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The Social Cognitive Dimension of Pantomime

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Abstract

Pantomime production is commonly interpreted as reflecting tool-use-related cognitive processes. Yet, in everyday life, pantomime deserves a communication function and the exaggeration of amplitude found during pantomime compared to real tool use may reflect the individual's attempt to communicate the intended gesture. Therefore, the question arises about whether pantomime is a communicative behavior that is nevertheless supported only by non-social cognitive processes. We contribute to answering this question by using kinematic analyses. Participants performed the pantomime of using a saw or a hammer from visual presentation in three conditions: Free (no specific instructions), Self (focus on the real tool-use action), and Others (focus on the communicative dimension). Finally, they used the tool with the corresponding object (Actual condition). Participants' social cognition were assessed using gold standard questionnaires. Our results indicated that the manipulation of instructions had a minor effect on the exaggeration of amplitude during pantomime. We reported a link between the social cognition score and the amplitude in the Others condition for the hammer, which suggests that social cognitive processes could take part in pantomime production in some conditions. Nevertheless, this result does not alter our conclusion that social cognitive processes might be far from necessary for pantomime production.

Keywords: Apraxia; Communication; Gesture; Kinematics; Social Cognition; Tool Use.

1. Introduction

Pantomime refers to bodily movement that has no effect on objects or tools in the world but represent the actions that would have such an effect (e.g., pretending to pound a nail with a hammer as if the hammer was held in the hand) (Hogrefe et al., 2017). In everyday life, pantomime serves a communicative function (Goodglass & Kaplan, 1963), either by accompanying speech or taking the place of speech when it is not desirable or possible to talk, or by facilitating the learning of technical content in others (i.e., teaching). In this latter respect, pantomime has been hypothesized to be an early form of proto-language, which has contributed to the emergence of cumulative technological culture in our lineage (Arbib, 2017; Morgan et al., 2015). This is consistent with the large body of literature that has documented the beneficial effects of pantomimes – and more broadly gestures – in the communicate context (e.g., Cook et al., 2016; Goldin-Meadow, 1999, 2011; Ianì & Bucciarelli, 2017, 2018; Ianì et al., 2018). The pantomime production task – hereafter shortened pantomime – has a long-standing tradition in clinical neuropsychology, in which the communicative/social dimension of pantomime has been rarely stressed (Finkel et al., 2018; Goldenberg et al., 2003; Goodglass & Kaplan, 1963). Indeed, this task remains commonly conceived in the neuropsychological literature as a real tool-use task minus some components (e.g., the possibility of holding the tool in hand; for a review, see Osiurak et al., 2021). Thus, although the most influential models of apraxia, a disorder of skilled movements (Osiurak & Rossetti, 2017) have been built on pantomime tasks (Buxbaum, 2001; Cubelli et al., 2000; Heilman et al., 1982; Rothi et al., 1991), none of them include social cognitive processes that could regulate the behavior (but see Bartolo & Stieglitz Ham, 2016). The question is whether pantomime is really a paradoxical behavior, that is, a communicative behavior that is nevertheless supported

only by non-social cognitive processes. The goal of the present study is to contribute to answering this question.

As pantomime serves a communicative function, one may consider that it is a sort of symbolic gesture as waving goodbye. Thus, pantomime might be based on cognitive processes that are not central to real tool use (i.e., the actual use of a tool with an object). Although we cannot exclude the idea that some pantomimes could be conventional and, when performed, require cognitive processes that are not involved at all during the real use of the corresponding tool, evidence suggests that these cases would be marginal. Indeed, a strong link between pantomime and real tool use has been repeatedly found in left brain-damaged patients (Belanger et al., 1994, 1996; Foundas et al., 1995; Goldenberg & Hagmann, 1998b, 1998a; Hartmann et al., 2005; Heilman et al., 1997; Neiman et al., 2000; Osiurak et al., 2008; Randerath et al., 2011). Brain-lesion and neuroimaging studies have also revealed that both tasks involve a common brain network (for a review, see Osiurak et al., 2021). Taken together, these findings indicate that pantomime production necessitates the extraction of the salient features of the real tool-use action and, as a result, relies on non-social, tool-use-related cognitive processes whose interpretation is subject to debate (e.g., technical reasoning, manipulation knowledge; see Buxbaum, 2017; Osiurak & Badets, 2016). Crucially, it has also been repeatedly shown that performance in apraxic patients is systematically worse in pantomime than in real tool use as compared to healthy participants, implying that pantomime requires something more (Clark et al., 1994; Goldenberg et al., 2004; Jarry et al., 2013; Lesourd et al., 2013; Osiurak et al., 2008, 2009; Randerath et al., 2011; for two controversial case-studies showing the opposite pattern, see Fukutake, 2003; Motomura & Yamadori, 1994; for discussion about methodological limitations associated with these cases, see Bartolo et al., 2003). Some

have interpreted this “something more” as additional non-social cognitive processes, others as additional social cognitive processes. Let us begin with the former.

Pantomime is not a routine but an improvised and creative – and even sometimes artistic – act notably because of the lack of external cues and feedback (Bartolo et al., 2003; Bartolo & Stieglitz Ham, 2016; Goldstein, 1948; Goodglass & Kaplan, 1963; Roy & Hall, 1992). Some studies have attempted to increase the presence of tactile feedback to explore whether this experimental manipulation could enhance performance, without providing any conclusive evidence (Goldenberg et al., 2004; Graham et al., 1999; Heath et al., 2003; Hermsdörfer et al., 2006; Neiman et al., 2000; Wada et al., 1999). Others have stressed the potential role of working memory to maintain temporally the information associated with the absent elements (Bardakan et al., 2022; Bartolo et al., 2003; Bartolo & Stieglitz Ham, 2016; Osiurak et al., 2011; Randerath et al., 2011). This interpretation has been recently supported by data indicating that gesture performance in apraxic tasks is correlated to working-memory performance in major depressive disorder (Pavlidou et al., 2021). This interpretation implies that pantomime deficits should be found in all the patients with working-memory deficits, a prediction that needs to be confirmed. As stressed above, another – not necessarily exclusive – way of interpreting the specificity of pantomime compared to real tool use is to consider that additional social cognitive processes (e.g., empathy, perspective-taking; Quesque & Rossetti, 2020) are at work, which is consistent with its communicative function. Support for this comes from the fact that pantomime, but not real tool use, can be impaired in some pathologies that are characterized by communicative deficits (autism spectrum disorder: e.g., Mostofsky et al., 2006; Stieglitz Ham et al., 2011; schizophrenia: e.g., Martin et al., 1994; Walther et al., 2013, 2020). Some have argued that the difficulties reported in some of these patients, such as in schizophrenic patients, must nevertheless be viewed as a true apraxia (i.e.,

resulting from impaired tool-use-related cognitive skills) and not as a gestural disorder due to their communicative disorder (Walther et al., 2020). By contrast, other studies have reported an association between pantomime performance and communication scales in some of these patients (e.g., autism spectrum disorders; Dziuk et al., 2007), which justifies the potential link between pantomime and social cognitive processes at least in some patients with communicative deficits. It has also been stressed that individuals tend to exaggerate the amplitude of their pantomime compared to the real tool-use action (Clark et al., 1994; Hermsdörfer et al., 2006, 2013; Poizner et al., 1995), as if there was an implicit attempt to facilitate the recognition of the action by the observers (for the same effect reported in non-tool-use contexts, see Quesque & Coello, 2014; Quesque et al., 2016, 2017). Finally, evidence indicates that the development of pantomime in childhood parallels that of theory-of-mind skills (Leslie, 1987; Suddendorf et al., 1999). Taken together, these findings suggest that pantomime, although originating in non-social tool-use-related cognitive processes, is likely to involve additional social cognitive processes because of its communicative dimension.

The goal of the present study was to explore this avenue by using kinematic analyses. We hypothesized that the gestural exaggeration found during pantomime reflects the involvement of social cognitive processes. Healthy participants had to perform the pantomime of using a saw or a hammer from visual presentation (i.e., the photograph of the real tool). There were three conditions. In the *Free condition*, the participants had to show how they would use the tool presented. In the *Self condition*, they were also instructed to do so by imitating as accurately as possible the action they would do if they really had the tool in the hand. In the *Others condition*, they had to show how they would mime the use of the tool presented to help an observer recognize it. Finally, they also had to use the tool with the corresponding object (i.e., sawing a wooden board

with the saw and pounding a nail with the hammer; *Actual condition*). Participants' social cognition was assessed with several gold standard tests. Our rationale was as follows. If pantomime does not require any additional social cognitive processes, then manipulating the instructions should have no effect on the exaggeration of the pantomime particularly when the participants are asked to pantomime for someone else. No link with the social cognition score should be found. However, if additional social cognitive processes are involved during pantomime, then we can expect that the spontaneous exaggeration of the pantomime should be positively linked to the social cognition score and that increasing the social demand should increase this exaggeration (i.e., greater amplitude in the Others than the Self condition, with a potential intermediate position for Free).

2. Methods

2.1. Participants

Thirty-nine participants took part in the experiment ($M_{age} = 23.7$, $SD_{age} = 3.6$, range: 18-34; 22 females). Twenty-three participants were undergraduate students in psychology and cognitive science at the University of Lyon. The remaining 16 participants were former students who were henceforth employed ($n = 14$) or looking for work ($n = 2$). All participants were right-handed (Edinburgh Inventory; Oldfield, 1971). The study was conducted in accordance with the Declaration of Helsinki, seventh revision, and approved by the institutional review board (IRB00003888; n°19-569). Informed consent was obtained from all participants.

2.2. Materials and procedure

For the kinematic analyses, we followed standard recommendations with respect to motion capture (e.g., at least 3 trials/cycles for a given movement), which are known to achieve good performance stability and test-retest reliability for multiple kinematic

variables in persons with and without upper extremity impairments (e.g., Fryckberg et al., 2021). Four tools (i.e., saw, hammer, fan, and toothbrush) were used for the experiment but only the results obtained with the hammer and the saw were reported here because the data obtained with the fan and the toothbrush were not exploitable, i.e., within-trial and between-trial spatiotemporal variability of kinematics were extremely high. The photographs of the tools shown to participants (as well as other elements of materials used in the present study) are available at <https://osf.io/rxt2d/>. All the participants started with the Free condition, in which they were instructed to show how they would use the tool presented on the picture. The order of tools was always the same (saw, hammer, fan, and toothbrush). For each tool, a beep informed the participants that they could start the pantomime and a second one that they could stop. The second beep was triggered by the experimenter and occurred after at least 15 repetitions of the pantomime (i.e., 15 cycles). For each tool, this procedure was repeated three times, so there were 3 successive recordings of 15 cycles for each tool for each condition. Half of the participants were then invited to perform the pantomime again in the Self condition and the Others condition and inversely for the other half. In the Self condition, participants had to show how they would use the tool presented on the picture by imitating as accurately as possible the action they would do if they really had the tool in the hand. In the Others condition, they had to show how they would mime the use of the tool presented to help an observer recognize it. Finally, they also had to use the tool with the corresponding object (i.e., sawing a real wooden board with the saw and pounding a real wooden “nail” with the hammer; Actual condition). In other words, half of the participants followed the following condition order, Free, Self, Others, Actual, and the other half, Free, Others, Self, Actual. In all the pantomime conditions, the participants were seated on a chair. In the Actual condition, for the hammer, they were seated on a

chair in front of an adjustable custom table, which was one-meter square and 75-90-cm high. This height was adjusted for each participant to make the execution of the action comfortable. A wooden nail (10-cm length; 2-cm diameter) was placed at the center of the table. In the Actual condition, for the saw, the participants were standing in front of the adjustable table at the center of which a wooden board (40-cm width; 15-cm depth; 2-cm height) with slots was installed.

After the pantomime task, participants were asked to complete three tests assessing their social cognitive skills. The first was the Interpersonal Reactivity Index (IRI; Davis, 1983), which is the most used scale to evaluate social cognitive skills (Eddy, 2019). The IRI is a self-report 28-item questionnaire (i.e., Likert scale, 1-7, 1 being disagree, 7 being agree) that is composed of four 7-item subscales referring to different socio-emotional components (fantasy, empathic concern, perspective-taking, and personal distress, Range: 28-196). We used the French version of this questionnaire, which has been validated according to the psychometrics standards (Gilet et al., 2013). The second was the “Reading-the Mind-in the Eyes” (RME) test (Baron-Cohen et al., 2001; Prevost et al., 2014 for the French version), which measure individuals’ sensitivity to subtle social cues and has shown a high potential to distinguish individuals tendency to attend to others in joint cognitive tasks (Ruys & Aarts, 2010). Specifically, participants had to choose which of four words best described what a person on a photograph was feeling or thinking (36 items; Range: 0-36; time limit 3 min) based on their eyes.). The third was the “privilege knowledge” test (Keysar, 1994) which allows to estimate participants’ tendency to spontaneously take the perspective of a other person. Participants had to predict how a naïve recipient would interpret an ambiguous sarcastic message (1 item; Range 0-6, 0 reflecting an other-centered response, 6 an ego-centered response; no time limit).

2.3. Motion capture

Hand movements were recorded using a 3D optoelectronic motion capture system (Motion Analysis®) composed of nine infrared stroboscopes at a sample rate of 200 Hz. Nine infrared passive reflective markers were placed in specified body landmarks using bone palpation: Acromioclavicular joint, lateral and medial epicondyle, radial and ulnar styloid, 2nd and 5th metacarpals heads, two technical markers on arm and forearm for three-dimensional reconstruction purpose (for a photograph of the position of the markers, see <https://osf.io/rxt2d/>). After recording and 3D reconstruction, the position of each marker was filtered with a Butterworth low-band pass filter, with a cut-off frequency of 6 Hz using a semi-automatic procedure with trial-by-trial validation by an expert (L.D. or P.R.). Then, from the markers' spatial position on arm and forearm, elbow flexion and extension were computed. Each arm movement recording was divided into cycles defined from the minimal opening elbow flexion angle event (start of cycle) to the next one (end of cycle). Three-dimensional path of the radial styloid marker was extracted from each cycle. Due to technical motion capture limitations, too much of the 3D trajectories were lost for 8 (Saw) and 6 (Hammer) participants, preventing us to calculate accurate arm cycles. In addition, the motion unpredictability of fan and toothbrush movements caused too many marker occlusions to compute arm cycles and radial styloid marker paths, rendering data unexploitable.

2.4. Data analysis

Our kinematic analyses focused on the amplitude defined as the three-dimensional path length of the radial styloid for one cycle. For empathy, we considered only the total score obtained with the IRI as preliminary analyses indicated non-expected links or an absence of link between the RME score and the privilege knowledge score and the other

tests or subscales. Therefore, we preferred to focus our analyses on the IRI as a self-reported measure of social cognitive skills. Two main statistical analyses were performed separately for each tool (i.e., saw and hammer). First, we carried out a Bayesian repeated-measure ANOVA with the amplitude as dependent variable and Condition (Free versus Self versus Others versus Actual) as within-subject factor followed by pairwise comparisons (jamovi, version 2.2.5; The jamovi project, 2021). Second, we explored the influence of condition and social cognition on the amplitude. To do so, we transformed the amplitude for each condition into the difference between the amplitude in each of the three pantomime conditions (i.e., Free, Self, Others) minus the one of the Actual condition. We made this transformation to characterize for each participant the exaggeration of the pantomime relative to their corresponding real tool-use action. We used Bayesian regression modeling in R (R Development Core Team, 2011; rstanarm package; Gabry & Goodrich, 2017) to fit a linear model with the amplitude difference as outcome variable, Condition (Free versus Self versus Others) and IRI Score as fixed effects, and Participants' ID and Order (Self-then-Others versus Others-then-Self) as random effects. The same analysis was conducted for the two tools. We followed the taxonomy proposed by Jeffreys (1961) to assign verbal labels to the strength of evidence: Bayes Factors (BF) of 1 as no evidence, between 1 and 3 as anecdotal, 3 and 10 as moderate, 10 and 30 as strong, 30 and 100 as very strong, and larger than 100 as extreme evidence in favor of the alternative hypothesis, and BF between 1/3 and 1 as anecdotal, 1/10 and 1/3 as moderate, 1/30 and 1/10 as strong, 1/100 and 1/30 as very strong, and smaller than 1/100 as extreme evidence in favor of the null hypothesis.

3. Results

As shown in **Fig. 1a** and **Fig. 1b**, the movement amplitude differed between the conditions for the Saw, $BF = 2.10^{+18}$, and for the Hammer, $BF = 7.25^{+11}$. For both tools, the amplitude was greater in the three pantomime conditions than in the Actual condition (all $BF = 38676$). We also found for the Hammer moderate evidence for a difference between the Free condition and the Others condition ($BF = 6.72$). No other difference as found between the pantomime conditions. We then explored the influence of condition and IRI score on the amplitude (**Fig. 1c** and **1d**). As explained above, this analysis was based on the difference between the amplitude in each pantomime condition and the Actual condition. For the Saw, we obtained a linear model with the Free condition as Intercept. The analysis revealed anecdotal to strong evidence for the null hypothesis for the main and interaction effects (all BF between 0.08 and 0.27). For the Hammer, we also obtained a linear model with the Free condition as Intercept. The analysis revealed strong evidence for the null hypothesis for the main effect of the IRI score ($BF = 0.07$). By contrast, it indicated moderate evidence for the alternative hypothesis for the IRI score*Others condition interaction (IRI score*Others condition estimate: -3.44; 95% CI: -6.54 to -0.59; $BF = 3.06$), which suggested that the greater the IRI score the smaller the absolute amplitude difference in the Others condition. Anecdotal evidence for the null hypothesis was found for the other effects (all BF between 0.33 and 0.92).

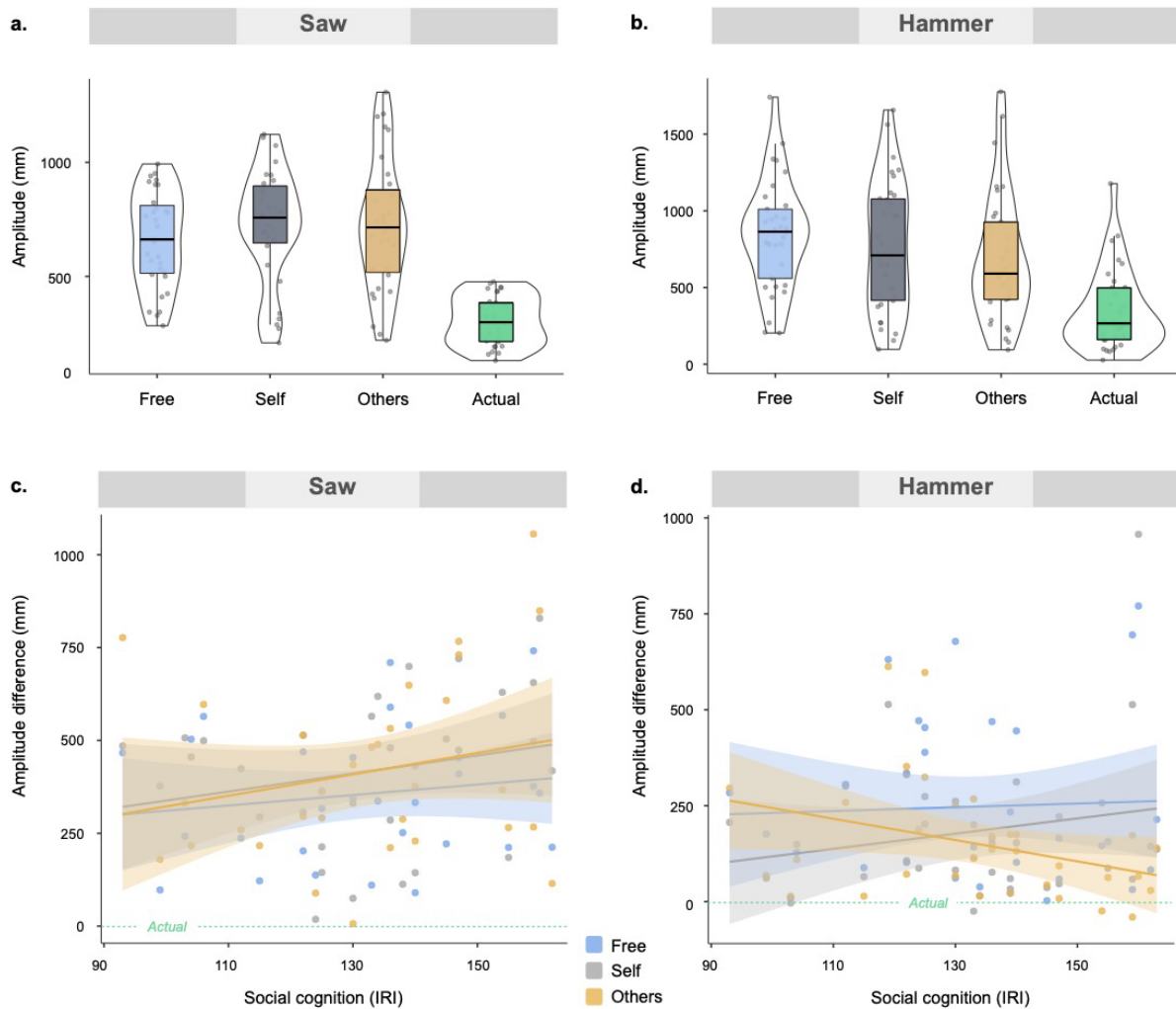


Figure 1. Amplitude as a function of condition and participants' empathy score. Amplitude (a, b) is defined as the three-dimensional path length for one cycle. Boxplots represent the median, the first and third quartiles, the minimum within lower whisker, and the maximum within upper whisker. Amplitude difference (c, d) refers to the difference of amplitude between each pantomime condition (Free, Self, Others) and the real tool-use action (Actual). Empathy score is the total score obtained on the interpersonal reactivity index (IRI). In this case, a value of 0 reflects an amplitude similar to the one for the Actual condition. The straight lines reflect the linear model fits, and the light shaded areas are the standard errors.

4. Discussion

The goal of the present study was to explore the social dimension of pantomime using kinematic analyses. We hypothesized that the gestural exaggeration found during pantomime reflects the involvement of social cognitive processes. Therefore, in the Free condition, we expected that this exaggeration was positively linked to the participants' social cognition. We also hypothesized that manipulating the instructions could modify

this exaggeration, with a greater amplitude in the Others condition than in the Self condition, with a potential intermediate position for Free. Our results did not confirm our predictions and were more consistent with the alternative hypothesis of an absence of involvement of social cognitive processes according to which neither effects of social cognition nor of instructions should be found at all. The link found between the IRI score and the amplitude in the Others condition for the hammer is nevertheless informative, suggesting that social cognitive processes could take part in the production of pantomime, although they would be far from necessary for it. For us, two main conclusions can be drawn from these results.

The first conclusion is that the exaggeration of the pantomime is not driven by social cognitive processes. The idea that this exaggeration may result from specific social cognitive processes is not new and has been repeatedly stressed in the literature as a plausible hypothesis. For instance, Hermsdörfer et al. (2006) wrote that “the extension of movement amplitude may reflect the subjects’ attempt to symbolize the intended gesture by exaggerating its most salient feature” (p. 1649). Our findings did not confirm this interpretation. Our participants did not exaggerate the amplitude of their movements during pantomime to help others better recognize it. This conclusion is also supported by other results. For instance, we did not report any modulation of the amplitude in the three pantomime conditions for the saw, which suggests that even when the participants were sometimes instructed to focus on the communicative dimension of their movements, the amount of exaggeration did not change. We did find a statistical effect of instructions for the hammer, particularly in the Others condition. However, contrary to our predictions, the participants did not increase but decreased the amplitude of their pantomime in this condition to make it comparable with the real tool-use condition. This effect was mediated by the IRI score, suggesting that it was the most empathic participants of our sample who

exhibited this behavior. In other words, these results indicate that even when a subtle influence of potential social cognitive processes can be found, this influence goes in the opposite direction of an exaggeration. The more people perceive themselves as sensitive to others, the more they seem to produce a pantomime close to the real tool-use action, at least in some conditions. In sum, people do not exaggerate their pantomime because of a communicative purpose.

This leads us to the second conclusion, which is as follows. The most plausible interpretation of the gestural exaggeration during pantomime is that pantomime is an improvised and creative task, which is cognitively demanding (Bartolo et al., 2003; Osiurak et al., 2011; Roy & Hall, 1992). Therefore, when individuals perform it, they organize their performance around the most salient feature of the tool-use action and sacrifice the less important aspects of the gesture. This may explain why the global kinematics is generally preserved whereas the posture of the hand is more frequently incorrectly produced (Osiurak et al., 2021). These aspects along with the absence of the mechanical constraints that are present in the real tool-use situation provide likely explanations for the exaggeration of the movements. The fact that we observed that this exaggeration could be almost completely reduced for the hammer in participants with the highest self-reported social cognitive skills in the Others condition demonstrates that people can perform a pantomime that is very close to the real tool-use action. In this case, it was as if the participant's sensitivity to others led them to enhance their cognitive efforts in terms of mental imagery, working memory, or specific tool-use-related processes (e.g., technical reasoning) to perform a more recognizable gesture, which would be beneficial at the dyad level even if costly at the personal one. In a way, this finding informs us that people can correct their exaggeration, but they do not do so spontaneously by preferring to carry out a more approximate gesture because of the

cognitive economy it provides. If our interpretation is correct, the correction of amplitude exaggeration when producing pantomimes should be modulated by the collaborative versus competitive nature of the context, contrasting with observations reported for unconstrained object-directed reaching movements (Quesque et al., 2017).

Taken together, these two conclusions suggest that pantomime production does not require high-level social cognitive processes. This may appear paradoxical with the idea that pantomime deserves a communicative function, but it is not. People communicate frequently without recruiting their social cognitive processes. After all, the language network itself (Na et al., 2022) is not the same as that of the theory-of-mind or mentalizing network (Van Overwalle & Baetens, 2009), and children can develop their language skills before their high-level social cognitive skills (Lockl & Schneider, 2006). Thus, basic communication does not necessarily involve high-level social cognitive processes such as perspective-taking. This is actually trivial because numerous nonhuman animals can use communication modes without possessing such cognitive processes (e.g., ants). Thus, even when someone intends to communicate an information to someone else through a pantomime, the sender can perform a pantomime without the need of taking into consideration how the receiver will understand the pantomime. Instead, the sender merely performs the pantomime. In many cases, the context can be enough to help the receiver understand the pantomime, so that the communication can occur without the sender recruits any high-level social cognitive processes to potentially improve the pantomime. Nevertheless, in some cases, the context may not be supportive enough and, in this case, additional social cognitive processes might be recruited to enhance the quality of the pantomime in a similar way as in the present study with the Others condition for the hammer. One limitation of our present study is that we did not really reproduce such a scenario, in which there is a true interaction between a sender and a

receiver and in which the receiver could request the sender to repeat the pantomime because they do not recognize it. In this vein, previous works on motor control in non-pantomime contexts have suggested that kinematic exaggerations are directed towards the receiver, both in communicative (Cleret de Langavant et al., 2011) and non-communicative (Quesque & Coello, 2014) dyad interactions. The absence of a real confederate in our setting may have influenced the production of pantomime. However, experimenters were present during the whole recording even if not involved in the interaction and may still have represented potential receivers. Another limitation is that we did not assess the quality of the pantomime produced by our participants (for controversial results about pantomime recognition, see Osiurak et al., 2012). If our interpretation is right, then such an experiment with true interactions should confirm that senders do not spontaneously use their social cognitive processes to produce their pantomime except in cases in which the receiver requests repetitions. In these cases, we could also expect that the exaggeration associated with the pantomime decreases when the sender repeats their pantomime. Future work is required to test these predictions.

As explained in introduction, pantomime deficits have been reported in patients with communicative disorders such as in autism spectrum disorders or schizophrenia. The debate has been to determine whether communicative disorders are at the origins or not of pantomime deficits. Although in autism spectrum disorders, some links have been found with communicative scales, a series of studies conducted in schizophrenic patients have led Walther et al. (2020) to argue that “the gestural disorder frequently observed in schizophrenia shares both the clinical and neurophysiological features of true apraxia” (p. 65). Even if their conclusion was broader by including other gestural performance than pantomime only, our key findings confirm their interpretation. The outstanding question is why a potential link has been reported in patients with autism spectrum disorders. At

a clinical level, our findings also question the use of the pantomime production task as a proxy for studying real tool-use disorders. Indeed, if the improvised and creative dimension of pantomime makes it multidetermined at a cognitive level by involving a potential range of non-social cognitive processes (e.g., working memory, mental imagery) that are not recruited in the case of real tool use, then the risk for a clinician is to meet great difficulties in interpreting the cognitive origins of the deficit (for discussion about this aspect, see Osiurak et al., 2011, 2012, 2021). One way of overcoming these difficulties is to scrutinize the patient's performance on other tasks to determine the nature of the pantomime deficit. Nevertheless, the question is what is the interest of using the pantomime production task for a clinician if they are not able to know why this task remains fundamental for understanding the patient's daily living and if additional tasks are required to interpret the deficit? Although this statement may appear provocative, we are convinced that the usefulness of the pantomime production task for the clinical neuropsychology remains to be demonstrated.

We are aware that the present study is far from sufficient to fully address the question of the role of social cognitive processes in pantomime production. Future studies are needed to explore whether these processes are further involved in contexts of true interactions between a sender and a receiver. Future studies are also required to investigate whether our results obtained from the visual presentation of real tools can be extended to pantomime production on verbal commands, i.e., in a condition in which no information about the structural properties of the tool can be extracted compared to real tool use. Regardless, our findings indicate that social cognitive processes would not be spontaneously recruited when people produce pantomime. This conclusion is interesting with regard to the literature about cumulative technological culture, in which pantomime has been repeatedly hypothesized to be an early form of proto-language (Morgan et al.,

2015). As discussed above, people can use language to communicate without necessarily recruiting high-level social cognitive processes. Given that pantomime would be also a form of language, the same should be true for it. This also implies that pantomime could have been an early form of proto-language used by ancestors to communicate, i.e., without high-level social cognitive processes (i.e., natural pedagogy; for discussion, Csibra & Gergely, 2009, 2011). This interpretation opens interesting avenues for building bridges between clinical neuropsychology and anthropology, which might definitely help us understand the cognitive origins of pantomime and what pantomime deficits really reflect.

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Data and code availability

The data that support the findings of the study and the codes used in this paper are available at <https://osf.io/rxt2d/>.

Competing interests

The authors declare no competing interests.

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