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review article

Decision-making in sports: the role of attention, anticipation and memory

A tomada de decisão no desporto: o papel da atenção, da antecipação e da memória

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Abstract – Expertise is a core goal for the achievement of elite-level performances. In sport, expertise is deeply related to the ability of making accurate decisions. In this context, decision-making becomes highly complex, due to a large number of relevant cues and interactions, as well as to multiple non-linear cause-and-effect relationships and severe time pressure. In this paper, three core components underlying decision-making were analyzed: attention, anticipation, and memory. They were explored within high-complexity contexts. The goals of this review were to: (i) provide a sound knowledge and contextual framing for the concepts of attention, anticipation, and memory in the context of decision-making in sports; and (ii) analyze how their effects vary according to situational constraints. Analysis of the literature allowed highlighting that, in sports, attention should be mainly goal-driven, selective, with external broadband focus. Anticipation, a tenet for attaining elite-level performances, is justified when it doesn't increase the rate of errors and is sensitive to counter-communication strategies applied by the opponents; therefore, certain contexts invite the players to adopt waiting strategies, especially when the risk taken by anticipation leads to a reduction in effectiveness. Memory provides a solid basis for attention and anticipation, and also originates and supports intuitive and strategic thinking. The knowledge obtained potentiates a better-calibrated perception of relevant variables for decision-making, therefore enhancing the contribution of scientific research towards practice.

Key words: Anticipation; Attention; Decision-making; Memory.

Resumo – *A perícia é uma importante meta a alcançar na busca de elevadas performances. No caso dos jogos desportivos, a perícia está profundamente associada à capacidade de tomar decisões. Neste contexto, a decisão assume contornos de elevada complexidade, derivada dum conjunto alargado de indicadores e de interações a atender às múltiplas e não-lineares relações entre ação e efeito e à pressão temporal envolvente. Neste artigo, investigaram-se três componentes nucleares subjacentes à tomada de decisões: a atenção, a antecipação e a memória. Percorreram-se as suas características em contextos de alta complexidade e de forte imponderabilidade. Os objetivos do presente artigo consistiram em: (i) aprofundar e contextualizar os conceitos de atenção, antecipação e memória no âmbito da tomada de decisão nos jogos desportivos; e (ii) analisar se os efeitos destas componentes dependerão de constrangimentos situacionais. Da revisão de literatura efetuada, salienta-se que, nos jogos desportivos, a atenção deverá ser essencialmente guiada por objetivos, seletiva, de foco externo e banda larga. A antecipação, potenciadora de elevadas performances desportivas, justifica-se no caso de não aumentar exageradamente a taxa de erros cometidos e é sensível a estratégias de contra-comunicação dos oponentes, pelo que determinados contextos convidam à adoção de estratégias de espera, nomeadamente quando o risco assumido pela antecipação se traduz numa redução da eficácia. A memória, informando quer a atenção, quer a antecipação, origina e suporta o pensamento intuitivo e alicerça o pensamento estratégico. Os conhecimentos obtidos permitem uma melhor perceção calibrada das variáveis especificadoras, potenciando os contributos da investigação científica para a prática.*

Palavras-chave: *Antecipação; Atenção; Memória; Tomada de decisão.*

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INTRODUCTION

Experts represent a select group of people who stand out from their peers for the excellence with which they achieve high-level results. This expertise is closely associated with the ability to make decisions[1], an intricate process that occurs in complex situations and under high time pressure[2]. Since expert decision-making is a core component in the achievement of high performances in sports[3], it is relevant and useful to ask which factors contribute the most to proficient decision-making.

The ability to make effective decisions seems to depend on a suitable orientation of the decider towards relevant indicators. This happens through the attunement to the affordances of the environment, which are 'invitations' to action, a functional concept of action possibilities that relates the environments' characteristics with the abilities of the individual[4]. To this end, individuals use attention, which is considered the best predictor of sports performance[5]. In fact, experts are better at catching early relevant indicators of the specific task[6], using their attention abilities to better anticipate the outcomes of their own actions and the actions of opponents. However, anticipation is a phenomenon that has both advantages and disadvantages, emerging as beneficial in certain contexts, but detrimental in others[7].

In this sense, the action of directing attention and predicting when the adoption of an anticipation strategy will be positive is embedded in a reference system that allows assessing the convenience of this decision: the memory[8]. The processes and manifestations of memory that influence the attentional and anticipatory processes may be multiple, ranging in depth and in the extent of its influence. The question becomes more complex if we invoke the concepts of *history of choices*[9] – integrating multiple decisions in a coherent whole and resorting directly to strategic thinking – and *intuition*, as the culmination of potentiation processes developed through experience and learning[10].

In particular, gaining expertise in sports games (SG) greatly depends on the ability to make decisions[3] in circumstances of great imponderability. In this regard, the process of decision-making emerges from how attention[5], anticipation[7], and memory[8] interact. The purposes of the present paper were: (i) to deepen and contextualize the concepts of attention, anticipation and memory in the context of decision-making in sports games; and (ii) to analyze if the effects of these components depend on situational constraints.

DEVELOPMENT

The role of attention in decision-making

The control of attention can be mainly goal-driven or stimuli-driven[11]. Most sensory receptors tend to adapt to continuous and regular stimuli, becoming, therefore, less sensitive to them, but simultaneously allocating more attention to new and unexpected stimuli[12]. Thus, the ongoing ac-

tions may be corrupted by the perception of new and relevant information sets[13]. The downside consists in the possibility of performance impairment, when the allocation of attention is directed to irrelevant indicators and/or distractors. Thus, in sports, it is important that players be able to make use of a strongly goal-driven[14] attentional control, becoming less exposed to distractors, though still maintaining some room for the detection of unexpected but relevant indicators.

Once this premise is observed, the *style* of attentional control may vary. Attention may be selective – focused on a specific aspect – or divided – distributed in several tasks concurrently. When information overload is excessive, selective attention guides the limited perceptive resources towards the most relevant set of information[11], limiting the number of indicators to be processed by working memory in each moment. The working memory allows a limited amount of information to be kept in a readily accessible state, for rapid 'consultation'[15]. However, information about the emotional and cognitive domains is available on a pre-attention form, and may highly interfere with attention allocation[16,17].

Moreover, attentional focus may be external or internal. An external focus results in decreased brain activity, implying a simpler and more automatic action[7]. By contrast, the internal attention foci tend to be associated with impaired performance, although this effect may depend on the complexity of the task[18]. Less complex tasks and tasks in which the context calls less to decision making, lead to a greater internal focus, a greater concentration on aspects related to the performance of the movements per se. The priority use of an external attention focus is beneficial in sports, and this focus may be restricted to a specific region of space (narrow band), with high resolving power, or spread over a broader region (broad band), but with less power resolution[19]. In SG, most emerging situations promote the maintenance of an external attention focus[17], because the game is a source of unpredictability and uncertainty, requiring the maintenance of alert states for a diverse set of indicators[4]. Furthermore, broadband attention, which is more diffuse, stimulates the obtaining of information in a more global way, and thus, gives it greater meaning[20].

In short, attentional control, be it goal-driven or stimuli-driven, selected or divided, of internal or external focus, broadband or short band, is the responsible for enhancing or inhibiting the achievement of high performances. By directing attention to relevant indicators, athletes can use the collected information, allowing the anticipation of the unfolding scenario, which, consequently, is reflected in a performance more suited to the constraints of the task.

Anticipation – concepts, capabilities and limitations

There is a strong relationship between the accuracy of decision-making and the time required to performed it[9,21], a relevant relationship in sports, because a great degree of precision is required, but with an adequate answer speed[22]. What happens is that in sports uncertainty permeates

decision-making, and the decisions have to be made even in the absence of complete information[23]. Theoretically, performance in sports, particularly in SG, would benefit from the use of anticipation strategies, especially, in very fast paced situations[2]. The adoption of such strategies is possible when there is an adequate guidance towards the relevant indicators, providing the athlete with certain information that arises relatively early in the scenario and that, via probabilistic relationships, allow to predict the outcome of the action[6].

However, anticipation is far from being a simple phenomenon, as it may be useful and productive in some scenarios but harmful in others[2]. In a study performed with soccer goalkeepers, exposed to video scenarios in real size, Savelsbergh et al.[24] verified that the individuals most likely to adopt an anticipation behavior, beginning their actions earlier, obtained worse success rates in accuracy and adequacy of their motor responses. Inversely, the most successful goalkeepers were those who waited longer, obtaining more information from involvement. Therefore, in this case, an overly early anticipation will tend to be harmful to performance. This study was developed in the laboratory and was based on their performance on a film-based test, but the question is even more complex in contexts of real practice, since a prolonged wait, even though it may allow collecting more information and thus increasing the success rate of the response *intention*, it can also make the actual response ineffective, for not allowing the motor action to be produced in real time. That is, in a prolonged wait anticipation is accurate, but the action is late, and thus, unsuccessful.

From this it follows that the decision to choose between anticipation and waiting strategies depends on the specific situation, and it is necessary to weigh, in each case, the pros and cons[22]. Therefore, it seems that a faster, anticipatory decision only becomes advantageous if it does not result compromised by excessive errors[7]. Accordingly, because sports games are essentially tactical, they give this problematic even more complexity. By establishing a complex network of counter-communication in SG, certain game indicators may be created by the opponent in order to guide the opposing team in the wrong direction, creating false cues[25]. In this context, estimates and anticipation may induce the player to choose the wrong path[26]. To this extent, the cost-benefit correlation can, often, tip the scale in favor of strategies of waiting.

There are, however, situations in which time pressure is high, making the waiting strategies[27] unfeasible and calling for the adoption of anticipation strategies. For these reasons, anticipation, generally considered a mark of experts, should be addressed on the basis of the specific tasks and contexts, always after an assessment of their advantages and disadvantages[9]. Such analysis will depend, therefore, on a good knowledge of the situational probabilities, which allows to better define the scope of the analysis and to increase the speed and precision of decision-making[28].

The mediating role of memory in attention and anticipation

The direction of attention and adoption of strategies to anticipate depend largely on the memory. The ability to compare new data with data previously stored in the memory shapes progressively more sophisticated[8] knowledge structures, fostering a better ability to make decisions. A better organization of information, by grouping it in units or coherent sets, full of functional meaning, speeds the process of relevant information recovery from memory, through a more efficient mental search[29]. However, some misconceptions seem to persist on the nature of memory and the way it operates.

Memory is a complex, multifaceted and reconstructive process[30]. Thus, the concept of active and continuous processing should be emphasized, as opposed to a more static, concept of storage[29]. Indeed, memory can be conceptualized as a ubiquitous energy field, conditioning responses to the multiple stimuli to which individuals are sensitive, shaping mental activity at each instant[12]. Due to synaptic plasticity, mental representations become dynamic maps, constantly reorganized and highly sensitive to experience and to learning[31]. Thus, progress in motor skills and decision-making produce substantive changes in long-term memory[32].

Although long-term memory is determinant to an effective higher ability to make decisions, it is insufficient. In fact, if the relevant information is kept only in long-term memory, it can be of reduced use for an effective understanding in a given situation. For decisions to be informed by memory, some relevant aspects should be adjoining the situation of decision-making, immediately available in working memory[33]. However, this type of memory is limited to a few items, regardless of the complexity of the task[15], requiring a careful selection of the most relevant information[16].

Research has demonstrated that working memory has the same physical limitations, both in experts and novices, and it seems that long-term memory is the one that allows distinguishing experts from non-experts[34]. However, this effect emerges only in the specific tasks of a given domain[35]. Indeed, in random or non-specific scenarios, experts did not show better data recovery from long-term memory than novices[36]. Thus we may infer that, to enhance memory advantages, players must be properly attuned to the task-relevant constraints[34]. For working memory to be functional, it should be correctly guided by long-term memory, for this is the orientation that allows to carefully selecting the most relevant information to be available in working memory[16].

From the above, it should be pointed out that memory is a process that encompasses a continuum of manifestations, interacting with decision-making in a dynamic and flexible way, exerting a strong modulation, an almost total constraint, or even an irrelevant role in decision. In this regard, it is possible to distinguish two kinds of information processing[23]: *a)* top-down, highly influenced by memory, purposes, expectations and specific knowledge of the situation; *b)* bottom-up, more related with the detection of novelty, with the unexpected. Both kinds of information processing are relevant in the context of SG: top-down processing informs the action

based on the historic of the player, while bottom-up processing maintains the athlete open to unexpected emergencies. From memory emerges, also, intuitive thinking[10], which shapes embodied knowledge, and strategic thinking[37], and translates the time sequences of the coherent decisions.

Regarding strategic thinking, it is known that a decision should be placed in its historic context. In eminently tactical sports, knowledge of the past and present situations interferes with every decision made[37], so that the decisional process is continuous and not disconnected[9]. As such, the present actions will constrain the possibilities afforded to future actions[14], in some extent. In this context, it is introduced the possibility of using strategies of the style, 'lose now, win later"[3]. Therefore, it is important to distinguish between a purely tactical decision and a strategic decision, since the latter implies a deeper planning and an interconnection of the various decision-makings undertaken at different moments[38].

Memory can also be characterized by its explicit or declarative, and implicit or procedural facets[39]. Although the explicit component – the one we are aware of – is important, the implicit component may be more relevant in sports. With the accumulation of experience, some learning is embedded in the neuronal connections, meaning that, although people may not be aware of these memories, their body will respond accordingly. This phenomenon, called priming or potentiation, operates unconsciously, but greatly affects behavior[10,22]. Taking this into account, we must be cautious in how to approach the concept of intuition in the decision-making process.

In everyday life, many decisions are guided by clearly unconscious reasons, especially in environments that place heavy time pressures, among which sports are included[10]. In these contexts, constraints induce a more intuitive, more heuristic strategy of problem solving[21]. Indeed, when rational thought is taken to the extreme, performance tends to be impaired, a phenomenon called paralysis induced by analysis. However, intuition still tends to be faced as a somewhat mystical process, associated to the famous *eureka* of Archimedes. However, intuitive thought is filled with rationality, albeit to a sub-conscious level, precisely owed to the implicit learning processes that are incorporated and developed throughout life and learning[10].

In fact, the practice and learning form consistent interconnections between perceptions and actions; then, the courses of action are enhanced by certain perceptions, causing the possibility of actions to be activated without emerging to consciousness[10,23]. A negative aspect of this process of potentiation is its high dependence on a proper adjustment of the association between condition-action; when these associations are inappropriate or inaccurate, there is a high probability of actions to be inappropriate and, therefore, ineffective. Not even experts are immune to this negative effect of potentiation, with regard to intuitive-thinking[40]. This implies that the quality and design of the preparation process decisively influence the implicit memory, and consequently, the intuitive process. To do so in a positive direction for performances, they will need to recreate specific and relevant condition-action adjustments.

FINAL CONSIDERATIONS

In eminently tactical sports such as SG, attention benefits from a strong goal-driven control[14], though allowing some space for the stimuli-driven control. This commitment allows the execution of tactically aware actions, but permeable to the detection of unexpected elements in engagement. Due to the information overload usually present, selective attention tends to enhance performance[11], reducing the amount of potential indicators to be considered in decision-making. On the other hand, an external focus tends to benefit performance, by enabling better attunement to the constraints of the task and to the involvement, a nuclear aspect in SG[17].

Due to a swift action based on incomplete information, individuals have to make a commitment between response speed and its adequacy[21]. In this context, anticipation emerges as a way to produce a rapid and adequate answer to the demands of the situation. In SG, anticipation can be a powerful booster of high standard performances, but only if it does not drastically increase the rate of errors[7] and if it is not eluded by strategies of 'deception' drawn up by opponents[26]. Therefore, although anticipation usually has a positive connotation, in some circumstances, waiting strategies may be more beneficial.

In order to know how to direct attention and anticipate the results of actions, individuals need a support structure to inform these two components (attention and anticipation): memory[8], which is an active, reconstructive and diffuse process, highly sensitive to learning[30], informing how we should or could run our actions. Concisely, it is the memory that embodies the knowledge of situational probabilities and, thus, enables the emergence of attention and anticipation. Because of its high specificity, the potentiating effect of memory is revealed only in specific tasks of a given domain[35]. From memory emerge, still, intuitive[10] and strategic thinking[37]. The first embodies internalized knowledge, which become implicit; the second links each decision taken into a coherent whole. As such, it seems correct to defend a practice heavily based on the specificity of the requests, only then enabling the stimulation of attention and anticipation in a realistic and flexible manner.

In short, it should be emphasized that the triad attention-anticipation-memory helps the understanding of the factors underlying decision-making in sports, particularly in the search for variable specifiers, determinants of success in tactical action. The attunement to the variable specifiers of the situation is what allows a correct perception of the affordances of the system[14]. In this sense, knowing the specifier variables in their multiple and complex manifestations allows us to enhance the tuning affordances, influencing not only programs of practice development, but also the experimental designs used in scientific research.

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