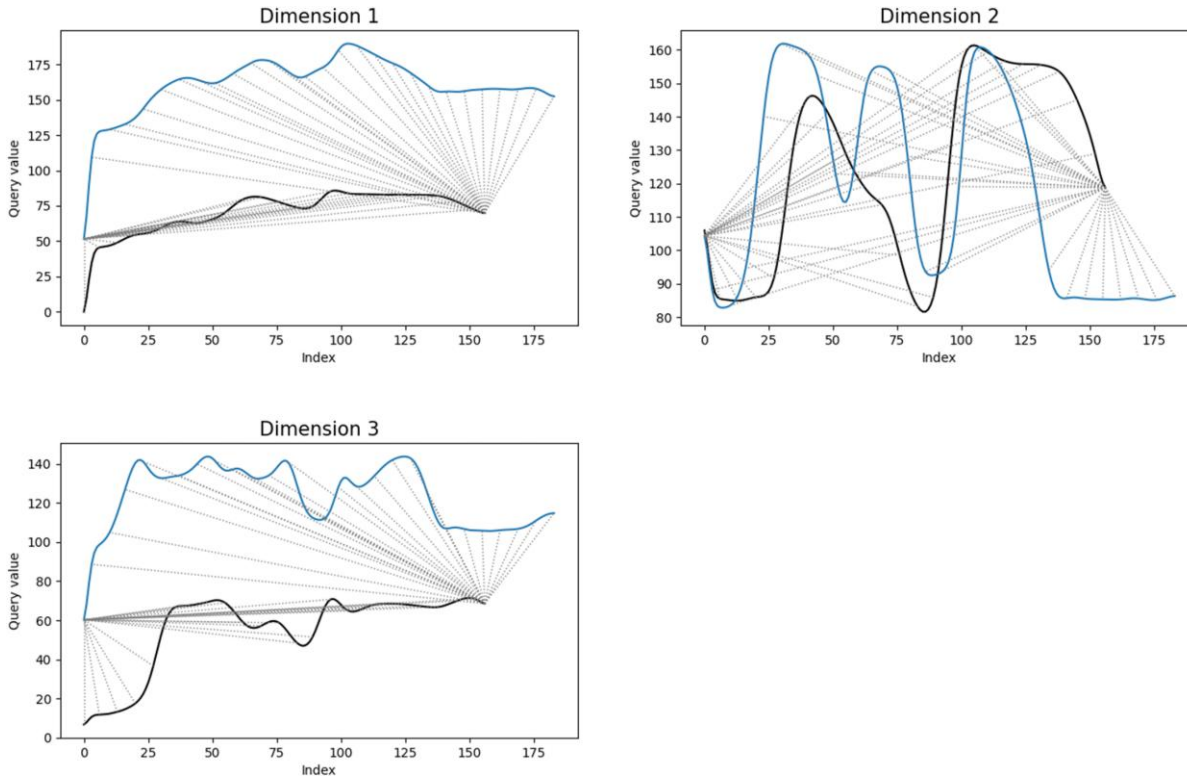

Figure 2 Dynamic time warping plot for "to throw an idea" and "to throw a ball" in the first round of the game. Normalized shape dynamic time warping for this pair of pantomimes is 80.

intercept added for the dyad as well. We also coded the round predictor using backward difference coding. The model intercept is the model's grand mean, i.e. the expected outcome when all backward-difference contrasts equal 0. See Table 3 and Fig. 4 for the results of fitting the model with the bounding box as the outcome variable.

The model indicates that there is a significant difference in terms of the bounding box of movement volume between the first and the second round of the game for concrete meanings (estimate = −0.18, $P = 0.02$), but the BBMV does not decrease statistically significantly between the second and the third round of the game. The results of the model also suggest that, overall, metaphorical meanings occupy more space (estimate = 0.30, $P = 0.02$). In addition, metaphorical pantomimes do not reduce in terms of volume between rounds: all contrasts are statistically insignificant.

The third model conditioned path on round. See Table 4 and Fig. 5 for the results. See also Figs 6 and 7 for a visualization of right hand movement from a single participant from the first and the final round of the game.

The model we fit to the data shows that movement path decreases significantly across all rounds of the game for concrete actions (Round 2 – Round 1 estimate = −0.60, $P = 0.01$; Round 3 – Round 2 estimate = −0.13, $P = 0.01$). The results of the model also suggest that overall metaphorical meanings result in pantomimes in which joints traverse larger distances (estimate = 0.32, $P = 0.02$), and that this distance decreases between the second and the first round of the game (estimate = −0.29, $P = 0.01$), but there is no significant difference between the second and the third round of the game. The third model conditioned speed on round. See Table 5 and Fig. 8 for the results.

The model we fit to the data shows that movement speed increases significantly across all rounds of the game for concrete actions (Round 2 – Round 1 estimate = 0.42, $P = 0.01$; Round 3 – Round 2 estimate = 0.31, $P = 0.01$). The results of the model also suggest no difference between metaphorical and nonmetaphorical meanings in terms of speed in Round 1. Speed does not change significantly across rounds in the metaphorical condition.

We finally model the influence of round and status of the meaning (metaphorical or not) on guessing time to answer Research Question 3. The model output is shown in Table 6 and visualized in Fig. 9.

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

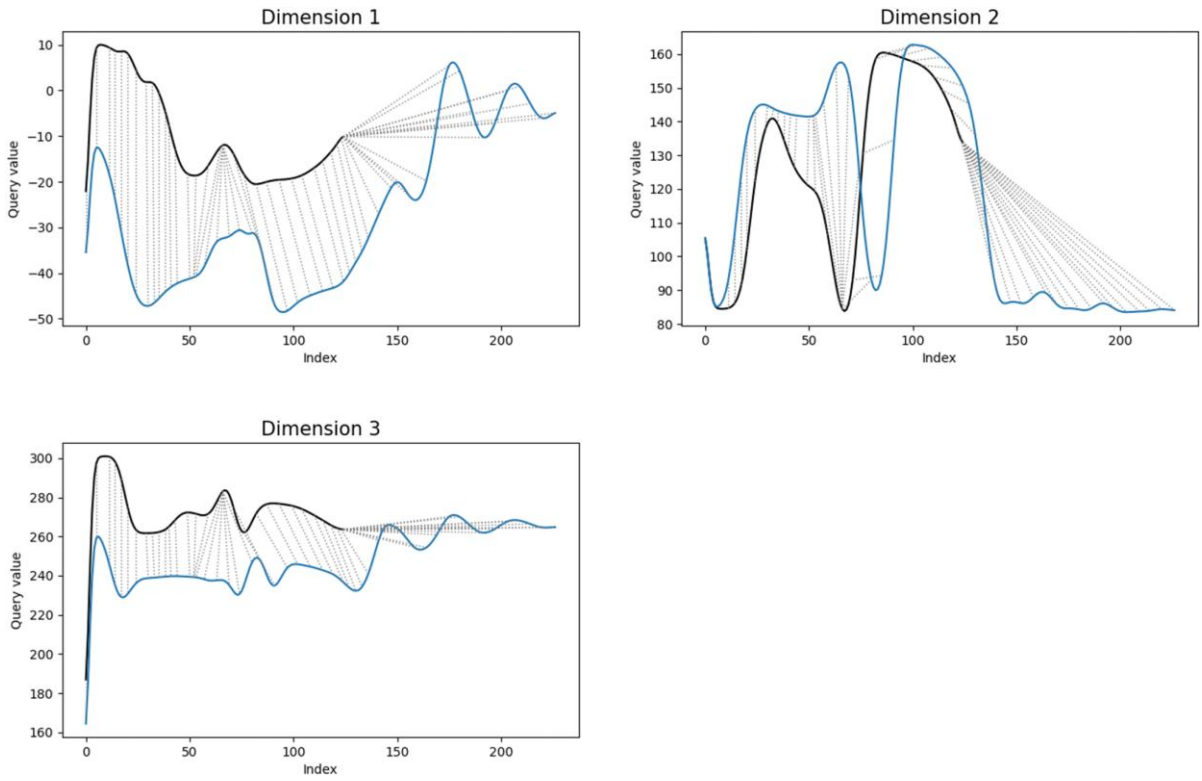

Figure 3 Dynamic time warping plot for "to throw an idea" and "to throw a ball" in the third round of the game. Normalized shape dynamic time warping for this pair of pantomimes is 50.

Table 3 The influence of round and metaphorical status on the bounding box of movement volume.

	Estimate	Std. error	Df	*t* value	*P*
Intercept	−0.08	0.13	22.51	−0.62	0.54
Round 2 – Round 1, concrete meaning	−0.18	0.06	2,055.40	−2.28	0.02
Round 3 – Round 2, condcrete meaning	0.01	0.06	2,050.34	−0.19	0.85
Metaphorical meaning	0.30	0.10	18.00	2.77	0.02
Round 2 – Round 1, metaphorical meaning	−0.10	0.08	2,050.49	−1.28	0.20
Round 3—Round 2, metaphorical meaning	−0.12	0.08	2,050.40	−1.47	0.14

The model shows significant results across all predictors and interactions and aligns with our predictions. Metaphorical meanings took longer to guess at the beginning of the experiment (estimate = 0.31). Guessing times decreased across rounds for both nonmetaphorical referents (Round 2 – Round 1 estimate = −0.64; Round 3 – Round 2 estimate = −0.12) and metaphorical ones (round 2 – round 1 estimate = −0.29; round 3 – round 2 estimate = −0.15), though with a much steeper slope for the nonmetaphorical meanings between the first and the second round of the game.

4. Discussion

In this article, we aimed to address three research questions about the dynamics of concrete and metaphorical expressions in pantomimic communication: RQ1: whether we will observe metaphorical mapping; RQ2: whether, in both types of meaning, we will observe the same trajectory of usualization; and RQ3: whether processing effort will decrease and, if so, whether in the same manner for both types of meaning. For RQ1, we operationalized mapping as shape dynamic time warping

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

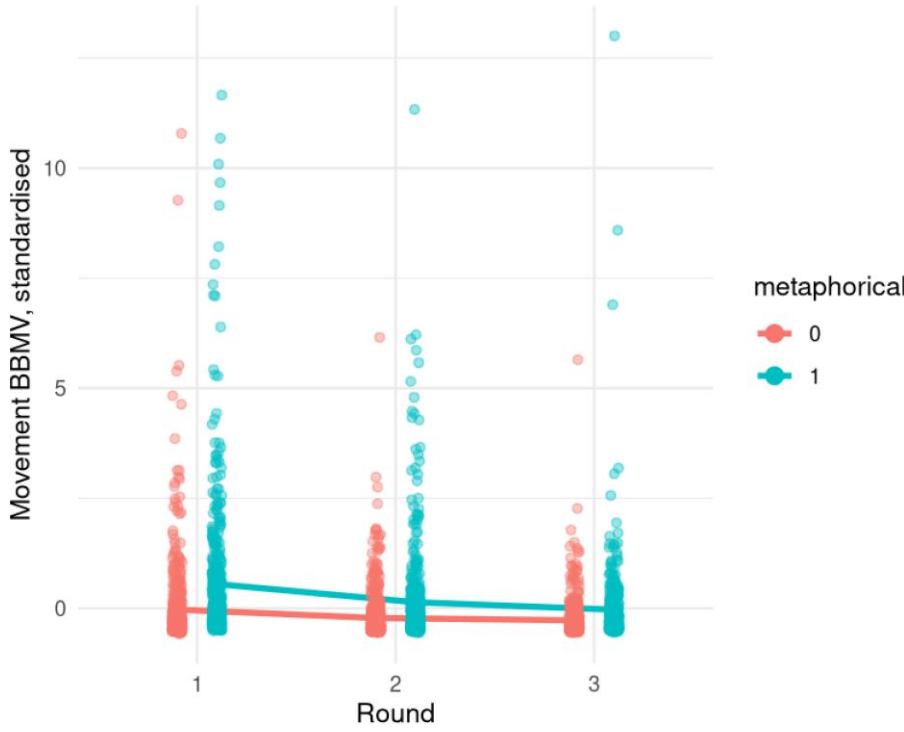

Figure 4 Bounding box of movement volume for metaphorical and nonmetaphorical meanings over rounds.

Table 4 The influence of round on the path of movements.

	Estimate	Std. error	df	*t* value	*P*
Intercept	−0.12	0.10	39.21	−1.22	0.22
Round 2 – Round 1, concrete meaning	−0.60	0.04	3,243.23	−13.70	0.01
Round 3 – Round 2, concrete meaning	−0.13	0.05	3,242.43	−3.05	0.01
Metaphorical meaning	0.32	0.12	18.00	2.69	0.02
Round 2 – Round 1, metaphorical meaning	−0.29	0.06	3,240.83	−4.45	0.01
Round 3 – Round 2, metaphorical meaning	−0.09	0.06	3,240.77	−1.49	0.13

distance between two movements and observed that it decreases over rounds of the game. We take this as an index of mapping from the concrete, providing a positive answer to RQ1, namely that participants do make metaphoric mappings from concrete to abstract in pantomimic communication. RQ2 and RQ3 can be seen as two faces of the same general process, that is, communicative efficiency. On the one hand, we expected more economical movements (RQ2), and, on the other, greater communicative success (RQ3), quantified respectively as kinematic properties and response time. While we observed lower response times over rounds for both meaning types, the answer to RQ2 is more complex: we see a decreased path and volume of movement and an increased speed for concrete meanings, but the results for metaphorical meanings are not uniform. We discuss this below.

The models for RQ2 suggest a complex pattern of results. On the one hand, forms representing concrete meanings recapitulate findings from other experimental semiotic studies: notably, movement space becomes reduced, both in terms of path and bounding box of movement volume (Namboodiripad et al. 2016; ANONYMOUS 3) while speed increases (Żywiczyński et al. 2024); on the other, forms representing metaphorical meanings do so only partially.

The results described in Section 3.4 indicate a reduction in signing space for concrete actions across the first two rounds of the experiment (operationalized as the

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

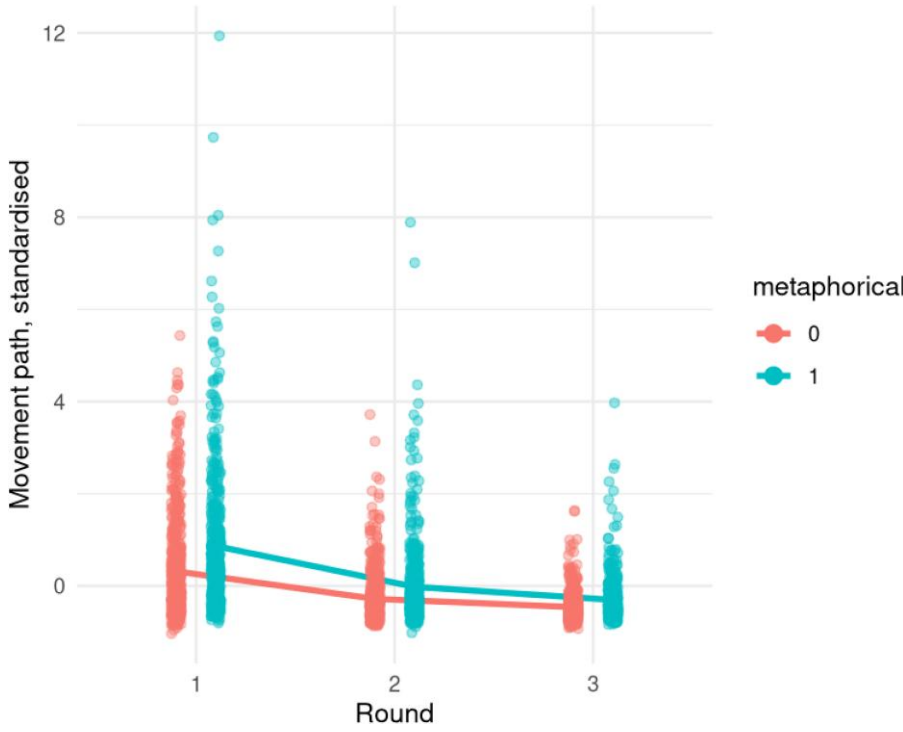

Figure 5 Movement path for metaphorical and nonmetaphorical meanings over rounds.

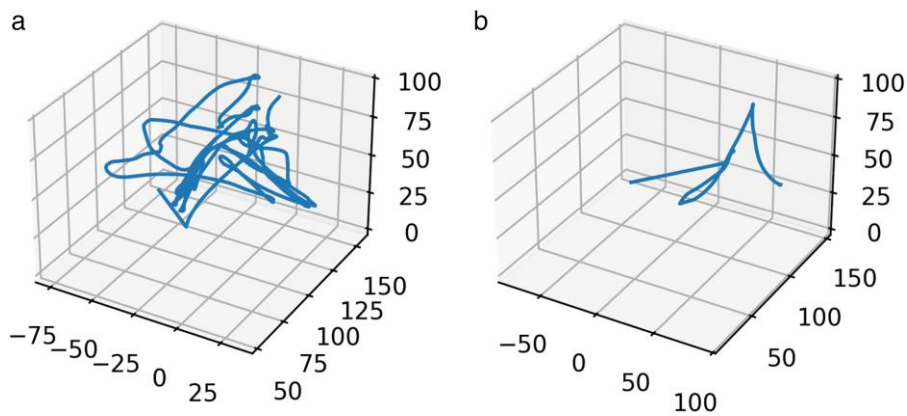

Figure 6 Movement of the right hand in the first (a) and the final (b) round of the game from the same participant for "to lift up a child".

bounding box of movement volume, see Table 3 and Fig. 4). The same trend was observed for the total distance traversed by the articulators, but across all rounds: each round of the game resulted in a significant decrease in terms of distance. The metaphorical forms take up more gesture space and more distance from the outset. Their path decreases from Round 1 to Round 2, but their slope is less steep in comparison with concrete meanings (estimate for concrete meanings = –0.60 vs estimate for metaphorical meanings = –0.29). Path remains at a constant level between the second and the third round of the game in the case of forms representing metaphorical

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

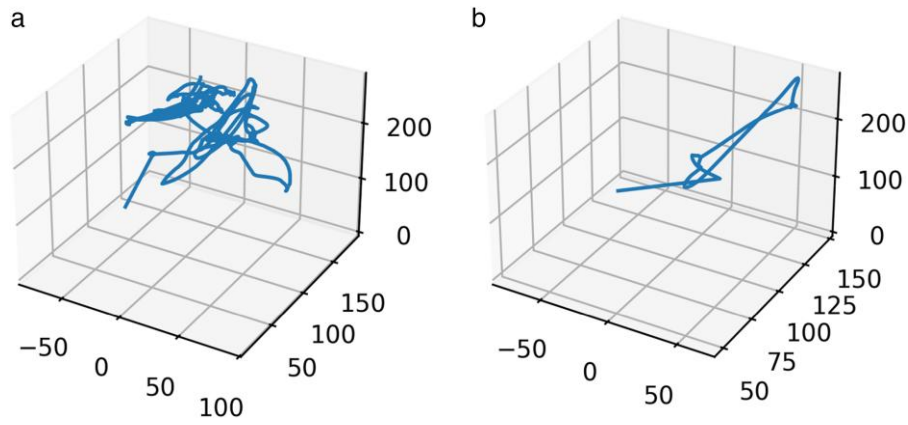

Figure 7 Movement of the right hand in the first (a) and the final (b) round of the game from the same participant for " to raise prices".

Table 5 The influence of round on the speed of movements.

	Estimate	Std. error	Df	*t* value	*P*
Intercept	−0.03	0.14	36.15	−0.26	0.79
Round 2 – Round 1, concrete meaning	0.42	0.06	2,060.16	7.75	0.01
Round 3 – Round 2, concrete meaning	0.31	0.05	2,052.08	5.73	0.01
Metaphorical meaning	0.10	0.17	18.00	0.60	0.56
Round 2 – Round 1, metaphorical meaning	0.13	0.09	2,052.17	1.69	0.09
Round 3—Round 2, metaphorical meaning	0.11	0.08	2,052.12	1.35	0.18

meanings. Volume only changes significantly for concrete meanings from Round 1 to Round 2, but not from Round 2 to Round 3, and it does not change significantly for metaphorical meanings at all. Metaphorical meanings become simplified in terms of smaller path trajectories; however they are still "exaggerated" compared to concrete actions, as their volume and speed do not change. Across rounds, participants use similar forms in concrete and metaphorical mappings, suggesting that they map the concrete meaning to a metaphorical meaning.

As we can observe, at the beginning concrete meanings and metaphorical meanings initially follow similar usualization trajectories from Round 1 to Round 2 in terms of path. Just as concrete meanings, metaphorical meanings require more space and energy at the beginning of the experiment and then they get reduced, with the difference that the expression of metaphorical meanings initially takes more space. These overall results are in line with work on communicative efficiency in social interaction, which has been shown to operate across modalities (Rasenberg et al. 2022). For example, both signs in signed languages as well as gestures tend to become optimized and exhibit reduction in kinematic effort (Napoli et al. 2014; Napoli and Liapis 2019). As shown in previous research, for example, pressures for communicative efficiency and optimization also operate on miniature lexicons (Kanwal et al. 2017). In addition, formal reduction is also a result of the routinization and automatization of articulation (Bybee 2010; Divjak 2019; Levshina 2022), which is likely another factor explaining the overall reduction found in our experiment. Repetition in discourse tends to lead to reduction in articulation. For example, a word that is mentioned in discourse a second time becomes phonetically reduced (Fowler and Housum 1987).

However, after Round 2 the trajectories of concrete and metaphorical meanings differ, with the latter exhibiting no further changes in path. Concrete meanings, in contrast, continue to exhibit significant change across speed and path for the whole duration of the experiment. This is in line with our predictions for RQ2, namely that the trajectory of metaphorical meanings will differ from that of concrete meanings. This can be interpreted in line with the career of metaphor hypothesis and suggests that metaphorical meanings usualise and conventionalize differently from concrete meanings.

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

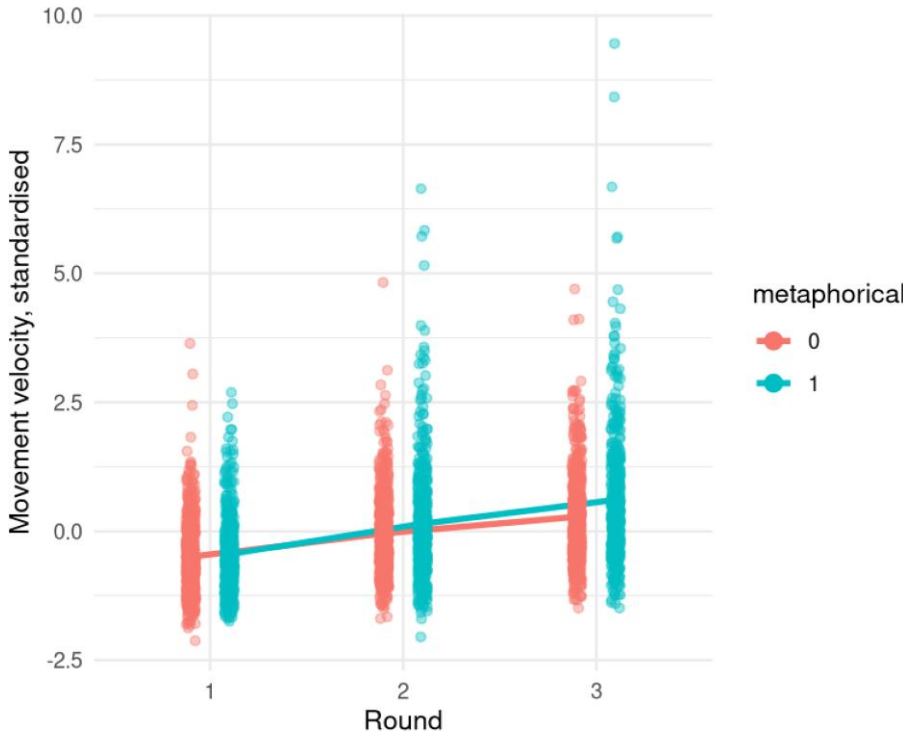

Figure 8 Movement speed for metaphorical and nonmetaphorical meanings over rounds.

Table 6 The influence of round and status (metaphorical or not) on successful guessing time. .

Term	Estimate	Std. error	df	*t* value	*P*
Intercept	−0.11	0.09	40.87	−1.15	0.25
Round 2 – Round 1, concrete meaning	−0.64	0.04	3,012.03	−14.60	0.01
Round 3 – Round 2, concrete meaning	−0.12	0.04	3,012.17	−2.77	0.01
Metaphorical meaning	0.31	0.12	17.99	2.58	0.02
Round 2 – Round 1, metaphorical meaning	−0.29	0.06	3,010.10	−4.29	0.01
Round 3 – Round 2, metaphorical meaning	−0.15	0.06	3,010.00	−2.227	0.03

We argue that this is the case because after 3 rounds of the experiments, metaphors have not reached the status of being processed and expressed as simple categorization statements, but still as metaphorical conceptual mappings. For example, as long as they are not conventionalized or sufficiently contextually supported, metaphorical mappings can also activate literal meanings that have to be inhibited, which demands cognitive processing effort (Sana et al. 2021). It also requires more cognitive effort to translate metaphors between languages than literal meanings (Liu et al. 2025), and the task participants faced arguably involved a form of "translating" a metaphorical statement in Polish into a novel pantomimic expression. Therefore, the existing evidence suggests that the metaphorical mappings participants had to express are cognitively more demanding than the expression of categorical concrete expressions.

Concrete meanings overall are more accessible, which might be the reason why they undergo more reduction than metaphorical meanings. This is in line with research on communicative efficiency in spoken languages showing that forms with higher meaning accessibility, that is accessibility in semantic and pragmatic interpretation, tend to get reduced in form phonetically, leading to formal reduction (Levshina 2022: 119). This means that the less costly form of an expression tends to express the

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

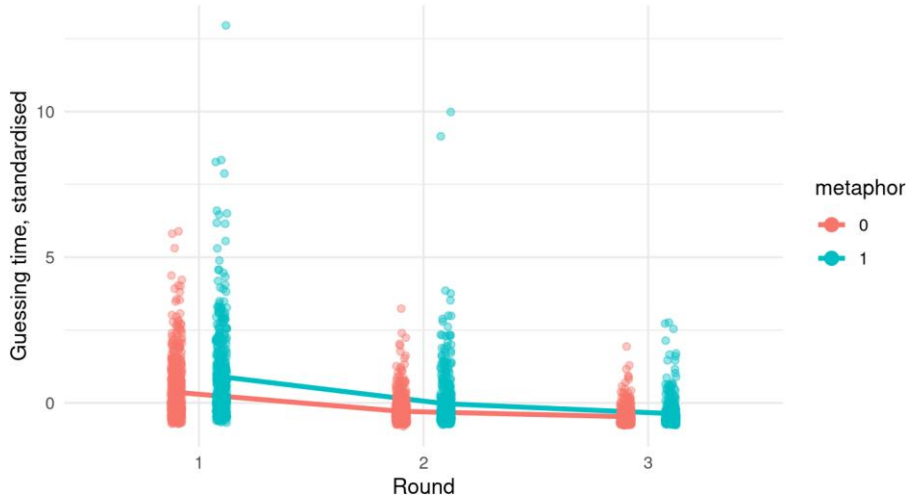

Figure 9 Guessing time for metaphorical and nonmetaphorical meanings over rounds.

more accessible meaning, and the form that is more costly represents the category whose meaning is less accessible (Levshina 2022: 134).

The difference in meaning accessibility of concrete versus metaphorical expressions can therefore be seen as one of the reasons why metaphorical meanings show less reduction than concrete meanings. Overall, then, these arguments make it likely that such factors influencing communicative efficiency can explain both the overall reduction after Round 1, but also the difference in form reduction between concrete vs metaphorical meanings observed in this experiment from Round 2 to 3. In fact, this is also in line with research on artificial language learning showing that learners tend to mark less accessible meanings in some way (Kurumada and Grimm 2019), which serves as a further potential explanation why metaphorical expressions remain less reduced and therefore more marked in our experiment.

The results for speed follow the same distinct trajectories of concrete vs metaphorical meaning as for the bounding box of movement volume. For concrete meanings, the speed of movements increases across all rounds of the game, whereas for metaphorical meanings it does not. This result confirms evidence from a study which compared the performance of actual actions (praxis) with demonstrative and communicative actions (Żywiczyński et al. 2024). In that study, the speed of movement in the communicative condition was not different from the praxic condition, but was slower in the demonstrative condition. Our results indicate that the grounding of concepts for metaphorical meanings resembled demonstration more throughout the whole experiment—it was more exaggerated, as described above—and slower.

Another avenue of explaining the differences in the trajectories of concrete vs metaphorical meanings can be found when we look at the cognitive demand of metaphorical mappings in the kinematic domain, specifically. Our previously mentioned argument that the differences in usualization and less reduced kinematic features are due to the higher cognitive and communicative effort of metaphorisation receives additional support from Taub's (2001) theory of metaphorical signs in signed languages. According to Taub (2001), gestural-kinematic expressions of metaphorical meanings are cognitively more demanding when compared to direct iconic mappings of the kind found in the concrete pantomimic mappings found in our experiment. Such metaphorical expressions are argued to be more cognitively complex because they represent a double mapping process.

While Taub's (2001) analog building model was developed to model the process of iconic mappings in sign languages, it can be adapted to also explain this process in the pantomimic domain. In this model, producers first perform *image selection* by choosing a mental image that is associated with the concept to be communicated (e.g. the iconic sign TREE in ASL). Producers then *schematize* essential features of the mental image for production. For iconic signs in signed languages, the schema is then *encoded* by using parameters of Sign Language Phonology, such as handshape, location, movement, and palm orientation.

The key difference to pantomimic representations is that signed languages are fully fledged languages with conventionalized articulation parameters, whereas for pantomimic representations this encoding onto the visual-bodily kinematic dimension is *ad hoc*. However, an adaptation of the analog building model can be

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

used to explain iconic mappings in pantomime, such as the ones that participants in our experiment performed when communicating concrete meanings. Importantly, metaphorical signs require an additional step in Taub's (2001) model, which indicates that they are more complex communicatively and cognitively in terms of processing. Specifically, she argues that the steps of image selection, schematization, and encoding are preceded by a conceptual mapping step. This means that to communicate an abstract meaning, first an abstract target concept has to be mapped onto a concrete source concept. After that, the source concept is given an appropriate mental image and is then mapped iconically onto a visual-kinematic representation. In other words, on this view, bodily kinematic metaphors involve both conceptual metaphorical mapping and iconic mapping (Taub 2001; Kaneko and Sutton-Spence 2017). As the expressions of concrete meanings via pantomime only require iconic mapping, they are cognitively less complex and less demanding, which we propose is one of the factors influencing their further articulatory and spatial reduction compared to metaphorical pantomimic expressions.

While these explanations have independent evidential support from various strands of literature and therefore have the potential to explain the observed patterns in the data, it has of course to be acknowledged that other interpretations are possible. Specifically, we did not directly measure the processing demands, cognitive complexity and accessibility of the concrete vs metaphoric stimuli participants had to express, and did not independently establish these measures for our stimuli through other methods. This means that while our interpretations and suggestions of factors influencing the patterns we found are consistent with the existing evidence, more research is needed to validate them. One important question for future research is therefore how to precisely explain the differences and similarities in the trajectories of concrete vs metaphorical mappings. Specifically, this concerns the pattern that concrete and metaphorical meanings initially show similar trajectories of change for path, but then diverge. Concrete meanings keep changing, while metaphorical meanings plateau. It is possible that pressures for communicative efficiency initially exert a strong pressure for kinematic reduction, which is then slowed down or stopped at a certain point due to the lower accessibility and higher cognitive processing cost of metaphoric expressions after a certain number of repetitions. However, the interaction of communicative efficiency, kinematic reduction, and accessibility and complexity needs to be investigated in more detail in future work to see if this is really the case. We also have to add a caveat that with regard to our appeal to communicative efficiency, while we saw a reduction in movement parameters, and a reduction in successful guessing time across rounds, we did not directly measure the processing effort of the recipient. Definitions of communicative efficiency (e.g. Levshina and Moran 2021) usually take into account both reduction in production effort (which we observed, to different degrees, in both concrete and metaphoric expressions), and reduction in processing effort (which can partially but not fully be captured by the decrease in guessing time).

Future work should also try to disentangle more precisely which aspects of the metaphorical expression hinder the further change of kinematic parameters. In our discussion of how to explain the results, we assumed that it is the metaphorical nature of the expression, that is of the metaphorical mapping to be expressed, that is the reason for the observed differences between concrete and metaphoric pantomimes. However, it is also possible that it is the presence of abstract words (such as "ball" vs "idea" in *podrzucić piłkę*, eng. "to throw a ball," vs *podrzucić pomysłm* eng. "to throw an idea") itself that is responsible for this. Both views are consistent with our analysis, as our main argument is that it is the accessibility and complexity of the metaphoric mapping that is the influential factor, but future work should try to disentangle whether the difference in accessibility and complexity related to the mapping of the entire conceptual situation, or the mapping of a particular abstract concept.

It also has to be noted that, as we were mostly interested in differences in usualization between concrete vs abstract/metaphorical uses, we asked participants to communicate conventionalized concrete and metaphorical meanings of expressions in Polish. That is, participants were in a way primed to use particular conceptual metaphorical mappings to successfully communicate meanings. We have shown that metaphorical meanings can be expressed in an experimental semiotic communication game design using pantomime. From an evolutionary perspective this also indicates a potential pathway for metaphoric expressions in a possible pantomimic stage of language evolution. This is of central importance for evolutionary accounts because it gives an answer to the key question of how an initial communication system based on concrete meanings could have been expanded to express nonconcrete meanings. Here we show that metaphorical extension of concrete meanings can also be achieved in a pantomimic communication game. However, even though our experiment shows that metaphoric pantomimic expressions can emerge, due to our prompting we cannot show that the particular conceptual mappings we had participants communicate about would also have emerged without prompts and existing conventionalized linguistic

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

mappings. For example, one of the meanings we had participants communicate was *być zjedzonym przez stres* (eng. "to be eaten by stress"). However, in many existing sign languages the sign EAT cannot be used to express the abstract metaphorical meaning of consumption of that kind. This is due to what Meir (2010) calls the "double mapping constraint": A metaphorical mapping of an iconic form should preserve the structural correspondences of the iconic mapping. Double-mapping should be structure-preserving.

This also means that there are still open questions regarding RQ1, as the question remains what exactly it is that motivates the metaphorical mappings expressed via pantomime. However, even if the linguistic stimuli serve as primes for motivating the metaphoric mappings, the order in the experiment of concrete meanings being shown first and metaphoric meanings being shown second presumably recapitulates how these metaphoric meanings emerged in the history of Polish. This suggests that the metaphorical mappings participants were asked to express are conceptually salient and as the results show, in principle analogical similarities between a concrete and a metaphoric conceptual mapping can be expressed pantomimically, regardless of the exact motivations for metaphorical mappings, which however, should be further explored in future work.

Overall, our study supports approaches which have assigned a pivotal role to metaphor in the evolution of language (Smith and Höfler 2015; Knight and Lewis 2017; Gil and Shen 2021). Metaphor, in this view, can be seen as a generalizing process that licenses the emergence of new form-meaning pairings and their extension to new meanings. It can therefore be seen as an important factor leading to the emergence of a more complex, structured, semiotic system. Metaphor can thus be argued to have played an important role in the gradual transition from a protolinguistic stage to fully fledged language.

5. Conclusion

Our study investigated the differences in changes to the kinematic parameters of movements across successive rounds of dyadic pantomimic whole-body communication about concrete versus metaphorical meanings. In line with previous studies (Namboodiripad et al. 2016; Author et al. 2023) we found overall changes in kinematic parameters consistent with a process of routinization or usualization. The movement parameters of path and, for concrete meanings, bounding box of movement volume, were reduced with time. Over multiple rounds of interaction participants' movement became more efficient by undergoing reduction in the path traveled by the articulators and, for concrete meanings, by accelerating the velocity of movements.

However, we also found that these changes continued for longer and were more pronounced in later rounds for concrete versus metaphoric meanings. For concrete meanings, path reduction increase was evident across all rounds. In contrast, metaphorical meanings showed significant change only from Round 1 to Round 2, and then plateaued, or stabilized. This suggests that metaphoric meanings require some kind of differentiation from concrete meanings which in a way "blocks" their further kinematic reduction and overall speed, and that further automation and routinization might also be hindered by the lower accessibility and higher cognitive complexity of metaphoric mappings.

Our study shows that in principle both concrete and metaphoric meanings can be expressed, and become more socially coordinated, usualized and structured in pantomimic communication, but that the trajectories of conventionalization and structuring differ between concrete versus metaphoric conceptualizations. This in turn has important implications for the "career of metaphor" and subsequent conventionalizations of concrete and metaphoric conceptualizations.

Acknowledgements

We would like to acknowledge the support of our assistants, Mahzad Berenji, Klaudia Karkowska, Darya Namednikava, Julia Zaborowska, and Antoni Żyndul, who assisted us with data collection. We would like to express our gratitude for Miłosz Zieliński and Piotr Zimmerman for assisting with data extraction.

Conflicts of interest

None declared.

Funding

This research is part of the project No. 2021/43/P/HS2/02729 co-funded by the National Science Centre and the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement no. 945339.

Data availability

All data and code used for the purposes of this publication is available under this link: https://osf.io/gvqpw

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

References

Allan, K. and Robinson, J. A. eds. (2012) *Current Methods in Historical Semantics*. Berlin: De Gruyter.

Anderson, W. (2017) 'Metaphor and Diachronic Variation', in E. Semino and Z. Demjén, (eds.) *Routledge Handbook of Metaphor and Language*, pp. 233–46. New York: Routledge.

Barr, D. J. et al. (2013) 'Random Effects Structure for Confirmatory Hypothesis Testing: Keep it Maximal', *Journal of Memory and Language*, 68: 255–78. https://doi.org/10.1016/j.jml.2012.11.001

Bowdle, B. F. and Gentner, D. (2005) 'The Career of Metaphor', *Psychological Review*, 112: 193–216. https://doi.org/10.1037/0033-295X.112.1.193

Bowerman, J. and Smith, K. (2022) 'An Experimental Study of Semantic Extension in a Novel Communication System', *Proceedings of the Annual Meeting of the Cognitive Science Society*, Vol. 44, pp. 163–9. Austin, TX: Cognitive Science Society.

Brennan, S. E. and Clark, H. H. (1996) 'Conceptual Pacts and Lexical Choice in Conversation', *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 22: 1482–1493. https://doi.org/10.1037/0278-7393.22.6.1482

Brysbaert, M. et al. (2016) 'How Many Words Do We Know? Practical Estimates of Vocabulary Size Dependent on Word Definition, the Degree of Language Input and the Participant's Age', *Frontiers in Psychology*, 7: 1116. https://doi.org/10.3389/fpsyg.2016.01116

Bybee, J. (2010) *Language, Usage and Cognition*. Cambridge: Cambridge University Press.

Cienki, A. and Müller, C. (2008) *Metaphor and Gesture*. Amsterdam: John Benjamins Publishing Company.

Clark, H. H. and Wilkes-Gibbs, D. (1986) 'Referring as a Collaborative Process', *Cognition*, 22: 1–39. https://doi.org/10.1016/0010-0277(86)90010-7

Dąbrowska, E. and Divjak, D. eds. (2015) *Handbook of Cognitive Linguistics*. Berlin: De Gruyter.

D'Anna, C. A., Zechmeister, E. B. and Hall, J. W. (1991) 'Toward a Meaningful Definition of Vocabulary Size', *Journal of Reading Behavior*, 23: 109–22. https://doi.org/10.1080/10862969109547729

Delliponti, A. et al. (2023) 'Experimental Semiotics: A Systematic Categorization of Experimental Studies on the Bootstrapping of Communication Systems', *Biosemiotics*, 16: 291–310. https://doi.org./10.1007/s12304-023-09534-x

Divjak, D. (2019) *Frequency in Language: Memory, Attention and Learning*. Cambridge: Cambridge University Press.

Ellison, T. M. and Reinöhl, U. (2022) 'Compositionality, Metaphor, and the Evolution of Language', *International Journal of Primatology*, 45, 703–19. https://doi.org/10.1007/s10764-022-00315-w

Erben Johansson, N., Carr, J. W. and Kirby, S. (2021) 'Cultural Evolution Leads to Vocal Iconicity in an Experimental Iterated Learning Task', *Journal of Language Evolution*, 6: 1–25. https://doi.org/10.1093/jole/lzab001

Escudero-Arnanz, Ó et al. (2023) 'dtwParallel: A Python Package to Efficiently Compute Dynamic Time Warping Between Time Series', *SoftwareX*, 22: 101364. https://doi.org/10.1016/j.softx.2023.101364

Esling, P. and Agon, C. (2012) 'Time-series Data Mining', *ACM Computing Surveys*, 45: 12:1–12:34. https://doi.org/10.1145/2379776.2379788

Fay, N. et al. (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

Flaherty, M., Sato, A. and Kirby, S. (2023) 'Documenting a Reduction in Signing Space in Nicaraguan Sign Language Using Depth and Motion Capture', *Cognitive Science*, 47: e13277. https://doi.org/10.1111/cogs.13277

Floyd, S. and Goldberg, A. E. (2021) 'Children Make use of Relationships Across Meanings in Word Learning', *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 47: 29–44. https://doi.org/10.1037/xlm0000821

Fowler, C. A. and Housum, J. (1987) 'Talkers' Signaling of "New" and "Old" Words in Speech and Listeners' Perception and Use of the Distinction', *Journal of Memory and Language*, 26: 489–504. https://doi.org/10.1016/0749-596X(87)90136-7

Galantucci, B., Garrod, S. and Roberts, G. (2012) 'Experimental Semiotics', *Language and Linguistics Compass*, 6: 477–493. https://doi.org/10.1002/lnc3.2012.6.issue-8

Garrod, S. et al. (2007) 'Foundations of Representation: Where Might Graphical Symbol Systems Come From?', *Cognitive Science*, 31: 961–87. https://doi.org/10.1080/03640210701703659

Geeraerts, D. and Cuyckens, H. eds. (2007) *The Oxford Handbook of Cognitive Linguistics*. Oxford: Oxford University Press.

Gentner, D. and King, D. (2024) 'The Career of Verb Metaphor: Language Evolution Parallels Online Processing Differences Between Nouns and Verbs', in J. Nölle, L. Raviv, K. E. Graham, S. Hartmann, Y. Jadoul, M. Josserand, T. Matzinger, K. Mudd, M. Pleyer, A. Slonimska, S. Wacewicz and S. Watson, (eds.) *The Evolution of Language: Proceedings of the 15th International Conference (Evolang XV)*, pp. 202–208. Nijmegen: The Evolution of Language Conferences. https://doi.org/10.17617/2.3587960

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

Gil, D. and Shen, Y. (2021) 'Metaphors: The Evolutionary Journey from Bidirectionality to Unidirectionality', *Philosophical Transactions of the Royal Society B*, 376: 20200193. https://doi.org/10.1098/rstb.2020.0193

Giora, R. (1997) 'Understanding Figurative and Literal Language: The Graded Salience Hypothesis', *Cognitive Linguistics*, 8: 183–206. https://doi.org/10.1515/cogl.1997.8.3.183

Goulden, R., Nation, P. and Read, J. (1990) 'How Large Can a Receptive Vocabulary Be?', *Applied Linguistics*, 11: 341–63. https://doi.org/10.1093/applin/11.4.341

Gries, S. T. (2015) 'Polysemy', in E. Dabrowska, and D. Divjak, (eds.) *Handbook of Cognitive Linguistics*, pp. 472–90. Berlin: De Gruyter.

Hockett, C. F. (1960) 'The Origin of Speech', *Scientific American*, 203: 88–97. https://doi.org/10.1038/scientificamerican0960-88

Kaneko, M. and Sutton-Spence, R. (2017) 'Metaphor in sign language'*The Routledge Handbook of Metaphor and Language*, pp. 263–280. New York: Routledge.

Kanwal, J. et al. (2017) 'Zipf's Law of Abbreviation and the Principle of Least Effort: Language Users Optimise a Miniature Lexicon for Efficient Communication', *Cognition*, 165: 45–52. https://doi.org/10.1016/j.cognition.2017.05.001

Kirby, S. et al. (2015) 'Compression and Communication in the Cultural Evolution of Linguistic Structure', *Cognition*, 141: 87–102. https://doi.org/10.1016/j.cognition.2015.03.016

Kirton, F. et al. (2021) 'Constituent Order in Silent Gesture Reflects the Perspective of the Producer', *Journal of Language Evolution*, 6: 54–76. https://doi.org/10.1093/jole/lzaa010

Knight, C. and Lewis, J. D. (2017) 'Wild Voices: Mimicry, Reversal, Metaphor, and the Emergence of Language', *Current Anthropology*, 58: 435–53. https://doi.org/10.1086/692905

Kövecses, Z. (2010) *Metaphor: A Practical Introduction*, 2nd ed. Oxford: Oxford University Press.

Kövecses, Z. (2020) *Extended Conceptual Metaphor Theory*. Cambridge: Cambridge University Press.

Kurumada, C. and Grimm, S. (2019) 'Predictability of Meaning in Grammatical Encoding: Optional Plural Marking', *Cognition*, 191: 103953. https://doi.org/10.1016/j.cognition.2019.04.022

Lakoff, G. and Johnson, M. (1980) *Metaphors We Live by*. Chicago: University of Chicago Press.

Levshina, N. (2022) *Communicative Efficiency: Language Structure and Use*. Cambridge: Cambridge University Press. https://doi.org/10.1017/9781108887809.

Levshina, N. and Moran, S. (2021) 'Efficiency in Human Languages: Corpus Evidence for Universal Principles', *Linguistics Vanguard*, 7: 20200081. https://doi.org/10.1515/lingvan-2020-0081

Liu, T. et al. (2025) 'Exploring Cognitive Effort and Divergent Thinking in Metaphor Translation Using Eye-Tracking and EEG Technology', *Scientific Reports*, 15: 18177. https://doi.org/10.1038/s41598-025-03248-5

Meir, I. (2010) 'Iconicity and Metaphor: Constraints on Metaphorical Extension of Iconic Forms', *Language*, 86: 865–96. https://doi.org/10.1353/lan.2010.0044

Namboodiripad, S. et al. (2016) 'Measuring Conventionalization in the Manual Modality', *Journal of Language Evolution*, 1: 109–18. https://doi.org/10.1093/jole/lzw005

Napoli, D. J. and Liapis, S. (2019) 'Effort Reduction in Articulation in Sign Languages and Dance', *Journal of Cultural Cognitive Science*, 3: 31–61. https://doi.org/10.1007/s41809-019-00027-3

Napoli, D. J., Sanders, N. and Wright, R. (2014) 'On the Linguistic Effects of Articulatory Ease, with a Focus on Sign Languages', *Language*, 90: 424–56. https://doi.org/10.1353/lan.2014.0026

Nölle, J. and Galantucci, B. (2023) 'Experimental Semiotics: Past, Present, and Future', in A. M. G. A. Ibáñez, (ed.) *The Routledge Handbook of Semiosis and the Brain*, pp. 66–81. New York: Routledge.

Peirce, J. W. et al. (2019) 'PsychoPy2: Experiments in Behavior Made Easy', *Behavior Research Methods*, 51: 195–20. https://doi.org/10.3758/s13428-018-01193-y

Placiński, M. et al. (2023) 'Evolution of Pantomime in Dyadic Interaction. A Motion Capture Study', *Journal of Language Evolution*, 8: 134–148. https://doi.org/10.1093/jole/lzad010

Planer, R. J. and Sterelny, K. (2021) *From Signal to Symbol: The Evolution of Language*. Cambridge, MA: MIT Press.

Pleyer, M. et al. (2025) 'The 'design features' of language revisited', *Trends in Cognitive Sciences*, xx: xx. https://doi.org/10.1016/j.tics.2025.10.004

Pleyer, M., Kuleshova, S. and Placiński, M. (2024a) 'Integrating Approaches to The Role of Metaphor in the Evolutionary Dynamics of Language', *Yearbook of the German Cognitive Linguistics Association*, 12: 145–176. https://doi.org/10.1515/gcla-2024-0007

Pleyer, M, Lepic, R. and Hartmann, S. (2024b) 'Compositionality in Different Modalities: A View from Usage-Based Linguistics', *International Journal of Primatology*, 45: 670–702. https://doi.org/10.1007/s10764-022-00330-x

Poddar, S., Kumar, V. and Kumar, A. (2017) 'A Comprehensive Overview of Inertial Sensor Calibration Techniques', *Journal of Dynamic Systems,*

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

Measurement, and Control, 139: 011006. https://doi.org/10.1115/1.4034419

Pouw, W. et al. (2021) 'A Systematic Investigation of Gesture Kinematics in Evolving Manual Languages in the Lab', *Cognitive Science*, 45: e13014. https://doi.org/10.1111/cogs.13014

Pouw, W. and Dixon, J. A. (2020) 'Gesture Networks: Introducing Dynamic Time Warping and Network Analysis for the Kinematic Study of Gesture Ensembles', *Discourse Processes*, 57: 301–9. https://doi.org/10.1080/0163853X.2019.1678967

Rasenberg, M. et al. (2022) 'The Multimodal Nature of Communicative Efficiency in Social Interaction', *Scientific Reports*, 12: 19111. https://doi.org/10.1038/s41598-022-22883-w

Rekant, J., Rothenberger, S. and Chambers, A. (2022) 'Inertial Measurement Unit-Based Motion Capture to Replace Camera-Based Systems for Assessing Gait in Healthy Young Adults: Proceed With Caution', *Measurement: Sensors*, 23: 100396. https://doi.org/10.1016/j.measen.2022.100396

Roberts, G. and Clark, R. (2020) 'Dispersion, Communication, and Alignment: An Experimental Study of the Emergence of Structure in Combinatorial Phonology', *Journal of Language Evolution*, 5: 121–39. https://doi.org/10.1093/jole/lzaa004

Ryan, M.-L. (2012) 'Narration in Various Media', in P. Hühn, J. C. Meister, J. Pier, and W. Schmid, (eds.) *The Living Handbook of Narratology*. Hamburg University.

Sakoe, H. and Chiba, S. (1978) 'Dynamic Programming Algorithm Optimization for Spoken Word Recognition', *IEEE Transactions on Acoustics, Speech, and Signal Processing*, 26: 43–9. https://doi.org/10.1109/TASSP.1978.1163055

Sana, F. et al. (2021) 'The Interplay Between Inhibitory Control and Metaphor Conventionality', *Memory & Cognition*, 49: 1267–84. https://doi.org/10.3758/s13421-021-01152-7

Sato, A., Kirby, S. and Flaherty, M. (2022) 'Language Emergence can Take Multiple Paths: Using Motion Capture to Track Axis use in Nicaraguan Sign Language', *Glossa: A Journal of General Linguistics*, 7: Article 1. https://doi.org/10.16995/glossa.6151

Schmid, H. -J. (2020) *The Dynamics of the Linguistic System: Usage, Conventionalization, and Entrenchment*. Oxford: Oxford University Press.

Sibierska, M. et al. (2023) 'Constraints on Communicating the Order of Events in Stories Through Pantomime', *Journal of Language Evolution*, 8: 18–32. https://doi.org/10.1093/jole/lzad008

Smith, A. D. and Höfler, S. (2015) 'The Pivotal Role of Metaphor in the Evolution of Human Language', in J. E. Díaz-Vera, (ed.) *Metaphor and Metonymy Across Time and Cultures: Perspectives on the Sociohistorical Linguistics of Figurative Language*, pp. 123–39. Berlin: De Gruyter.

Smith, K., Bowerman, J. and Smith, A. D. (2025) 'Semantic Extension in a Novel Communication System is Facilitated by Salient Shared Associations', *Cognition*, 261: 106129. https://doi.org/10.1016/j.cognition.2025.106129

Srinivasan, M. and Rabagliati, H. (2015) 'How Concepts and Conventions Structure the Lexicon: Cross-Linguistic Evidence from Polysemy', *Lingua*, 157: 124–52. https://doi.org/10.1016/j.lingua.2014.12.004

Stamp, R. et al. (2024) 'Kinect-ing the Dots: Using Motion-Capture Technology to Distinguish Sign Language Linguistic From Gestural Expressions', *Language and Speech*, 67: 255–76. https://doi.org/10.1177/00238309231169502

Stampoulidis, G., Bolognesi, M. and Zlatev, J. (2019) 'A Cognitive Semiotic Exploration of Metaphors in Greek Street Art', *Cognitive Semiotics*, 12: 20192008. https://doi.org/10.1515/cogsem-2019-2008

Sweetser, E. (1990) *From Etymology to Pragmatics: Metaphorical and Cultural Aspects of Semantic Structure*. Cambridge: Cambridge University Press.

Taub, S. F. (2001) *Language from the Body: Iconicity and Metaphor in American Sign Language*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511509629.

Trujillo, J. P. et al. (2020) 'The Communicative Advantage: How Kinematic Signaling Supports Semantic Comprehension', *Psychological Research*, 84: 1897–911. https://doi.org/10.1007/s00426-019-01198-y

Turner, N. E. and Katz, A. N. (1997) 'The Availability of Conventional and of Literal Meaning During the Comprehension of Proverbs', *Pragmatics & Cognition*, 5: 199–233. https://doi.org/10.1075/pc.5.2.02tur

Verhoef, T. et al. (2024) 'Brain Responses to a lab-Evolved Artificial Language with Space-Time Metaphors', *Cognition*, 246: 105763. https://doi.org/10.1016/j.cognition.2024.105763

Verhoef, T., Walker, E. and Marghetis, T. (2016) 'Cognitive Biases and Social Coordination in the Emergence of Temporal Language', *Proceedings of the 38th Annual*

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026

Conference of the Cognitive Science Society, pp. 2615–20. Austin, TX: Cognitive Science Society.

Verhoef, T., Walker, E. and Marghetis, T. (2022) 'Interaction Dynamics Affect the Emergence of Compositional Structure in Cultural Transmission of Space-Time Mappings', *Proceedings of the Annual Meeting of the Cognitive Science Society*, Vol. 44, pp. 2133–9. Austin, TX: Cognitive Science Society.

Vicente, A. and Falkum, I. L. (2017) 'Polysemy', *Oxford Research Encyclopedia in Linguistics*. Oxford: Oxford University Press. https://doi.org/10.1093/acrefore/9780199384655.013.325

Wilcox, P. P. (2000) *Metaphor in American Sign Language*. Washington, DC: Gallaudet University Press.

Zhao, J. and Itti, L. (2018) 'shapeDTW: Shape Dynamic Time Warping', *Pattern Recognition*, 74: 171–84. https://doi.org/10.1016/j.patcog.2017.09.020

Zlatev, J. et al. (2017) 'Multimodal-First or Pantomime-First? : Communicating Events Through Pantomime With and Without Vocalization', *Interaction Studies*, 18: 465–88. https://doi.org/10.1075/is.18.3.08zla

Zlatev, J., Żywiczyński, P. and Wacewicz, S. (2020) 'Pantomime as the Original Human-Specific Communicative System', *Journal of Language Evolution*, 5: 156–74. https://doi.org/10.1093/jole/lzaa006

Żywiczyński, P. et al. (2021) 'Evolution of Conventional Communication. A Cross-Cultural Study of Pantomimic Re-enactments of Transitive Events', *Language & Communication*, 80: 191–203. https://doi.org/10.1016/j.langcom.2021.07.002

Żywiczyński, P. et al. (2024) 'Praxis, Demonstration and Pantomime: A Motion Capture Investigation of Differences in Action Performances', *Language and Cognition*, 16: 1338–1365. https://doi.org/10.1017/langcog.2024.8

Żywiczyński, P., Wacewicz, S. and Sibierska, M. (2018) 'Defining Pantomime for Language Evolution Research', *Topoi: An International Review of Philosophy*, 37: 307–18. https://doi.org/10.1007/s11245-016-9425-9

Downloaded from https://academic.oup.com/jole/article/doi/10.1093/jole/lzag003/8726548 by guest on 10 July 2026