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From Enhancement to Substitution: A Strategic Provocation on Simulation-Based Sport

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Abstract

Advances in artificial intelligence, large-scale machine learning, and simulation technologies are rapidly transforming how sport is played, analyzed, and consumed. To date, most scholarly and industry discussions frame these technologies as tools that enhance embodied sport by improving performance, officiating, media production, and fan engagement. This paper extends that conversation by posing a more provocative strategic question: under what conditions might simulation move from enhancement to substitution? Focusing explicitly on sport as a business and entertainment enterprise, we argue that many of sport's core sources of cultural and economic value—uncertainty of outcome, narrative continuity, legitimacy, and collective meaning—are structurally produced and not inherently dependent on human physical performance.

Keywords: AI, machine learning, management, simulation-based sport, technology

Considering the current technological advances and those very likely in the near future, simulation-based sport could plausibly render embodied sport's position of cultural and economic dominance obsolete. Our goal with this paper is simple – strategic provocation. That said, we do not aim to use provocation to create conflict but rather to stimulate thought about the integration of large-scale machine learning, simulation, and sport in the future. As former athletes, we acknowledge that participation in sports has many positive physical, social, mental, and developmental outcomes, most of which can be carried throughout life. To be clear, we are focusing on sport as a business and entertainment enterprise. We will present the case that much of the appeal of sport can be viewed as independent of physical performance, thus maintaining the desirable outcomes of sports while mitigating, if not completely removing, the limitations and risks.

From Enhancement to Substitution

If such a scenario is possible through simulation, informed by deep learning and other machine learning algorithms, would embodied sport be necessary at all? Can the central product of sport – competition – not be produced without actual athletes and their limitations? Advanced technologies, such as recurrent neural networks (RNNs), convolutional neural networks (CNNs), generative adversarial networks (GANs), transformers, and so on, have already and will likely continue to influence sports. In an excellent review of AI in sports, Li and colleagues (2025) point out how technological advances have enhanced observation, influenced in- and out-of-game decision-making, optimizing training, and even refining officiating. Their review focuses on four interconnected technological domains – perception, reconstruction, recognition, and prediction. We agree with the authors' observations about how AI has transformed sport, and we want to take the implications a bit further as a thought experiment. With the (1) availability of these technologies, (2) the proliferation of computing power, and (3) what fans have already accepted, if sport can be fully observed, digitally reconstructable, predictable, and simulatable, then what prevents simulation from becoming sport itself? Or more to the point, why are such transformations to sport acceptable and continuously developed, but sport remains immutable?

Sport's Cultural & Economic Value

Two interconnected issues at the core of this line of inquiry are the cultural and economic value of sport. Why do fans care about, watch, and pay for sport? Sport creates a unique entertainment economy through repeated consumptions by generating attention and emotional investment. Common values or outcomes promoted through sport are uncertainty of outcome, drama, compelling narrative, belonging/community, meritocracy, fairness, socially acceptable emotion expression, competition/rivalry. Despite new analytics that may assign a high probability certain outcomes, the results of competition are not knowable in advance. Uncertainty not only naturally encourages suspense and emotional investment, but it also provides the foundation for media rights and betting markets because fans want to witness the drama unfold in real time. Sport also provides structure for generating narratives to accompany games, rivalries, seasons or so-called dynasties. Due to common rules being enforced by independent officials,

outcomes may have perceived legitimacy through the process of fair competition. Finally, sport provides recurring opportunities for large gatherings of fans to express their common affiliations, traditions, and experiences, which offers a sense of belonging for many. Interestingly, the promotion of these values or outcomes is provided by the structure of sport, not any biological or embodiment feature. In fact, structure of sport does not necessitate risk of injury, live physical presence, or human bodies. The belief that bodies are indispensable to sport's value is less an economic conclusion than an inherited assumption because these same benefits are not only possible but may be specifically enhanced via fully simulated sports.

Embodiment Assumption as an Industry Constraint

When considering ongoing debates about the defining features of sport, embodiment (i.e., the performance of human bodies) is commonly viewed as an immutable asset. From a business perspective, the embodiment criterion plays a critical role in labor relations, investments, and risk tolerance within the industry. The fixed view that sport requires physical performance of human bodies locks sports organizations into a production model that costly, risky, and resistant to change. This view, whether directly acknowledged or not, plays a critical role in player contracts and collective bargaining to manage the scarcity and vulnerability of human bodies. The need for such formalized agreements and protections highlights the escalating payroll, chronic injury risk, and labor conflict. To our knowledge no other industry relies so heavily on workers whose productive value depends on maintaining peak physical condition in the presence of systemic and systematic wear, injury, and decline.

The dependence on humans' physical capabilities also shapes financial and investment decisions in ways that limit flexibility and increase economic risk. Facilities (e.g., stadiums, arena, training facilities, medical facilities), staff (e.g., trainers, medical staff, nutritionists), and insurance represent massive costs built on the assumption that competition based on human output is the only legitimate product, or expression of sport. Seasons being disrupted, athletes being injured or load managed, or events being canceled could, individually or collectively, have negative economic consequence that is immediate and difficult to absorb primarily because the core asset, being fixed, cannot be substituted, replicated, or redistributed.

Protective measures, such as concussion protocols, load management debates, performance enhancement monitoring, and rule changes (e.g., targeting, NFL kick offs) are structural realities of managing sports physical risk. Teams, organizations, and leagues face a narrowing set of options to contend with these challenges. On one hand, they can continue to reduce exposure and intensity, which could potentially reduce the appeal or perceived legitimacy of sport outcomes. On the other hand, they can accept legal, medical, and reputational risk as the cost of doing business, which can negatively impact their bottom line. From this perspective, reliance on human athletic performance increasingly appears less as a source of value and more as a constraint that require constant attention and consideration.

Technology Paradox in Sport

The interaction between sport and technology creates a difficult dilemma for sports organizations. Ironically, the integration of advanced technology in the name of improved competition continues to

separate fans from experiencing the raw underlying product – embodied sport. Sport consumption is mediated by technology enhanced officiating, machine learning enhanced coaching, and data-driven storytelling. Notice how the commentary of many halftime shows of collegiate and professional sports are little more than regurgitation of first half statistics. Yet the industry remains committed to human body as the exclusive location of competition. Why? Embracing technological optimization while rejecting technological substitution limits strategic imagination at precisely the moment when alternative competitive products are becoming viable. Considering this paradox, simulation-based competition seems a rational response to the structural constraints of embodied sport.

Simulation as a Rational Substitution

As sport continues its transformation through the integration of advanced technology, the discussion of whether simulation ever feel like sport seems to be increasingly obsolete. Instead, the strategic question from a business and entertainment standpoint focuses on the conditions under which simulated competition can reproduce enough of sport's core values that the substitution becomes suitable for achieving desired outcomes for each of the relevant stakeholder groups. To be clear, we are using substitution to communicate partial displacement of physical sport, not necessarily the wholesale disappearance of sport's cultural meaning or premium live-event value.

A key consideration of the business of embodied sport is that its primary asset is depreciating injury-prone – the human body. In a recent scoping review on the cost of sports injuries, Turnbull and colleagues (2024) identified different kinds of costs associated with injury. They discuss direct costs (i.e., costs of diagnosis, treatment, rehabilitation, and non-healthcare costs) and indirect costs (i.e., financial loss due to injury-related loss of productivity), as well as the bearers of these financial burdens athletes/patients, families, society, healthcare systems, etc. Despite variability in cost estimates method, approach, and perspective, the underlying economic reality of actual physical competition is that the recurring risk and financial impact cannot be avoided without changing the product (Turnbull et al., 2024).

Embodied sport has implication for labor governance as well. Vohra (2023) presented a model for majority-rule collective bargaining between sports leagues and its players. Although outside the scope of our article, Vohra's work points out that heterogeneous player incentives and collective bargaining influences outcomes and the risk of production loss (and its associated value). The implication here is that when the input (i.e., physical competition) is both embodied and collectively organized, production is vulnerable to stoppages and bargaining frictions (Vohra, 2023). Simulation-based competition can redefine labor governance by reducing dependence on human bodies as the singular output constraint, if not eliminating elements of it completely.

Once competition can be simulated using a host of data sources and computational techniques, any element of competition becomes a design choice. Leagues can be designed to optimize, say, close games or blowouts, while assigning probabilities to any array of game or environmental features. Injury probabilities can be assigned to virtual players with no risk or burden to human athletes. That is, any sport-based product can be localized and versioned to meet the desires of markets and other stakeholders.

Simulation Already Works

This is not an imaginative exercise. In domains where physical testing is slow and expensive, credible simulation is adopted precisely to shift work into fast “what-if” exploration. For instance, an economic evaluation of a simulation platform for vascular scaffold testing reports substantial cost reductions (i.e., roughly halving costs – 857,811€ v. 424,355€) when simulated tests substitute for physical bench tests under comparable performance assumptions (Mincarone et al., 2021). Although Mincarone’s and colleagues’ (2021) work demonstrated the economic value of simulation for research and development on medical devices, physical demands in human athletic performance can also be risky and expensive. Calibrated simulation seems an obvious substitute large scale innovation capacity for entire systems (Mincarone et al., 2021).

Even if fully simulated sport remains uncommon in the short-term, they naturally align with where sports media is already going: more automation, more personalization, more digital-first distribution. Sports media executives are already investing in AI to automate production and tailor content to individual viewers, while moving away from traditional delivery methods (Geissler et al., 2025). Simulated competitions have a built-in advantage that is so obvious, it may be overlooked; that is, simulated competitions already digital, already generating data, already easy to slice into different camera angles, stats overlays, or interactive streams (Geissler et al., 2025).

Next, consider the immersive viewing experience. Research on “digital twins” of sports venues shows how virtual replicas could let fans experience games remotely in new ways—not just watching, but exploring the venue, choosing perspectives, engaging more actively (Glebova et al., 2023). Studies of sports in the metaverse point to a similar experience; that is, fans becoming participants rather than just spectators, though practical issues like virtual reality (VR) headset adoption and platform fragmentation remain real obstacles (Morgan & Kerr, 2025). Cohen (2022) reported a study conducted by Momentum Worldwide that 81% of sport consumers would be willing to pay to watch sporting events in the metaverse. When viewed in VR in high enough quality, is there a meaningful difference between viewing simulated and physical athletes, particularly in light of possibilities for co-creation or subscribing to leagues or events with desired rule structures or outcomes likelihoods?

In recent years, sports betting expanded to the point that is difficult to consume a televised sporting event without seeing an advertisement for a betting house or platform. The rise of sports betting has only accelerated demand for constant stimuli. Yaros (2025) reported that individuals have obsession with sports betting have higher levels of reported sports engagement. We are already seeing betting companies embrace simulated games. As reported by Morgan and Kerr (2025), the NBA partnered with a sports technology company to create a virtual NBA league, based on millions of data points from nearly half a billion simulations, with 3,000 simulated games per day to allow for 24/7 betting opportunities. The demand is real, and people want sports-like uncertainty on tap, even when real athletes are not playing (Morgan & Kerr, 2025; Yaros, 2025).

We have attempted to make the case that simulation can reproduce uncertainty, strategy, and compelling narratives while minimizing or even eliminating risk of injury and sidestepping many of the direct and indirect costs of physical sport. To be sure, simulation comes with different costs, but they likely

pale in comparison to those of managing sport franchises. Yet, there is still a place to embodied sport, but the source of its value may need to be updated. For example, sports organizations may need to squarely understand the value of whatever only a live game in a real stadium with actual human athlete can provide.

Hybrid Future

One pathway forward is a strategic repositioning of embodied sport around what simulation cannot fully replicate: physical presence, shared ritual, and high-stakes social experience. Perhaps, one plausible response is fewer games and greater eventization. Scarcity, although not a guarantee of value, can heighten anticipation and concentrate attention. From a behavioral perspective, scarcity can function as a reinforcement lever because limited opportunities increase anticipation, concentrate attention, and heighten perceived significance.

Evidence from participatory sport and sport tourism suggests that embodied experience remains a powerful driver of meaning and intention. As simulation increases the abundance of competition-like content, physical sport may thrive by leaning into performance, atmosphere, and cultural density rather than continuous optimization. The strategic takeaway is not replacement, but diversification in the face of increased competition. Leaders who respond effectively will integrate simulation where it improves performance, invest in parallel simulated properties where growth is fastest, and deliberately re-price embodied sport as scarce, spectacular, and culturally significant.

Trust as a Mediator Factor

Needless to say there are many considerations and areas of real concern should fully simulated sport become a mainstream enterprise, not the least of which is trust, broadly defined. Trust is a major potential systems problem with the advanced technologies needed to engage simulation of any kind. Questions immediately arise related to data sources, model training, model validity, transparency, ownership, auditing, incentives, privacy, and so on. Answers to these questions are deeply complex with little precedent. Betting adds an additional layer of complexity. Perhaps the most obvious question is “If these models can be created and tuned, who controls it and to what end?” Given the complexity of the analytics, “[w]e have no way to monitor, visualize, or analyze the performance of superintelligent agents” (Yampolskiy, 2019, p. 10). Even minor breaches of trust could cast doubt on the enterprise and nullify consumer and sportsbooking confidence. Vital questions that remain (and for which we could only speculate answers) are: What protections minimize external (or internal) manipulation of a simulated system to as near zero as possible? Who controls these systems? With whom does regulatory agency and authority reside? What happens when outside agents try to influence the algorithms in ways that run counter to the spirit of the enterprise (whatever that is)? The likelihood of system failure, on a long enough timeline, is functionally certain (Yampolskiy, 2019). Attending to systems-level governance questions would be wiser sooner than later.

Conclusion

Sport is not static, and it never has been. Sport always evolved alongside the technologies, economic forces, and cultural values of its time. What makes this moment different is not only there are new tools for technological enhancement; it is that the tools can generate plausible alternatives to physical competition itself all while preserving the values of sport and minimizing the risks and costs. Simulation and AI have potential not only to change how we play, analyze, or watch sports. They force us to ask: what actually needs to be physical? What could work just as well, or better, in digital form?

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