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The future of future-oriented cognition in non-humans: theory and the empirical case of the great apes

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Opinion piece

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One of the most contested areas in the field of animal cognition is non-human future-oriented cognition. We critically examine key underlying assumptions in the debate, which is mainly preoccupied with certain dichotomous positions, the most prevalent being whether or not 'real' future orientation is uniquely human. We argue that future orientation is a theoretical construct threatening to lead research astray. Cognitive operations occur in the present moment and can be influenced only by prior causation and the environment, at the same time that most appear directed towards future outcomes. Regarding the current debate, future orientation becomes a question of where on various continua cognition becomes 'truly' future-oriented. We question both the assumption that episodic cognition is the most important process in future-oriented cognition and the assumption that future-oriented cognition is uniquely human. We review the studies on future-oriented cognition in the great apes to find little doubt that our closest relatives possess such ability. We conclude by urging that future-oriented cognition not be viewed as expression of some select set of skills. Instead, research into future-oriented cognition should be approached more like research into social and physical cognition.

1. Introduction

We humans have the distinctive feeling of being able mentally to pre-experience future events. We readily and continually make plans for future goals. Many think of this cognitive future orientation as one of our most advanced, and unique, cognitive feats. Future-oriented cognition, in a sense, presents a puzzle for cognitive science: the future does not exist, neither does backward causation [1]. The future cannot influence a current behaviour or thought. Notions such as foresight or future orientation are mere metaphors from the spatial domain. Cognition is always based on past causation: the products of evolution, ontogeny and individual experiences. At the same time, anticipating and influencing future outcomes is at the core of cognition and probably the main reason why cognition evolved. Few would disagree that, for cognition to have evolved, it must have given organisms a readiness that affects their future. Numerous researchers regard the brain as essentially a prediction-making simulator of the environment [2].

If one cannot think about the future in any real sense, i.e. being causally affected by it, and if cognition evolved to prepare organisms for forthcoming changes, what is the meaning in contemporary research of terms such as 'foresight' or 'future-oriented cognition'? The past decade has witnessed an upsurge in studies on future-oriented cognition in human and, not the least, non-human animals. However—as is usually the case in fledgling research—no all-encompassing definitions of the core phenomena exist, although one finds some agreement over which criteria qualify cognitive processes as 'more' future-oriented than others.

One overarching criterion—to which most other criteria relate—is *flexibility* [3,4]. The behaviours must link to possible upcoming events in a non-stereotypical way, taking into account specific elements or novel combinations of those elements. Such behaviours are more easily understood as what they are not: purely innately released or merely associatively learned responses. The behaviours

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must, in some sense—again metaphorically—be more proactive than reactive. Another apparent consensus criterion is *contextual detachment* [4,5]. A future-oriented behaviour can be detached from immediate perceptual input or from psychological or physiological states relating to the situation in which the future-oriented behaviour is performed.

Obviously, more detailed criteria exist, e.g. intentionality and sense of time, but we believe the above criteria capture the essence of foresightedness or future orientation in the current debates on animal cognition. As we show, however, these criteria are far from clear-cut.

The research into and debate over future-oriented cognition has revolved closely around the so-called *episodic cognitive system* and the *mental time travel* it is said to enable. Many have argued vigorously that this cognitive skill is uniquely human; and, therefore, only the human animal is capable of future-oriented cognition as captured by the above criteria [4–6].

In this paper, we describe some of the key cognitive systems believed to support future-oriented cognition while critically examining certain assumptions in the current debate. Reviewing the research on future-oriented cognition in our closest living relatives—the great apes—we question whether these cognitive skills are, in fact, exclusively human. Our aim, through these examples, is to show that research into future-oriented cognition in non-human animals must broaden beyond the current ill-founded dichotomies if we wish truly to understand how cognition affects the future in various ways.

2. The episodic system

(a) Consciousness and mental time travel

The theoretical roots of much of the contemporary cognitive-foresight research lie in memory research. In 1972, Tulving [7] proposed a distinction between semantic and episodic memory, where semantic memory is our database of knowledge about the world. It does not register perceptible properties of inputs, but rather the cognitive referents of such inputs. Episodic memory, on the other hand, receives and stores information on temporally structured episodes or events, along with the spatio-temporal relationships between them, i.e. what happened, where and when. Tulving thought that episodic memory can *only* store perceptible properties, always in autobiographical reference to the already existing content of the episodic memory store.

Tulving gradually [8,9] refined the defining contents of these memory systems, referring to them as a memory system allowing us *mental travel* backwards in time, implying a sense of past. One notable extension on the original model was that a certain form of consciousness is a necessary correlate to episodic memories—what Tulving dubbed *autonoetic* ('self-knowing') consciousness, a type of first-person phenomenal experience of detached perceptions existing only as constructs in the mind, based on previous experiences, such that the feeling of them belongs to your temporal self [9]. This contrasts with the semantic system, where knowledge about facts is not subjectively tied but simply involves awareness of familiarity of knowing, i.e. *noetic* consciousness.

Tulving early on argued that episodic memory is not only oriented towards the past, but it also allows construction of possible future events [9]. Meanwhile, Suddendorf & Corballis [10] took Tulving's backward-time-travel metaphor further, coining the expression *mental time travel* both to emphasize the temporally dual nature of the episodic system and, more importantly, to capture the phenomenality when one remembers or when one thinks about the future. A traveller always travels from a first-person perspective; a mental time traveller makes excursions to past or future in the same way. The poetic turn of phrase stuck. Much research on memory and foresight in animals came to focus on whether some non-human animals are mental time travellers. Ample evidence from both psychology and neuroscience indeed shows that the episodic system is involved both in reconstructing past events and constructing possible future scenarios (for a review, see e.g. [11]).

However, the assumption of subjective experience as a necessary functional part of mental time travel has hampered animal research. For example, the series of clever studies on memory and foresight in corvids performed by Clayton and co-workers [12–17] show highly flexible behaviour, but cannot strictly be viewed as revealing operations of an episodic system, because any correlating phenomenal experiences cannot be measured. To avoid entangling themselves in the question of subjectivity, they drew on Tulving's earliest criterion for episodic memory, where the ability—in an integrated and flexible fashion—to remember information on the *what*, *where* and *when* relating to an event was the defining factor, unrelated to any consciousness. However, this approach was criticized on the grounds that the capacity to remember what, where and when is neither necessary nor sufficient for mental time travel [4]; moreover, one could, in principle, use only the semantic system and remember what, where and when as strictly factual information [18]. This is one example of how the question of phenomenal experience draws attention away from the central question of *how* memories and future-oriented cognition work, turning it instead into a dichotomous question about human uniqueness (for similar ideas, see [19]). As a remedy, we wish to point out why the study of animal episodic systems should not (currently) be part of the study of animal consciousness.

Subjective experience is justly treated with caution in animal cognition research for two main reasons. The first is the lack of a detailed model for what, in computational or neurological terms, constitutes subjective experience. We cannot as yet, in any scientifically useful sense, identify the physical principles behind phenomenal sensation. The second is our failure to identify what subjective experience is for, either ultimately or proximately. What fitness-raising benefits does a creature gain from subjective experience: what it can do in comparison with a 'mindless' cousin living in the same biological niche? No firmly grounded theories as yet exist. The possibility arises that subjective experience is a mere, non-functional by-product of other processes.

These problems obviously also apply to humans. Nevertheless, it is agreed that linguistic reports of subjective experience are sufficient proof of their existence, in line with the comforting non-solipsistic belief that one is not alone in the world as a conscious agent. With regards to the human episodic system, this raises no concerns; it is valid to assume that human episodic processes correlate to subjective experiences. Difficulties arise when confusing correlation with causation. Tulving [5] and Suddendorf & Corballis [4] explicitly view subjective experience as functional in episodic recollection and foresight even though no empirical evidence exists showing what subjective experiences do, or whether they are mere epiphenomena. Subjective experiences might well be functional;

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currently, we simply do not know. Therefore, for now, they have little room in investigations of future-oriented cognition in non-human animals. If we cannot distinguish what non-linguistic behaviours, if any, are a necessary consequence of subjective experience, then obviously we cannot identify them. We should focus instead on what is known, behaviourally and neurobiologically, about the structure of the episodic cognitive system.

Our point is easily illustrated by analogy. Research into animal vision is highly productive [20], with no need to infer whether the animals are phenomenally conscious of what meets their eyes—not even when studying colour vision! Some animal-vision scientists may think that their subjects have phenomenal experience, whereas others do not, but this has no bearing on the empirical research, which is based on behaviour and physiology. The same principle should apply to the study of episodic abilities and future-oriented cognition.

(b) What is the difference between a memory and a foresight—really?

At first glance, the difference between episodic memory and episodic foresight is clear: memories are about the past, foresights about the future. However, this dichotomy deserves some consideration, as it might influence our view on future orientation in cognition. Remember that the future does not yet exist and therefore cannot influence cognition, whereas the past exists for us in the current moment only through causal chains that have left traces in our cognition.

Plenty of evidence suggests that episodic memories are mere reconstructions of past events and not exact reproductions of what occurred [21]. Episodic foresights are obviously constructions as well, based on previous inputs. As we have mentioned, a large mechanistic overlap exists between these two types of constructions. Some have argued that the main evolutionary advantage of the episodic system is enabling planning for the future [4,5]. Klein [22] notes that memories themselves are for the future; pondering on the past with no consequences for the future carries little in the way of fitness benefits. Memories ensure that one acts appropriately wherever the current situation resembles a past situation; something in the current situation must cue the memory retrieval. In this way, memories are part of future-oriented cognition, as they make us act in a way that affects the future outcome. One can also use the recalled information to anticipate a future situation without needing to project oneself into an episodically constructed event [23,24]. Remembering the last time, I forgot my keys and locked myself out of my apartment does not imply that every time I take the keys I do so while projecting myself into the future event of calling the locksmith, even though the behavioural outcome of both situations—imagining the details of the future event versus just anticipating the negative effects of forgetting the key—is the same. I bring the keys.

If both memories and foresight are inexact constructs of past impressions, and if memories are part of future-oriented cognition, the distinction between memory and foresight blurs. The episodic system appears to provide a continuum of types of constructs. Arguably, the more novel the combinations of past impressions in the construct, the more flexibly creative or future-oriented it becomes, though finding any quantitative measure of this is difficult.

One approach is to assume that future orientation entails action towards the future situation is taken before one is facing the situation. This raises the question of cueing: that is, something in the current situation—e.g. current goals, mental or physiological state, environmental stimuli—must facilitate retrieval of the episodic construct. Such constructs cannot pop indiscriminately to mind without any functional relevance, as a retrieval mechanism like that would not evolve. One might therefore question whether such a thing as a complete contextual detachment exists, which is implied by the criteria for future oriented cognition. Tulving & Thompson [25] found that memories are more likely to be triggered when the context at time of encoding matches the context at retrieval: the *encoding specificity principle* by which memory retrieval depends on degree of cue overlap. One, again, ends up with a continuum, this time of cue types: from perceiving major parts of situations to more subtle cues. Where on the continuum does something become more future-oriented?

A related question is whether one needs to know that a particular construct appearing in the mind is about the future or past, or is it enough merely to know whether it has happened or not? Indeed, at least theoretically, it seems that nothing prevents an organism from lacking representation of the construct's temporality altogether, so long as it acts upon the construct with beneficial consequences. We know little about why constructs form or how they instigate action. Boyer [26] suggested that episodic constructs might work as a motivational break on any motivational states preceding them, the construct evoking an emotion that outcompetes the earlier one. This brings the future into the present so that, for example, a choice between immediate and delayed satisfaction becomes a choice between two (current) motivations. Temporality beyond the current moment remains hard to capture.

We believe that the sharp distinction between memory and foresight—past and future—is based more on folk psychology, introspection and cultural constructs of time than on any clear, objectively identifiable processes of temporality. This may be even more important to bear in mind when studying the cognition of non-human animals, where, in general, dichotomous yes-or-no questions appear unfruitful.

3. Beyond the episodic system

Despite substantial intellectual focus on the role of the episodic system in future-oriented cognition, it is generally agreed that several cognitive systems must work in concert to enable future orientation [4,27]. With few exceptions [27,28], little theoretical or empirical effort has been put into the question of how various cognitive mechanisms interact in future-oriented behaviours in non-human animals.

Already Tulving recognized that the episodic system would not function without the semantic system [9]. Without factual knowledge, episodic constructs would be meaningless (if they would form at all). Despite this, the semantic and the episodic systems have been thought of as distinct, with the semantic system preceding the episodic system in evolution [4,5]. We believe this to be an oversimplification. We submit that the systems have coevolved, at least since the last common ancestor of mammals and birds. We further believe that the semantic system may be more important to future-oriented cognition than has been recognized: indeed, the seemingly unparalleled foresight skills of humans might largely be the result of an unusually wide knowledge of the world.

There are good neurobiological reasons to assume that many animals share abilities to form perceptually detached constructs in a way similar to those provided by the episodic system. Humans do not seem to have radically different brain structures or pathways associated with mental simulations or episodic abilities. Simulating behaviour and perception most likely has ancient roots [2]. Allen & Fortin [29] argue that the episodic system traces back neurobiologically to the ancestor of all mammals, birds and reptiles. Reviewing the literature on the regions and pathways related to the episodic system in animals—the hippocampus, parahippocampal region and prefrontal cortex with its bird equivalents—they identify the core properties in (at least) all mammals and birds. They do not claim that all these animals have what is technically defined in humans as an episodic system—rather that such a system would easily have evolved from structures they all possess, structures that at the very least are able to represent spatiality (the 'where'-function). Indeed, this seems to be the earliest function of the hippocampus, existing also in teleost fishes. Behaviourally based neurobiological studies on rats, who share a last common ancestor with humans around 92 Ma, suggest that they have a 'spatial episodic' system advanced enough to anticipate paths they have not taken before [30]. Meanwhile, the so-called *default mode network*—the wakeful but resting brain's flow of memories and daydreams—which in humans is associated with mental time travel [31], has been shown also to exist in rats [32], monkeys [33] and chimpanzees [34].

These distant evolutionary roots of the episodic system make consideration of the semantic and episodic systems' interaction worthwhile: such interactions might have a coevolutionary history stretching over hundreds of millions of years. It has been suggested that the contents of episodic memory invariably involve semantic representation and that a clear interdependency between episodic and semantic memories exists at both encoding and retrieval [35]. It follows that episodic future constructs contain semantic elements. A recent meta-analysis of 120 neuroimaging studies revealed that semantic and episodic memory brain networks do indeed overlap [36]. This empirically supports that semantic knowledge is intrinsic to episodic constructs and that the semantic system plays a key role in future-oriented cognition [37].

A study on a patient with episodic amnesia revealed that, even though he could not think about any future events relating to himself—like what he would do tomorrow—he performed on a normal level when it came to answering questions about a non-personal future, involving, for example, global politics or technology [38]. On the other hand, patients with semantic dementia have been shown to have deficits in their future thinking [39]. Taken together, these clearly suggest that both the semantic and episodic systems are necessary for future-oriented cognition in humans.

Given all of this, it is not obvious why the episodic system has received more attention than the semantic. It is even more difficult to understand why the episodic system is believed to be exclusive to humans and make our future-oriented cognition surpass that of other animals. Of course, our future-oriented skills would be extremely poor without an episodic system; at the same time, without our extensive knowledge of the world, transferred through language and stored in texts and the brains of many, we would likewise not be impressive. A favourite example cited [40] as one of the most remarkable planning feats by humans is the trip to the moon. It is, indeed, a good example of what humans can do with our extensively shared semantic knowledge. When John F. Kennedy laid out his famous plan with the line 'we choose to go to the moon'—which took roughly 3 s to say—he most likely did not episodically simulate the endeavour that took 400 000 people a decade to fulfil, if only because the size of his brain was not large enough to manage such an operation. When we, humans, perform long-term planning stretching over years or decades, we probably depend much on our semantic system. We know about such facts as retirement, academic degrees and other concepts referring to our future. The flip side of the coin is that animals exhibiting future-oriented cognition usually do so in relation to their own subject, characteristic of the use of an episodic system. Some of the restrictions of future-oriented cognition in non-human animals might well be caused by limited factual knowledge of the world.

Here, we have stressed the importance of the semantic system in trying to balance the picture of what is needed for what we think of as future-oriented cognition. Several other mechanisms may have equal importance in various foresight feats such as executive function, associative learning, means-end-reasoning and recursion. We touch on some of these in reviewing what is known about future-oriented cognition in our closest living relatives: the great apes.

4. Theory and empirical results: great ape foresight

(a) Behavioural criteria for future-oriented cognition in great apes

The first serious theorizing on cognitive foresight began in the field of great-ape psychology almost 100 years ago. Wolfgang Köhler, who from 1913 to 1917 studied chimpanzees at his anthropoid station, identified empirically verifiable distinctions for varying complexities of foresight [41], relating in several aspects to modern hypotheses. Köhler observed chimpanzees to anticipate events, which they appeared to plan. However, all the acts he observed were made in the face of a visible reward; it would be a higher achievement, he thought, if such acts were carried out for goals out of sight. He argued that even more advanced planning skills would be revealed if the chimpanzee disregarded a strong immediate motivation in favour of the mere expectation of a larger future benefit. Köhler never experimented on these issues; however, he suggested a simple experimental paradigm based on two rooms: one room would contain a reward, the other the means to get it. Access to the rooms would be temporally separated: having entered the 'reward' room, the chimpanzee could not immediately return to the room with the tools. The key behaviour to watch for was transportation of the requisite tool, when allowed, to the 'reward' room. Tulving [5] and Suddendorf & Corballis [42], have suggested similar set-ups. Their versions, however, stress more explicitly that associative learning, other learning and innate responses must be precluded. They also take Köhler's ideas about contextual detachment a bit further: not only must the end goal be out of sight, but the future-oriented behaviour must not be instigated by, nor satisfy, a present need or be governed by present physiological states.

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Perhaps the most famous hypothesis on the necessary behavioural criteria and the purportedly uniquely human skill of future-oriented cognition is Suddendorf & Corballis' [10] *Bischof-Köhler hypothesis*, which states that animals other than humans cannot anticipate future needs and drive states and are therefore bound to a present that is defined by their current motivational state.

As should have been implied already, their criteria, and the Bischof-Köhler hypothesis, are theoretically problematic. In one way or another, cognitive operations must be instigated in the current situation; actions directed towards the future must logically be based on current motivational states. And, one cannot plan for events containing elements one has no experience of whatsoever. Nevertheless, their criteria are currently generally taken as setting a standard for complex, future-oriented cognition that may be uniquely human. We review what is known about great-ape foresight in relation to these criteria, then discuss memory studies that relate to future-oriented cognition. We also briefly comment on other work on great apes relating to future-oriented cognition.

(b) Studies of great apes

Great apes have been reported to display complex future-oriented behaviours in the wild. Chimpanzees in the Taï forest are known to carry tools to nut-cracking sites even when those sites are out of view [43,44]. Chimpanzees in the Goualougo Triangle not only transport tools from one termite mound to another, but also further transport specific tools for specific tasks [45]. It seems likely that the chimpanzees plan ahead when selecting the appropriate tool for the task, even though that task is currently out of view [45,46]. Orangutans in the wild have recently been reported as displaying future-oriented behaviours [47]. The study tested whether males' long calls are indicative of future travel direction. The results suggest that males vocalized in the direction that the female group followed the day after and that male subordinates avoided. The authors interpret the results as evidence for future planning: males not only decided the travel route in advance, but also communicated it to other members of the group. Although all of these reports are suggestive, they cannot necessarily be understood as fulfilling the above-mentioned criteria for future-oriented cognition, not least because of the difficulty controlling for various factors in the wild. Nevertheless, we find it difficult not to see the parsimonious interpretation being one of future-oriented cognition, given what has been discovered in studies on captive great apes.

Studies in the laboratory have attempted to address the criteria for future-oriented behaviour more directly. The first systematic study on cognitive foresight in great apes was conducted on orangutans and bonobos [48]. The apes were presented with a reward out of reach and a set of both useful and useless tools, which they could select from and take into a waiting room. To obtain the reward, they had to return to the room where the reward was placed carrying the appropriate tool, either 1 (first experiment) or 14 h (second experiment) after seeing the reward. The results showed that the apes were capable of saving the tools needed for a relatively distant future. A third experiment showed that it was unnecessary for the apes to see the reward before selecting the appropriate tool. However, critics argued, among other things, that the apes could potentially have experienced a desire for the reward throughout the waiting period; thus the experiment did not directly address the Bischof-Köhler hypothesis [4].

A more recent study addressed some of these criticisms [49]. Once again, chimpanzees and orangutans were presented with a tool-use task; however, in all four experimental set-ups, the reward apparatus was out of sight at a different location from where the tools were selected. The apparatus was not even installed until the waiting time of seventy minutes had passed. One experiment showed that subjects could disregard an immediate small but highly desirable reward in favour of the appropriate tool for gaining access to the larger future reward, in line with Köhler's ideas. Another experiment showed that the functional tool was selected not merely as an associatively learned stimulus, but rather also based on its functionality. In yet another experiment, subjects had to select the functional tool from a set of tools they had never encountered before. The authors concluded that the subjects were engaging in future-oriented planning behaviours by outcompeting current drives and mentally pre-experiencing an upcoming event (see [40] for a critical commentary and [49] for a response). The results seem to argue against the Bischof-Köhler hypothesis and preclude associative learning as a primary mechanism.

Another study focused on whether chimpanzees could prepare for future exchange with a human [50]. Subjects were trained extensively in an immediate context to exchange an object for a food reward; they were then tested in a delayed context where they could select the exchangeable item, transport it and keep it for later exchange. Despite the extensive training, subjects failed at the delayed exchange-task. However, the same subjects succeeded in the tool-use planning task. The authors speculated that the failure might have been caused by limitations in ability to plan for social situations, i.e. the upcoming exchange event with a human agent. However, a replication of the experiment showed that apes can, indeed, defer exchange [51]. The authors of this study suggested that the different outcomes could be the result of two different captive populations with differing long-term experiences of humans and, therefore, different semantic knowledge about the world. Although more research is needed, this could be the first indication of a role for the semantic system in great-ape future-oriented cognition.

An observational study on the spontaneous behaviour of a single male chimpanzee in captivity reported that he would gather stones hours in advance, before any zoo visitors were present, for later throwing at the visitors [52]. He placed them in caches next to the areas where the visitors would later stand. During the collection phase, his behaviour appeared calm, in contrast to the very agitated state in which he displayed and threw the projectiles. The results again suggest that great apes can take actions well in advance of a future goal, and again refute the Bischof-Köhler hypothesis. A follow-up study on the same chimpanzee used more controlled observations and methods [53]. The steps of the stone-related behaviour were monitored over the course of one zoo season. The chimpanzee was observed preparing for deception by hiding stones under heaps of hay and inhibiting his normally aggressive display behaviour when appearing before the visitors. In this way, the visitors did not know to back away in time before he could release a projectile. The authors believe themselves to have observed the very first instance of this new behaviour. The results suggest that great apes can complexly recombine previous experiences and knowledge into projection of a new situation, not just react to a 'whole' previous memory. More experimental studies on additional subjects are needed to gain more insights.

As noted earlier, the relationship between memory and planning has received little empirical investigation. To address this, a recent study investigated how encoding of information, either intentionally or incidentally, affects subjects' performance in a tool-use task [54]. Chimpanzees, orangutans, bonobos and human children were all tested under a highly similar set-up. The results showed that when information relevant for the tool-use task was encoded incidentally, subjects performed worse than when they knew the information's relevance (intentional encoding). This suggests that the type of memory available in a simple planning task is crucial to performance for great apes.

On the same lines, another recent study with chimpanzees and orangutans investigated the contribution of long-term memory to a simple tool-use planning task [55]. The results suggest that the chimpanzees and orangutans could remember a tool-finding event that took place on four occasions 3 years earlier as well as a unique tool-finding event that happened two weeks before. The experimental paradigm worked as follows: subjects were presented with relevant cues that were present in the original event (same experimenter, same set-up, same context), to assess whether the cues would trigger the memory of where to search for the tools. The results highlight two issues. First, the apes' memories for past events could be triggered by distinctive relevant cues, similar to human memory. The results thereby question the very idea of complete contextual detachment as a requirement for future-oriented cognition. Second, the apes could act on events that happened a few times either years ago or two weeks ago but only once. The results thereby provide insights into the contribution of memory to future-oriented cognition. It is difficult to argue that the apes were not relying on some episodic elements of their memories to succeed in these tasks.

The above-cited empirical examples relate mainly to the behavioural criteria that have been suggested for future-oriented cognition and to purported operations of the episodic system. Several other studies on great apes concerning future-orientated cognition are worth mentioning, focusing on another of the abilities Köhler pondered upon: exerting self-control in the current moment in return for future benefit. Self-control is an inhibitory ability, crucial for future orientation. No matter how advanced other cognitive mechanisms are—episodic or otherwise—no action towards a future outcome will be taken unless one can overcome conflicting psychological states. Indeed, not long ago, non-human animals were generally thought of as inherently impulsive; this was taken as part of the evidence that they were 'stuck in time' [6]. The picture has changed, not least, thanks to great-ape studies revealing high levels of self-control [56–58]. This ability is obviously one piece of a conglomerate of mechanisms understood as future-oriented cognition. As suggested earlier, the episodic system might play a role in self-control, if it provides an episodic construct of the future outcome that can break the motivation towards immediate reward by evoking a stronger motivation [26]. On the other hand, the inhibitory control itself is probably not part of the episodic system. Indeed, a study on a patient with dense episodic amnesia found that he was able to exert self-control in the face of a smaller, temporally close reward and a larger, delayed one [59]. The context involved only hypothetical monetary rewards, where money itself is a symbolic stand-in for 'real' value. So, the set-up probably favours semantic operations more than 'real', non-symbolic rewards.

Although so far only a few studies on future-oriented cognition in great apes exist, those studies provide enough evidence to conclude that the great apes can exhibit future-oriented cognition according to the current, imprecise criteria. We have chosen to review the empirical results only on great apes and not other animals, because the great apes are our closest living non-human relatives (for a review including more taxa, see e.g. [27]). By the logics of evolution, which surely apply to cognition, closely related species sharing complex features not found to the same extent in any close out-group do so because of homologies. It violates parsimony to assume radically different cognitive mechanisms behind highly similar behaviours. If the similarities are accepted as homologies, this opens up the possibility for detailed investigations into the differences, which could then be used for the better to define and explain future-oriented cognition both in humans and other species of great apes in a more grounded way.

At the moment, the debate is highly polarized, constituting one of the most heated in the field of animal cognition today. Critics of the great-ape studies put much effort into conveying the lack of any essential similarities between humans and the other great apes in those aspects of future-oriented cognition that matter—sometimes with surprisingly little biological or epistemological sophistication. The relevant behaviours are typically viewed as the result of pure associative learning, e.g. [40,42], despite the absence of any identified mechanisms within the associative-learning paradigm allowing for such long-time intervals and—even more importantly—despite well-designed controls for associative learning [49,60], and other, clearly contradicting factors [51]. A frequent move is to view the conclusions from these studies as anthropomorphic or folk psychological, e.g. [61], although those conclusions are based on existing, well-established cognitive and biological theories, not on introspective folk psychology with its admitted anthropomorphic bias.

We could make the list of critiques that are wide of the mark much longer; this is just a representative selection. We believe the confusion is mainly a result of a lack of well-founded ideas about what future-oriented cognition really is. Lacking solid theoretical foundations and based in part on misunderstandings, existing behavioural criteria can, at best, be viewed as offering tentative guidelines for investigations, as they of course include intuitive grains of what we loosely think of as future orientation.

We conclude this section with a call for a biologically much broader approach to future-oriented cognition. For example, findings on future-oriented abilities in crow birds, e.g. [16,17], are particularly interesting, raising challenging questions about how parallel evolution—perhaps along with deep homologies—affects cognition.

5. Conclusion

We have critically examined some key theoretical issues in the current debate over future-oriented cognition in animals in general and great apes in particular. In doing so, we have not provided many original thoughts; instead, we have tried to bring attention to matters that sometimes appear to have been overlooked and to question such seemingly strict dichotomies as episodic cognition *or* not, memory *or* foresight, human *or* non-human.

Trying to make clear such demarcations may not be the most fruitful way to gain deeper understanding of future-oriented cognition. Of course, it is not uninteresting to learn what is typically human. However, at risk of stating the obvious: finding a cognitive singularity—e.g. the episodic system—is likely to fail, given our species long shared genetic history with thousands of other species. The cognition governing behaviour is complex and probably contains many layers of adaptations working in concert, in accordance with how evolution is understood to operate. The idea that the episodic system is uniquely human appears particularly ill-founded, given the ample evidence from neurobiology and behavioural studies of other animals. One finds no obvious unique evolutionary selective pressure for such a system in the human lineage. That said, if one tries to find the *exact* same system in other animals, it is logically all but guaranteed that one will fail. It is curious that so many try to define future-oriented cognition and cognitive foresight as close as possible to the human model, such that failure to meet even one part of the criteria means that the animal is not foresighted; taken to the logical extreme, this results in the empty conclusion that only humans have human skills. This is not to say that it is not beneficial to use the human animal as a less strict model: after all, the human animal is the best and most studied cognitively, and it shares an evolutionary history with many other species. Contemporary research into human foresight is, in contrast to the equivalent research in other species, more balanced and less dichotomous. For example, the intense focus on the episodic system, and its subjective experiences, in the debate over future-oriented cognition in non-human animals has drawn attention away from other important—probably necessary—mechanisms for the phenomena. We illustrated this with our brief discussion of the role of the semantic system in future orientation. Instead of teasing apart mechanisms to use only one or two for explaining such a broad skills as future-oriented cognition, one should first identify the parts—if one even can speak about 'cognitive parts' as anything more than theoretical constructs—and then ask how they interact.

In this paper, we have tried, so to speak, to move the future forward to the current moment. Any given organism ultimately has nothing but the present, including those traces of its history laid down in its cognition. Questions concerning future orientation are really about how cognition works in the current moment, influenced by environment and previous casual processes, in ways that can lead to action that affects future outcomes; and, in what diverse ways the future outcome can be affected? Most areas of cognitive science ask more or less these same general questions, because, as we argued earlier, cognition is for the yet-to-come. However, by no means are we arguing that it is meaningless to study or discuss future-oriented cognition and related notions. At the same time, we think that terms like 'future-oriented cognition' should represent a more open work field as, for example found in social or physical cognition. No one today would ask whether animals have physical cognition, or—for social animals—whether they have social cognition. What one finds instead in these areas is a variety of theories, paradigms and evolutionary accounts. We suggest that *future-oriented cognition* should best be understood as referring to a research interest rather than any singular skills or real state of the world; it is up to researchers to decide from time to time, given empirical input, what they find suitable to study within this sphere of interest.

One cannot help but wonder whether researchers themselves get fooled into thinking that it is actually possible to think about the future, owing to our cultural constructs of time and our remarkable skills in affecting future outcomes, thereby coming to believe in a distinct type of cognition that deals with the future in a way detached from the current moment. The cognitive future is now. The time for simple, clear-cut dichotomies in the field of future-oriented cognition in animals has passed.

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