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Do we represent intentional action as recursively embedded? The answer must be empirical. A comment on Vicari and Adenzato (2014)

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ABSTRACT

The relationship between linguistic syntax and action planning is of considerable interest in cognitive science because many researchers suggest that "motor syntax" shares certain key traits with language. In a recent manuscript in this journal, Vicari and Adenzato (henceforth VA) critiqued Hauser, Chomsky and Fitch's 2002 (henceforth HCF's) hypothesis that recursion is language-specific, and that its usage in other domains is parasitic on language resources. VA's main argument is that HCF's hypothesis is falsified by the fact that recursion typifies the structure of intentional action, and recursion in the domain of action is independent of language. Here, we argue that VA's argument is incomplete, and that their formalism can be contrasted with alternative frameworks that are equally consistent with existing data. Therefore their conclusions are premature without further empirical testing and support. In particular, to accept VA's argument it would be necessary to demonstrate both that humans in fact represent self-embedding in the structure of intentional action, and that language is not used to construct these representations.

1. Introduction

In 1951, Lashley published a justly famous exposition of an idea that has been repeated and refined in much subsequent research: that there is some fundamental cognitive link between the structure of complex motor plans, and the structures of linguistic syntax (Lashley, 1951). Particularly since the discovery of mirror neurons (Rizzolatti, Fadiga, Gallese, & Fogassi, 1996), this notion has entered the mainstream of thought in cognitive science. However, there is considerable variation among researchers about what the specific relevant parallels are (compare, for example, (Rizzolatti & Arbib, 1998) and (Pulvermüller, 2010)) along with considerable skepticism about whether these links are deep and interesting (Anscombe, 1957, 1965; Moro, 2014; Toni, de Lange, Noordzij, & Hagoort, 2008). Elsewhere, we have offered our own perspective on this question, hearkening back to Lashley's ideas that hierarchical organization is the key shared characteristic between action, music and language (Fitch & Martins, 2014).

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In a recent manuscript published in this journal, Vicari and Adenzato (Vicari & Adenzato, 2014), henceforth VA, analyze the plausibility of Hauser, Chomsky and Fitch's (henceforth HCF) hypothesis (Hauser, Chomsky, & Fitch, 2002) that recursion is either domain-specific to language, or that recursion's uses in other domains are parasitic upon linguistic recursion. VA aim to falsify this hypothesis by first identifying "the formal features of recursion" in intentional action, a non-linguistic domain, and then by showing that this domain is not grounded on language. For the latter argument they review data purportedly showing that "linguistic recursion might be embodied in motor processing", and that in some situations "linguistic and motor-intentional recursions might be double dissociated".

This is an interesting and plausible argument, and we certainly are sympathetic with VA's efforts to review and address the theoretical and methodological difficulties involved in investigating recursion. Although we agree that there are reasons to doubt HCF's hypothesis, especially considering recent empirical research concerning recursion in vision (Martins, 2012; Martins, Laaha, Freiberger, Choi, & Fitch, 2014; Martins, Mursic, Oh, & Fitch, 2015; Martins et al., 2014), we here argue that the argument presented by VA is inadequate on two grounds.

First, humans' ability to represent intentional action as recursive is an *assumption* of VA's model, not something that has been empirically demonstrated. Our argument is the following: although it is possible to formally represent several structures in the environment as generated by recursive rules (or as having a recursive structure), it is also quite possible that human subjects are unable to represent these structures cognitively or neurally (as formally modeled by VA). This would obviously make VA's formalism an unrealistic model of human cognition, and nullify the biological and evolutionary implications VA draw from it. A specific set of empirical studies would need to be successfully carried out to evaluate the accuracy of VA's assumptions, as we detail below. Clearly, we cannot use untested cognitive models to support claims about the properties and evolution of human cognition, unless there is empirical evidence supporting such models as a good approximation of what people actually do. This problem is certainly not limited to recursion, and occurs whenever distinct modeling strategies exist to adequately explain identical phenomenon, as is often the case in the field of language evolution (Baronchelli, Chater, Pastor-Satorras, & Christiansen, 2012; Chomsky, 2010; Christiansen & Kirby, 2003; Griffiths & Kalish, 2007; Griffiths, Kalish, & Lewandowsky, 2008; Kirby, 2001; Kirby, Cornish, & Smith, 2008; McCrohon, 2012; Niyogi & Berwick, 1997; Nowak, Komarova, & Niyogi, 2001).

The second flaw in VA's argument is their logical slip of taking the part for the whole, i.e., taking human *intentional* motor action as having the same identity and properties as *all* motor action. This becomes clear in VA's review of data on the neural bases of the motor system, taken as evidence that "linguistic recursion might be embodied in motor processing" (and hence in recursive intentional action). Clearly, even if we agree that some actions are intentional and recursive, it does not follow that *all* motor action is intentional and recursive. This is a particular problem when analyzing the properties of parts of the motor system with clear homologs in other mammals (e.g. the basal ganglia), and then using these to draw evolutionary conclusions about the primacy of motor recursion over language recursion.

It seems clear that pure theoretical analyses cannot replace empirical data in assessing the architecture of human cognition or in drawing further evolutionary conclusions. Indeed, such analyses can be evaluated empirically, but it is hard work. For instance, in a series of recent studies, we have tested for the existence of recursive cognitive abilities in the visuo-spatial domain. We have found that both human adults and children (Martins, 2012; Martins, Laaha et al., 2014) can represent visual recursion (operationalized as self-embedded hierarchical structure). This ability is neither affected by verbal interference (Martins et al., 2015) nor does it activate language brain areas (Martins, Fischmeister et al., 2014). These data provide an *empirical* falsification of the HCF hypothesis much more convincingly than previous arguments *assuming* that visual perception is recursive and independent of language (Jackendoff & Pinker, 2005).

Below, we will describe VA's article in further detail and demonstrate that there are alternative approaches to modeling motor processing. We argue that, despite the large number of cognitive domains in which recursion has been claimed to exist, from language to music to social intelligence to architecture, there are typically non-recursive alternative explanations for hierarchy in these domains, and that existing proposals do not successfully address the core issue of recursion in language and its relation (or lack thereof) to other domains of thought. Our central argument is that, by taking a plausible characterization of certain specific aspects of human intentionality as given, and then extending this characterization to motor planning in general (including motor behavior in nonhuman animals), VA greatly overstate their argument that action recursion is an evolutionary precursor of linguistic (or other cognitive) recursion. Indeed, we give several reasons to seriously doubt the existence of recursive representations in animal motor planning, even in intentional actions. We conclude that VA's argument, while interesting, lacks the empirical support required to make it plausible.

2. Vicari and Adenzato's argument

VA's reading of HCF leads them to specify four properties which are necessary and sufficient for recursion: self-embedding, long-distance dependency, identity preservation and discrete infinity. They conclude that the logical structure of intentional action satisfies all four conditions.

First, VA rely upon Searle's (Searle, 1983) analysis of intentional action, concluding from this that the structure of intentional action is self-referential. According to this analysis the content of an intentional action (e.g. "I want to raise my arm") has a structure of the form "arm rises + Intention (that the arm rises *because of this intention*)". As Searle and VA both correctly observe, this issue of accidental/intentional comes to the fore in ethical decisions (e.g. the distinction between murder and manslaughter). They argue that since such self-reference is a kind of self-embedding, intentional action satisfies the first condition for recursion. We return to this central component of their argument, which seems to us problematic, below.

Second, because complex actions (involving goals and sub-goals) can be decomposed into several subsidiary actions, the authors argue that we can find long distance dependencies between prior intentions and each subsidiary action. This would satisfy the second condition for recursion.

Third, in complex action we can posit a discrete and finite "vocabulary of acts", meaning a set of basic acts such as grasping, reaching etc., that are independent of the kinematics of the motor act. Good evidence for such a "vocabulary of acts" is found in neural data (e.g. mirror neuron research). These basic acts can then be embedded in larger causal contexts without losing their identity. Hence, complex motor action satisfies the condition of identity preservation, the third condition for recursion.

Fourth and finally, at least in competence terms, the causal chain of complex action could extend indefinitely, as for language. The limitations to this expansion process are empirical and limited by performance constraints, or specifically, to various practical limits on the agent's motor ability and/or intentionality. Thus, adopting the same standards that linguists use to postulate discrete infinity in language, we can do so for intentional action, thus satisfying the fourth condition for recursion.

VA also review empirical (mostly neural) data suggesting that complex action and language dissociate to some extent. Since they assume that complex action has a recursive structure, they conclude that "action recursion" is independent of linguistic recursion. However, they also review clinical and imaging data suggesting that impairment of complex action is more likely to affect language than the other way around. From these data, the authors conclude that linguistic recursion might have been preceded by recursive motor processing, rather than vice versa. Their argument here is that "ancient subcortical structures [such as the basal ganglia] designed for performing routine tasks and schemas and for flexibility in motor control play a key role in a higher-level cognitive process such as language, thereby suggesting a possible embodied root for language recursion."

In general we agree with their argument that (human) complex action satisfies desiderata 2–4, and involves generating an indefinite number of discrete and hierarchical actions (cf. (Fitch & Martins, 2014)). Our key disagreement concerns criterion 1: self-embedding. While we agree that Searle's model of intentional action entails a form of self-embedding, it is not at all obvious that this is true of action in general, especially of "primitive" forms of motor control that VA term "motor intentionality".

It is important before going further to identify a potential source of confusion concerning "intention" and "intentional" stemming from the specialized interpretations of these terms as traditionally used by philosophers, that differ considerably from their ordinary English meanings. In ordinary English, "intentional" means "on purpose", but philosophers use "intentionality" to designate a particular characteristic of mental states. For philosophers, intentional states are those that represent or stand for things, events or properties in the world. We can gloss this interpretation of intentionality as the "aboutness" that certain neural states bear to the outside world (words or sentences also have intentionality in the sense of aboutness). In this sense, intentionality is a pervasive and fundamental feature of mental states like beliefs or desires, but including a wide range of other states including memories, hopes, knowledge, love – or intentions (in the ordinary sense). Thus, from the philosophers perspective, intentions are just one among many different forms of intentional state. In Searle's model of intentional action they play a particular key role, but it is important to note that "intentionality" does not imply an "intention to do something".

3. Is self-embedding a basic feature of motor control?

Consider a cat whose goal (intention, in the ordinary sense) is to catch a mouse, and whose motor actions to this effect can be said to be "intentional" (in the philosopher's sense of "aboutness") with respect to mouse-catching. The cat wants the mouse, and cognitively represents this desire. Now it may be that, in a misguided attempt at escape, the mouse runs into the cat's claws and is captured and eaten. By Searle's analysis, we must conclude that the cat's intentional goal was not satisfied by its specific actions at that moment, and that this specific action/outcome pairing is thus not "intentional" in his sense. Similarly, an animal trapped in a box who exhibits random actions "to escape" is appropriately satisfied when it finally does escape, despite the fact that there is no clear (or clearly understood) casual link between its escape and most of the trial-and-error actions it performs. In other words, although some global goal is satisfied by a collection of actions, no particular action from this set can be said to be fully intentional in Searle's sense.

These are just extreme examples of a stochasticity that is typical in real-world actions: often one fiddles around with some problem (starting an engine, opening a container, assembling or disassembling some device, getting a key to turn in a lock) until it works, and there is a certain amount of chance involved by the time the ultimate goal is achieved. Thus we can't be sure which of our specific actions led to fulfillment of our general goal. But an indeterminate or imperfect link between our actions and their detailed causal consequences does not lead us to dismiss the intentionality (aboutness) of these actions – we are trying to get something done. Searle's model of intentional action is perhaps true of human action as a broad generalization about simple actions (raising your arm), but will often fail in the domain of complex sequences of actions where, despite a clear overall goal, the detailed sequence of subgoals and their consequences remains somewhat murky.

Evidently, some motor behavior, including complex hierarchical motor action, can be goal-directed and "intentional" (in the normal sense of "doing it on purpose") without fulfilling Searle's criterion of (philosopher's) "intentionality" (characterizing the "aboutness" of thoughts, beliefs and goals). The rather unfortunate philosopher's adoption of the term "intentional" in such a different manner as that of ordinary language encourages a conflation of these two, quite different, concepts and we think leads to some slippage in VA's arguments as well (since they end by concluding self-embedding in "motor competence" and *not* just in Searle-style "intentional action").[2] While we do not doubt that many human actions fulfill Searle's more stringent criterion, even for humans it seems overly restrictive to make this a *necessary* criterion. For animals, the situation is worse, since our main empirical criterion (following Anscombe (Anscombe, 1957, 1965)) for evaluating intentionality in any particular case is language: we ask the actor "why?" they performed some act. This empirical criterion obviously cannot be satisfied with animals.

The key idea here is that while complex action may sometimes be intentional in Searle's terms, much of human and animal action is not. Therefore, analyzing the basic properties of the motor system as a proxy of this higher-order intentional system is misleading, for instance when VA use neuroscience data on the implementation of motor procedures to argue that the intentional system is independent from language.

In fact, an alternative perspective on the source of Searle's self-embedded intentional action is illustrated by the Gricean (Grice, 1975) interpretation of *communicative* intentionality discussed by VA. Now, it is no doubt true in much human communication that I both want you to know *p*, and also *to know that I want you to know p*. But decades of research on primate communication suggests that precisely this Gricean aspect of human language is missing in nonhuman primate communication: it appears that in apes and monkeys, all of the Gricean work is done solely by the listener and the signaler has no explicit representation of the listeners' mental contents that it aims to intentionally modify with its signal (cf. (Cheney & Seyfarth, 1992, 1998; Seyfarth & Cheney, 2014). Again, even though actions and motor procedures are executed during animal communication, these actions are not intentional in Searle's sense, further demonstrating that complex action and intentionality can dissociate in other animals.

It seems quite likely, following (Tomasello, 2008), that the similarity between our representation of intentional action and linguistic syntax derives from our capacity to conceptualize *joint action* or *shared intentionality*: an ability argued by Tomasello to be uniquely human. Thus, the origin of the self-embedding would be that, in planning joint action, I need to observe not only my partners' actions but also to represent their intentions (cf. (Steedman, 2014). From this viewpoint, Searle's model of intentional action may in fact simply result from the solipsistic application, to our own actions, of our ability to read intentions in others.

All of these considerations suggest that VA have been too hasty in thinking that their and Searle's analysis refers to anything "primitive" or "basic" about motor action. If all of these domains share the same formal structure (which seems to us to be VA's core argument), but *none* are found in non-human animals, this would support an inference that self-embedding is not, in any sense, a "primitive" component of motor action. Indeed, this would support HCF's argument that, in these cases, the self-embedding aspect of intentional action is "parasitic" on language and FLN,[3] or alternatively support Tomasello's supposition that recursion in language is parasitic on shared intentionality.

Thus we think that viewing motor processing and intentional action as self-referential is an artifact of the particular formalism and approach that VA choose to adopt, in ways that remain obscure in their paper, partly due to a slippage between philosopher's intentionality (aboutness) and normal intentionality (done on purpose to achieve a goal). It also illustrates that, as much as VA may wish to avoid comparative discussions about animal capabilities, they are in fact linked closely to the human-centered questions of "domain generality/specificity" beloved of psychologists, as soon as we try to evaluate the issues empirically – at least if the argument involves such notions as "primitive" or "precursor" (as VA's does).

Other models explaining the causality of action representation can be proposed, which do not involve self-embedding (e.g. (Badre, 2008). For instance, instead of a system representing the 'intention (that the arm goes up because of this intention)', we could imagine a system that represents the 'desire to achieve a raised arm by means of voluntary control'. Since all of these different internally consistent frameworks can be proposed to model the same phenomena, the final criteria to decide among these different models must be empirical. We acknowledge that some formalisms in linguistics ignore this recommendation. However, this renders VA's manuscript more of a cautionary tale for linguistic research rather than a contribution to understanding the cognitive structure and neural implementation of recursion (or "recursions") in action or language.

[2] Even though VA (2014) acknowledge, in a footnote, that "intentionality [...] as a property of some mental states, differs from intentions (a specific kind of intentional mental states)", it is clear the crux of their analysis is not about intentionality in mental states, but about intentional action. They "[...] argue that there are sensory-motor recursive structures in the domain of intentional action – that is, at the sensory-motor level that mediates our fundamental interactions with the environment (p. 170)", and they hypothesize that "it is possible that the fundamental mechanisms of intentional action in human beings are shared with non-human animals, or that these mechanisms are also human-specific (p. 173)".

[3] FLN is the acronym for Faculty of Language in the Narrow Sense. The term was first introduced by HCF to refer to a set of cognitive abilities that would be unique to humans and to language. HCF hypothesized that this set was composed of a language domain-specific capacity for recursion, but also admitted that it could be empty. FLN is a useful concept to understand that human language is not a monolithic construct, but instead results from the interaction between several cognitive abilities. Some of these abilities (e.g. memory) exist in other species and cognitive domains, and belong to a set called Faculty of Language in the Broad sense. FLN is a concept that leaves open the possibility that specific cognitive innovations occurred in the human lineage which allowed language to emerge.

The structure of intentional action is by no means the first domain outside linguistic syntax where recursion has been hypothesized. Recursive models that generate hierarchical structures have been proposed in (at least): visual art (Eglash, 1997), visuo-spatial processing (Martins, Fischmeister et al., 2014), music (Jackendoff & Lerdahl, 2006; Lerdahl & Jackendoff, 1996), architecture (Eglash, 1998), humor (Eisenberg, 2008), theory of mind (Miller, 2009; Tomasello, 2008), problem solving (Schiemenz, 2002), action sequencing (Pulvermüller & Fadiga, 2010), phonology (Hulst, 2010; Hunyady, 2010; Schreuder, Gilbers, & Quené, 2009), pragmatics (Levinson, 2013), conceptual structure (Hofstadter, 2000; Picard et al., 2010), mathematical proofs (Odifreddi, 1999), and arithmetic operations (Friederici, Bahlmann, Friedrich, & Makuuchi, 2011).

Given this long list of hypothetical loci for recursion, the central question is not whether cognitive theorists can propose recursive models of behavior for these different domains, but whether normal humans actually *implement* such models, by representing structural self-similarity and using this knowledge to make inferences. For instance, although tonal structure in music (e.g. in Bach) certainly can be characterized as following recursive patterns (Jackendoff & Lerdahl, 2006; Lerdahl & Jackendoff, 1996), it remains unclear whether non-musicians encode such structural properties (Fitch, Hauser, & Chomsky, 2005; Tillmann & Bigand, 2004). This holds equally true for many other domains. The point is that models positing recursion are only relevant for human cognition if humans actually represent and use implicit knowledge of recursion in their activities: a demonstration of which requires hard empirical work.

4. Conclusion

In sum, VA do not, in our opinion, demonstrate recursion outside of language. Rather they build a theoretical model that *assumes* recursion in intentional action, and use this as a basis for a wider analysis doubting the primacy of recursion for language. While we find this analysis interesting, it remain unconvincing. If their claims about the recursive structure of intentional action remain unchallenged, and empirically unverified, they are more likely to generate confusion rather than clarity.

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