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Action anticipation in sports: A particular case of expert decision-making

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A soccer player asks his girlfriend to marry him. To celebrate, they buy a red car. That day, during practice, the soccer player shoots to score a goal, unprecedentedly using his left foot, anticipating the goalkeeper's next move. All of these actions result from social, consumer, and perceptual-motor decision-making (DM) processes. Although the soccer player might not be an expert decision maker in relationships or car deals, he is surely an expert when it comes to deciding how to score a goal. Not all decisions involve the same cognitive processes or neural underpinnings. Thus, when considering expert DM, it is crucial to clarify both the expertise domain and the decisional processes involved. Here, in this opinion mini-review, I present a brief overview of action anticipation (AA) in sports as a particular case of expert DM, making use of theories from economics to mathematical and clinical fields. Additionally, I discuss the cognitive and neural mechanisms subtending AA and show how certainty and saliency influence AA just like in other DM situations. Finally, I discuss how expert DM in the form of AA in sports can amount to a gut feeling, just like the gut feeling the soccer player needed to propose or buy a red car, instead of blue.

KEY WORDS: expert decision-making, action anticipation, level of certainty, familiarity.

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Are you an expert? In what?

If I were to say that someone is an expert, you might ask 'in what?'. Indeed, despite the existence of specific- and general-knowledge domains, it is the domain-specific knowledge that is said to play a significant role in distinguishing novices from experts [1, 2]. However, transfer-related effects have been described in children undergoing non-specific domain training [3] and in expert adults acquiring novel motor skills [4]. These studies seem to suggest that there are some domain-general skills that might be transferrable.

Thus, how transferrable are expert skills? Will you make better decisions as a coach, if you are an expert athlete? The issue of domain specificity is an important one. Some authors distinguish competence from expertise, linking competence to a specific knowledge set and describing expertise as extending to several related domains [5]. However, domain-general expert skills are harder to operationalize and assess compared to domain-specific performance. As such, expertise tends to be measured in specific domains [6]. One consequence of this is that depending on the domain of expertise under investigation (or even, the domain of expertise of the investigator) many definitions of expertise arise. One can be an expert musician, athlete, salesperson, surgeon, etc. We could go on to find as many domains of expertise as there are jobs, hobbies, and interests. However, whatever the domain of expertise, from psychomotor to executive functions, it is agreed that experts share stable and outstanding performances that depend on experience and practice [7]. Although actions can be easily measured to infer on the level of expertise, many domains of expertise depend specifically on expert decision-making (DM) (e.g., expert judge) or on both action and DM performance (e.g., expert soccer player) [8]. Although everyday expertise may be useful in DM strategies [9], limited evidence has been found to support the specificity of expertise in DM [10]. So the question remains concerning the importance of expertise specificity in DM. However, in the case of action anticipation (AA), specificity of expertise in DM might be synonymous with specificity of expertise in action. I suggest we take an in-depth look at this particular case of expert decision-making in sports.

Action anticipation as a particular case of expert decision-making

Despite the question about the specificity (or lack thereof) of expertise in DM, in the case of AA, mounting evidence suggests that it might be better to be an expert action performer than an expert decision maker concerning that same action. Aglioti et al. [11], for example, showed that despite stronger belief in one's own predictive capacity, visual (sports journalists) and visual-motor experts (coaches) were less efficient in predicting the actions of another ahead of time, when compared to expert performers (elite basketball players). Indeed, only in elite basketball athletes, did motor activation occur during the observation of erroneous basketball throws.

But why is AA so important? Understanding, recognizing and predicting action schemes and movement sequences in sports is paramount for the success of an athlete or a sports team. The capacity to anticipate the actions of an adversary, a teammate, or even the trajectory of a ball after a kick or a throw, allows for the collection of crucial information that might make the difference and lead to a successful tackle, reception, block, goal, match, etc. Some suggest that interactions between team players are based on informational flow fields that possess superorganismic properties [12]. However, no matter how tightly coordinated and goal-directed a sports team is, each individual athlete is constrained by his or her own specificities, one of which pertains to the decisional strategies applied during the observation of sports movements. If an athlete is able to anticipate the consequences of the action of another, he or she might better decide how to respond to that prediction, by choosing a specific response action.

Studies have demonstrated important differences in the neural correlates between experts and non-experts, during anticipation tasks in sports action contexts [13, 14]. The reason for these differences in brain activation, during action anticipation associated to expertise, might be explained by disparities in information processing. Experts resonate, in their own body, the observed action and, as such, look for body cues, while novices require the use of complex high-level DM strategies without the guidance of specific cues. In summary, expert athletes "read" the body in motion, recognize their mistakes at a conscious level and use body conscious mechanisms to anticipate the action of another [13]. These resonance mechanisms previously described by Aglioti et al. [11], find support in both Embodiment and Motor Imagery concepts.

The Embodied Cognition Theory states that the observation of human motor action can lead to the reactivation of action systems associated to the observed action [15]. TMS studies have provided much support for this theory. Urgesi et al. [16] demonstrate that the observation of specific actions can lead to the corticospinal excitation of the muscles involved in the execution of that same action. So embodiment can be seen as a type of motor simulation. Motor imagery, on the other hand, should refer to a type of mental simulation. The network of neural substrates associated to this type of cognition is adequately named Action-Observation Network (AON), involving the inferior frontal gyrus and the ventral premotor cortex, that are both activated when one executes or observes an action [17]. Given such AON, motor imagery, through motor mental practice without action, should reap some benefits as it ignites the same network that would be activated during action execution. Indeed, simple motor imagery leads the central nervous system to activate the effectors involved in actual action. This enhances the vigilance level as a result of motor anticipation [18]. Some authors sustain that motor imagery thus implies awareness and programing of movement [19]. Such awareness and programing experiences point to DM processes, since motor simulation can aid in motor inferences, part of the DM process [20].

One might gather from the evidence above that action observation might somehow facilitate action execution. Indeed, recent studies have shown that observing action can actually lead to the enhancement of force [21], and even improve some aspects related to cognitive performance and proneness to perform physical exercise

[22] as well as the autonomic responses associated to actual exercise [23, 22]. We can thus gather that observation can influence actual execution, but how does this lead to successful action anticipation? Possibly this might be better explained by considering both the influence of action observation in action execution and the influence of action execution in action observation. A shared neural network between action observation and execution suggests just this. Hence, we can understand how experts not only possess better sensorial and motor capacities, but also a better capacity to anticipate the behavior of others due to a shared neural network, and a finely tuned reactivation system [11]. Accordingly, the successful anticipation of the consequences of actions of others involves a functional reorganization that implies a fine association between anticipation, the capacity to detect errors and motor expertise [13].

Computational decisions or gut feeling?

In an earlier review on the neuroscientific bases of DM in sports, an important issue was raised concerning the influence of certainty offered by the situation on the type of DM [24]. Typically, certainty derives from perceptive cues and uncertainty results from unfamiliar situations implicating the need for additional cognitive processing [25]. When few cognitive resources are available to process an unfamiliar situation (e.g. a risky situation), choice behavior can be explained by the saliency of rewards or qualities of the options [26]. Saliency, therefore, should inform risky or unfamiliar decisions. In these cases, the level of certainty, as well as the informative component of saliency, should directly impact on the speed-accuracy tradeoff. Another crucial factor in modulating DM are emotions [27]. Bechara et al. [28] suggest that emotional information, indexed by the autonomic state of the body, can influence DM in situations of uncertainty. Thus, when in need to perform speedy decisions, as in sports contexts, salient cues picked up by experts should bias decisions. These considerations help us in understand how intuitive decisions might occur. So, does action anticipation result from a gut feeling? In sports, lengthy time-consuming decisions might not always be the most efficient and there is talk of intuition when describing motor decisions.

We have all marveled at the seemingly easy, fluid and integrated motions that expert athletes can demonstrate during game play. The voluntary movements of these athletes have been so incredibly polished by practice that the anticipation of environmental obstacles seems almost automatic. However, this anticipation is thought to be based on feed-forward control mechanisms [29]. Could then, specific action anticipation decisions be instinctive instead of rational? Do we act on gut feeling or is action the end-result of long DM processes? With the advent of new imaging technologies, in tandem with the development of neurosciences, these questions have been approached in a new light [30]. Rosenbloom et al. [31] defend that DM is a complex executive function, of which the anticipation of the outcome is but one of its components. Drawing up inferences from the statements above, could executive function feed-forward mechanisms, fueled by salient cues and somatic markers, triggered by emotions, constitute gut feelings? Well it seems that in clinical practice, for example, intuition can be seen as more than non-intentional knowledge. Intuition can be considered to be an actual cognitive skill involving pattern recognition and associated to expertise [32]. In a recent animal study, Zariwala et al. [33] show that optimal decision-making might sometimes increase without the addition of any temporal cost. These intuitive decisions or "hunches" rely on patterns of recognition that can be quickly processed by the brain. The authors suggest that with practice and consequential acquisition of expertise, deliberation might become redundant. However, this seminal study of rats performing an odor categorization task, suggesting that speed and accuracy might vary independently in uncertain situations, has still to be confirmed in humans. Furthermore, the question remains, whether the circuitry and mechanisms involved in speedy decisions are the same as those involved in time-consuming reflective ones.

The successful anticipation of action in sports might thus rely on such gut-feelings. However, it is also possible that expert athletes are simply processing the right information earlier [34, 35], thus timely predicting the ever-changing contextual constraints and successfully adapting their behavior. In a recent sponsored documentary, Cristiano Ronaldo, arguably one of the best soccer players of current times, was 'tested to the limit'. Although the results of these tests were not published in a scientific journal, they are certainly worth discussing. In one particular task, Cristiano Ronaldo is asked to score a goal as the lights are turned off before the assisting pass is concluded (i.e. even before the passer's foot touches the ball – see Figure 1). The world-class athlete is shown to be able

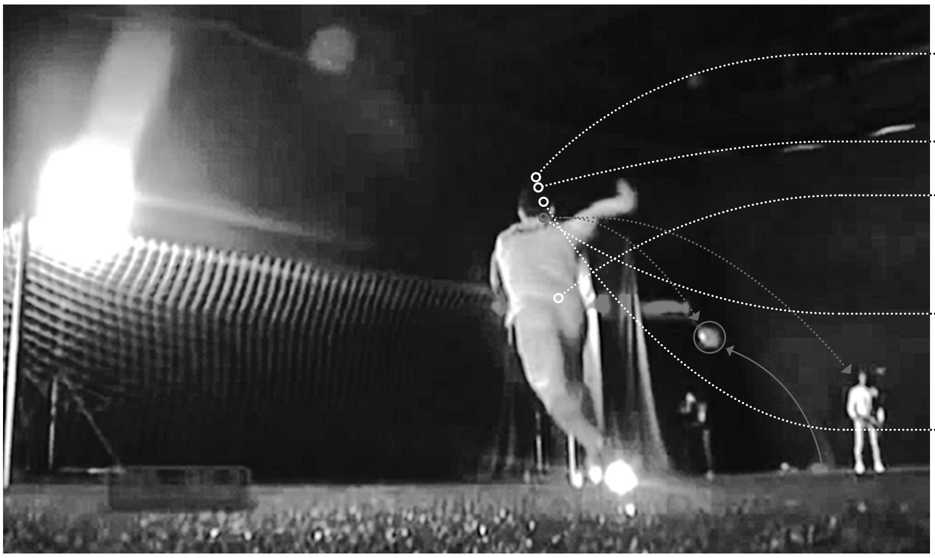

Figure 1. Processes subtending Expert Action Anticipation in sports. Cristiano Ronaldo scores a goal in the dark (uncertain situation leading to effective decision-making)

to compute the ball trajectory and anticipate its flight, optimally moving towards the target and scoring a goal. What then, are the mechanisms and processes of such effective behavioral adaptation and action anticipation? Is it pattern-recognition hunches or early information processing?

As stated above, motor experts may implicitly process body-related motion through motor resonance mechanisms [11], activating, during action anticipation, other nodes beyond the AON, such as the extrastriate body area (EBA) [13] involved in the visual processing of human bodies [36, 37, 38]. Furthermore, during situations of action leading to erroneous consequences (e.g. a ball missing its target), the anterior insular cortex is also activated, in tandem with the AON. This is proposed to be associated with a differential involvement of the neural system in awareness and error monitoring [13] as suggested by the role of the anterior insular cortex in heightened awareness and emotional processing [39]. Others have shown that even under deceptive conditions (higher uncertainty) highly skilled participants are more accurate in anticipating the consequences of action compared to novices. This superiority is associated with the activation of a cortico-subcortical network implicated in executive function and oculomotor control [40]. Despite the advances in neuroimaging that have afforded these new insights on the neural correlates of action anticipation in sports, not many inferences can be made concerning the nature of the subtending mechanisms of action anticipation, i.e., are the aforementioned neural bases associated to gut feelings or early information processing. The evidence seems to point to both processes. And the truth may lie in between. Action anticipation may be regulated by early, finely tuned, pattern recognition processes.

The role of the prefrontal cortex in executive functioning has also been described, as well as its unique contribution in DM by means of a False Tagging Theory that posits that the prefrontal cortex affixes false tags to perceptual and cognitive representations in order to bias distractions, beliefs, judgments and decisions that are negatively weighed [41]. Such tags seem to imply quick, representation-triggered mechanisms. So it seems that biases are very important in DM. However, one seldom discusses doing nothing as a possible decision. And doing nothing (or maintaining the previous or current decision) is exactly what we tend to do [42]. This anchoring phenomenon is not only specific to maintaining one's status quo, but it is frequently present as a pervasive judgment bias whereby we are systematically influenced by random or uninformative starting points. Chapman and Johnson [43] showed, in a series of experiments that prompting subjects to consider different features from that of the anchor, reduces anchoring. More recently, Tweed et al. [44] showed that less robust information can undermine more robust information in DM situations. Are then, expert athletes, more able to avoid anchoring biases, or do they possess finely tuned anchors that are more pertinent to the AA process? And are athletes more resistant to less robust information when deciding the consequences of the action of another or of a target? Both these statements might be true as AA in sports implies quick, finely tuned processes and, as stated above, the need for such prompt decisions might compare to a situation where limited cognitive resources are available (given that the time to process these resources is short). In such situations, 'saliency' takes charge [26]. Such choice guided by value (saliency) implies the activity of parietal and prefrontal areas [45]. Crucially, the prefrontal-parietal network has been shown to be implicated in the integration of perception with action across time [46]. The interaction of perception and action, on the other hand, has been shown to afford the prediction of future outcomes of actions [47]. This evidence, together with other studies that propose automatic action-outcome integration to be partly responsible for the control of voluntary action by anticipation of action goals [48], seem to nicely consolidate the idea that AA in sports might constitute a particular case of quick saliency-driven DM responses, as the result of motor resonance mechanisms, associated to expertise. Even if automatic, DM is a cognitive process [49]. In line with this, Oliveira et al. [22], propose that observing motor action might release a cognitive load allowing the engagement of attention for the resolution of cognitive tasks (such as DM). It is thus possible that motor action observation might help trigger the DM process in AA in sports.

What this paper adds?

In this review, I present recent findings from different areas of research (economics, social and sports science, and neuroscience) that support the idea that action anticipation (AA) is a particular case of expert decision-making. I suggest novel and innovative avenues for analyzing AA in sports, centered on saliency features of the environment and intuitive and automatic processes. Furthermore, I suggest these processes are grounded on motor resonance mechanisms.

Outlook

With this opinion review I do not pretend to solve the issue of what mechanisms and processes, AA in sports entails. However, I did aim to show, with the support of research in social, economic and neural sciences that, like proposing or buying a red car, kicking a ball to score a goal is also a DM process. Nonetheless, AA in sports entails a series of specific characteristics. These lead to early activation, simplification and automatization of prediction, depend on motor resonance and are deeply intertwined with perception of salient cues and actual experience. Such a conjunction of means, allows the rest of us to marvel, as a gifted soccer player scores a goal after eluding opponents and deceiving the goalkeeper.

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