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PERSPECTIVE

Serious Games and AI: Challenges and Opportunities for Computational Social Science

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ABSTRACT The gaming industry plays a crucial role in the realm of entertainment within our society. However, from Monopoly to Flight Simulators, serious games have also been appealing tools for learning a new language, conveying values, or training skills. The resurgence of Artificial Intelligence (AI) and data science in the last decade presents a unique window of opportunity for its integration into video games. This integration is of particular interest due to the vast amount of data that can be collected through a game, which is needed to feed the AI algorithms. This paper aims to identify relevant research paths in the intersection of serious games, AI, and computational social science, particularly in their utilization as novel research tools to comprehend human behavior and society. To provide a comprehensive context, we also present an overview of the serious game research field identifying the most prominent application areas and analyzing applications of AI in serious games that hold great potential for computational social science research. The goal of our work is to establish a valuable framework for researchers interested in utilizing serious games as a novel tool for AI-supported social research.

INDEX TERMS Serious games, artificial intelligence, computational social science, novel research tools, human behaviour

I. INTRODUCTION

Games have existed in all human societies and many other animal species. While some of the oldest board games, such as Go, Backgammon, or Checkers, are still played today, video games have become one of the most relevant forms of entertainment in our society, with budgets and profits far exceeding those of huge related industries such as cinema [1]. However, since the origin of games, they have had intentions and benefits beyond entertainment, such as teaching social norms, strengthening social bonds, or developing imagination and planning skills.

The rise of video games has had a remarkable social impact, helping to establish new social interaction and entertainment patterns [2], [3]. A prominent example of this trend is the gamification that our lives have experienced [4], from the workplace (e.g., *Habitica*, *LifeUp*) to romantic relationships (e.g., *Tinder*, *Grindr*) or education (e.g., *Kahoot!*, *Duolingo*). Video games, though high levels of interactivity, can raise motivation, engagement and fun in almost any activity. While the video game industry is proliferating, the board game industry continues growing [5]. We can draw a clear conclusion: our society loves games, and they permeate many of our activities and interactions.

Some games —referred to as *serious games* [6]— are explicitly designed for a primary purpose beyond pure entertainment (e.g., training or learning new skills, conveying values, awareness-raising). Nevertheless, being entertaining is part of their attractiveness. The first serious games were released in a wide range of formats, from sports to board games (e.g., *Monopoly*, *Suffragetto*), so this concept precedes the digital era.

The current re-emergence of serious games in industry and research [7] has coincided with the eruption of Artificial Intelligence (AI). Nowadays, and increasingly so, almost every entertainment element and digital product are at the

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service of data analysis and AI algorithms. Games are no exception [8], and in fact the amount of data available via video games far exceeds other media.

AI has demonstrated its potential to analyze and better understand the functioning of our societies, interactions, and behaviors. The synergy between serious games and AI offers an exceptional window of opportunity for large-scale, non-invasive, and inexpensive social studies, leveraging their disinhibition and entertainment effects to collect large amounts of meaningful data. Moreover, games' casual and playful nature can help break conventional communication boundaries, encouraging participants to interact openly and discuss topics that might otherwise be complicated or too sensitive.

The primary objective of this study is to identify gaps in research and potential areas of inquiry at the intersection of serious games, AI, and computational social science (CSS) [9] (Section V). Such an investigation represents a significant contribution to the field. In addition, to contextualize our work, we present a comprehensive overview of serious game research, identifying relevant application areas (Section III), differing from previous research examining only a single application or sector. Furthermore, while previous research has examined the potential applications of AI in serious games broadly [10], this paper adopts a more focused approach by identifying specific ways in which AI can enhance serious games for use in CSS research (Section IV). Through this comprehensive overview, our work offers valuable context for understanding the potential impact of serious games and AI in computational social science research. To facilitate readers' comprehension, Figure 1 provides a visual overview of the paper's content.

II. METHODOLOGY

This paper aims to explore the potential of Serious Games in combination with AI and Data Science, specifically focusing on the potential applications to CSS. To achieve this goal, the paper poses the following research questions:

RQ1: What are the main application fields of serious games?

RQ2: What are the main usages of AI and data science for serious games with potential applications for computational social science?

RQ3: What are the main challenges and new horizons for the interaction of AI and serious games for computational social science research applications?

We have analyzed the available scientific literature to answer these research questions. We conducted our search using the Google Scholar search engine. The inclusion and exclusion criteria of the large number of research pieces identified were based on factors such as the number of citations, popularity of the game, or the innovation of the approach. First, to get an overview of the field, terms such as ''serious games,'' ''serious games applications,'', ''serious games AI'' and ''serious games analytics'' were used. Next, specific search terms were used for each of the identified serious games application areas. For example, ''educational games'', ''game-based training'', ''social impact games'', ''game-based therapies'', etc.

Finally, we screened studies based on their title, abstract, and full text to determine whether they met our inclusion criteria. We excluded studies unrelated to serious games or AI, were not published in English, or did not meet our methodological standards.

III. APPLICATIONS OF SERIOUS GAMES

The upsurge that serious games have been experiencing in recent years [7] may lead us to think this is a new phenomenon. However, the origin of serious games dates back to the 1970s. Clark C. Abt is credited for coining the term *serious games*, defining them as ''games with an explicit and carefully thought-out educational purpose that are not intended to be played primarily for amusement''. Clark C. Abt studied the potential of games as a vehicle for political, educational, or marketing ideas. Another of the leading figures in the history of serious games is Ian Bogost, the author of groundbreaking books on the theory behind them, such as ''*Persuasive Games: The expressive power of video games*'' [11].

Even though both concepts mirror the same social phenomenon, it is relevant to highlight the distinction between gamification and serious games. Gamification consists of using and integrating game elements into non-game concepts, while serious games refer to the design of entire games for non-playful primary purposes. Although both are concepts from the last century, they have recently resurfaced in the academic and commercial arenas.

Among the first serious video games, we find examples of how they are employed to convey particular values (e.g., *Captain Bible in the Dome of Darkness*, *The Oregon Trail*, *Mobility*), disease awareness (e.g., *Captain Novolin*), or military training (e.g., *Bradley Trainer*). Nevertheless, the line between *regular* and *serious games* is quite blurred regarding games that convey specific beliefs or ideologies. Like any artistic or intellectual creation, video games always carry an implicit political and philosophical perspective. For example, popular video games such as *The Sims*, *Papers Please*, or *This War of Mine* convey strong political messages. However, they were not developed under the idea of being serious games.

Focusing on serious games that consider themselves to be such and are designed for that purpose, we find many areas in which they have proven their usefulness on numerous occasions. This section aims to answer RQ1.

A. EDUCATION

This category refers to serious games designed for the player to learn a series of concepts of a specific subject. To do so, the players must demonstrate their knowledge during the game and score their performances. Education has been one of the main focuses of action for serious games, based on the principle that learning while having fun is possible and efficient. This field has been extensively explored, and

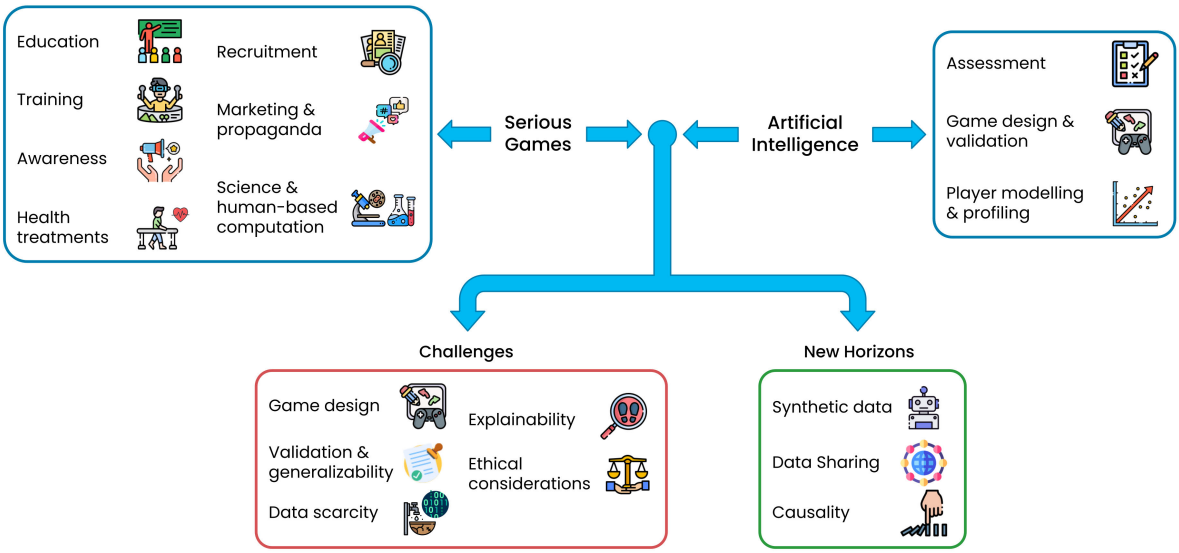

FIGURE 1. Graphical overview of the paper. The blue boxes are the applications found for serious games and AI applied to them. The red box indicates the challenges faced by this union for its use as a research tool. And the green box indicates promising lines of work in this direction.

success and failure factors have been analyzed in depth [12], [13]. Prominent examples of building STEM skills might include *Garfield's Count Me In* [14], *Minecraft: Education Edition* [15], the *Kahoot DragonBox* maths apps [16], and the *LightBot* coding apps [17]. Serious games for educational purposes have also become popular in higher medical education [18], although some authors question their usefulness at such high educational levels, possibly complementing to more traditional learning methods [19], [20].

B. TRAINING

Closely related to education, this category refers to games designed for players to learn and practice specific skills that will enable them to perform those actions in the real world with improved safety, confidence, and knowledge. This approach is widely used in companies where human failure is critical or costly. One of the best-known examples is flight simulators, such as *Microsoft Flight Simulator* [21], where aspiring pilots must spend hours practicing before flying an actual commercial aircraft. There are notable examples of training healthcare professionals [22], mine site inductions and safety [23], [24], industrial engine maintenance training [25], cybersecurity trainees [26], [27], law enforcement agencies or military forces [28], [29], [30]. Another widespread use is training to manage complex business situations or administering teams and resources, applied in private companies [31], [32] and universities [33], [34]. This training approach has also been used outside the workplace, for example, to teach people with intellectual disabilities how to use public transport [35].

C. AWARENESS

Thanks to their high levels of interactivity, games evoke deep levels of empathy, making them an ideal vehicle to convey an awareness of relevant social issues. A classic example is *Darfur is Dying* [36], which sought to tell the story of the humanitarian crisis in the Darfur region of South Sudan. We can find examples on a wide range of topics, such as drug consumption and trafficking [37], [38], cyberbullying [39], gender equality [40], misinformation [41], [42], climate change [43], and environmental sustainability [44], [45], [46], [47].

D. HEALTH TREATMENTS

This category is framed in healthcare but focuses more on patients than professionals. Well-known examples might be the *Wii Fit* and *Brain Training* games, which aim to have fun and stay fit (physically and mentally) simultaneously. Other notable examples can be found in the field of mental health therapy [48], [49], increasing self-efficacy and physical activity in people with chronic diseases [50], [51], helping the learning process and support of children with autism [52], [53], palliative care and memory training for older people or people with dementia [54], [55], and guidance and motivation in rehabilitation processes [56], [57], [58], [59]. Notably, in 2020 the US Food and Drug Administration approved the first video game-based treatment, *EndeavorRx*, targeting children between the ages of eight and twelve with certain types of Attention Deficit Hyperactivity Disorder (ADHD) [60].

E. RECRUITMENT

If we combine games' interactivity with players' ability to make decisions in a well-designed environment, we can infer some behaviors or aspects of the players' abilities with reasonable confidence. For this reason, serious games have also been used to optimize the recruitment process in private companies [61], [62] and even military forces [63]. In these games, players face complex situations where they must

make decisions and act under certain constraints or pressures. A recent notable example is the *CodinGame*[1] platform, where users practice their programming skills while playing, and many tech companies recruit profiles they find interesting. Another great example is the *GT Academy*,[2] a competition in which the best players of a car racing video game have the opportunity to become professional drivers.

F. MARKETING & PROPAGANDA

When the game is developed primarily for marketing purposes, it is often known as an *advergame*. This category of games aims to convey ideas and create desires in a less-intrusive and easily customizable way. It should not be confused with games that introduce advertising during gameplay for economic profit. The principal medium for these advergames is smartphones due to their proliferation, ease of development, and everyday use among young people.

Major brands such as *Volkswagen*, *Magnum*, *Chupa Chups*, and *M&Ms* have developed advergames. Related to the RECRUITMENT category, in some cases, companies use these games to present and profile themselves in order to attract new employees and trainees, or to discover talent. Likewise, there have also been attempts to use video games as a tool to disseminate electoral campaigns, such as the video game *Corbyn Run* [64], or to encourage citizen participation in public decisions [65].

G. SCIENCE & HUMAN-BASED COMPUTATION

This category encompasses games to advance scientific knowledge in some way. One of the most common approaches is employing human players to perform seemingly trivial tasks, either too costly, too complex, or unfeasible for computers. These tasks may include labelling data, transcribing text, using common sense, or activities based on the human experience.

One of the first examples of this category was "*The ESP Game*" [66], in which players in pairs had to guess the photo labels created by their partner, to address the problem of creating complex metadata. Google's reCAPTCHA[3] used human players to label images while identifying legitimate users for accessing online resources. In "*EteRNA*" [67] players had to design RNA sequences that fold into a particular form. The solutions were evaluated to improve computer-based RNA folding prediction models. Other prominent examples might be "*Foldit*" [68] to predict protein structures, "*Eyewire*" [69] to map retinal neurons, "*MalariaSpot*" [70] to help diagnose malaria cases, "*Phylo*" [71] to optimize alignments of nucleotide sequences, or "*Quantum Moves*" [72] to improve how atoms move in a quantum computer.

IV. ROLE OF AI AND DATA SCIENCE IN SERIOUS GAMES

Games have long been the test bed for AI as they provide a controlled environment with simple rules for algorithms to learn sophisticated strategies. AI is a rapidly evolving field that encompasses a vast array of techniques and methods, each with its own unique potential applications within the realm of serious games. Therefore, to narrow the contextualization to the point advocated by this paper, our research has focused on exploring the specific areas of serious games where AI has played a prominent role and has the potential to generate new insights and knowledge in the realm of CSS research.

In recent years, *regular* games have been utilized as sources of vast amounts of player data, providing relevant information about human players, which is helpful inside and outside the game. However, serious games have particular objectives that we want to satisfy, and as such, the techniques and purposes of AI and data analysis differ notably from those of regular games. Additionally, there is significant heterogeneity in these purposes of serious games, resulting in technical differences among them. Despite this heterogeneity, it is possible to discern the main branches encompassing all primary AI and data analysis applications in serious games with great potential for CSS. This section aims to answer RQ2.

A. ASSESSMENT

Game-based assessment is a fruitful field in serious games [73], primarily used in education, training, and recruitment. Players are scored based on their knowledge or skills in a particular subject. Reference [74] stipulate three primary purposes of assessment: (i) to assist learning (formative assessment), (ii) to evaluate the player's capabilities, and (iii) to evaluate programs. In general, collecting, analyzing, and extracting information through educational serious games is known as Game Learning Analytics [75].

The main difference with traditional evaluation methods or test gamification is that game-based assessment also uses in-game and interaction data (e.g., response times) to evaluate the player. Numerous authors have demonstrated the utility of using additional in-game data to evaluate students [76], [77], [78] or to predict learning results [79], [80]. It has also been used successfully to evaluate recruitment processes [81]. Although nowadays, they are more of a complement to the traditional exam-based assessment.

The techniques used are very diverse, from simple descriptive statistics and correlations to supervised machine learning algorithms (e.g., linear regression, decision trees, Naive Bayes, Neural Networks) [82], [83]. More rarely, some papers use knowledge inference with Bayesian networks [84], [85], which explicitly allows the application of causality and latent state models, but flawed assumptions will negatively influence the results significantly.

This branch of AI applications in serious games is one of the most researched and developed, thanks to the technological push that is changing the way education is delivered. However, much work remains to be done, particularly in demonstrating that they can outperform and generalize traditional approaches [86].

[1] CodinGame https://www.codingame.com
[2] GT Academy https://www.gran-turismo.com/es/academy/
[3] reCAPTCHA https://www.google.com/recaptcha/about/

B. GAME DESIGN & VALIDATION

Game design is planning the content, rules, and mechanics of a game to create valuable interactive experiences. The large number of artistic and technical factors involved in this process make any analytical information about the players extremely valuable. On the other hand, game validation employs data and evidence to verify and calibrate the game tasks and their difficulty. In the case of serious games, in addition to maintaining engagement, we also want to ensure that the game meets its primary objective (e.g., to train players in a particular skill, increase awareness of an issue, etc.).

Data-driven serious game design and validation have flourished in academia in recent years, where we can find successful examples of using analytics to design, improve, personalize, and test these games [87], [88], [78], [89], [90], [91]. This category is closely related to the previous one (ASSESSMENT), as it is almost essential to use data-driven validation during the development stage to calibrate how the game evaluates the players [92], [93]. Such analytics can go a step further to adapt the game's difficulty in real-time [94], [95] and even detect when the player is frustrated [96].

In this category, the most commonly used techniques are descriptive statistics and visualizations [97], [98], [99], Randomized Control Trials (to test the usefulness of an intervention) [89], [100] and unsupervised machine learning algorithms (to find similar types of players and common patterns in the game) [89]. Using these analytical techniques enables creators and researchers to ensure that their games are entertaining, engaging, and well-designed to fulfill their objectives. Designing games to adapt to players dynamically is inseparable from player modeling, so we will discuss this in the following subsection.

C. PLAYER MODELING & PROFILING

Player modeling is the creation of computational models to detect, predict and characterize the human player attributes that manifest while playing a game [101]. These models can be any mathematical representation, rule set, or probability set that maps parameters to observable variables and are built on dynamic information obtained during game-player interaction. On the other hand, player profiling usually refers to categorizing players based on static information that does not alter during gameplay (e.g., personality, cultural background, gender, age). Despite their dissimilarities, these two concepts can complement each other, contributing to more reliable player models.

Recent advances in AI, specifically in large language models such as *GPT*, *LLaMa*, and *Alpaca*, hold significant potential for advancing the modeling of player behaviors in serious games. These language models have demonstrated an ability to learn from vast amounts of natural language data and generate coherent and meaningful responses, enabling them to comprehend and simulate human language and behavior. Incorporating this technology into serious games can lead to a better understanding of human behavior and social dynamics, gaining insights into how individuals interact and make decisions. Moreover, incorporating them into the game design can provide more immersive and personalized experiences by tailoring the gameplay to the player's behavior, patterns, and preferences. However, there are also challenges to consider, such as the potential biases and ethical implications of using this technology.

Reference [10] provides a comprehensive review of the use of AI in serious games. In particular, it analyzes the literature on player experience modeling using facial emotion recognition and text analysis using natural language processing techniques. Reference [102] explores the use of AI and immersive technologies in serious educational games. In particular, it focuses on the use of AI to customize and personalize the player experience. It also examines AI-based serious games for teachers and students that do not require programming skills. Reference [103] conducted a systematic literature review that profoundly analyzes the computational and data-driven techniques used for player modeling between the period of 2008 to 2016. As this is such a broad and promising field, the variety of algorithms used is immense: descriptive statistics and correlations, path/network analysis, supervised learning (e.g., Neural Networks, Linear Regression, Hidden Markov Models, Decision Trees), unsupervised learning (e.g., k-means, Linear Discriminant Analysis, Self-Organizing Maps), probabilistic algorithms (e.g., Bayesian / Markov Networks), evolutionary methods (e.g., Genetic algorithms), reinforcement learning methods (e.g., Multi-armed bandits), etc. Some proposals based on latent mixture models (e.g., Bayesian hierarchical models) [104], [105] yield more interpretable results, but flawed assumptions will negatively influence the results significantly.

Player modeling can be helpful both inside and outside the game itself. The most straightforward goal is to improve the game design, tailoring the content to increase engagement and enhance the gaming or learning experience [106]. We find some prominent examples in the *regular* video game industry, such as *Left 4 Dead* [107], where an AI tracks player behavior and adapts future waves of enemies to maintain rhythm and tension. Perhaps the most famous example is the video game *Silent Hill Shattered Memories* [108], which uses a psychological approach where an AI system tries to manipulate players' emotions using the *Five Factor Model* of personality [109]. Outside the game itself, the most common use of player modeling in the gaming industry is for personalized marketing campaigns, since the commercial sector is very interested in understanding customer behaviors and preferences. In these cases, the games are often presented as free to play in exchange for an intrusion into personal privacy [110]. Besides the "advergames" discussed in the section MARKETING & PROPAGANDA, a famous example outside serious games is *Farmville* [111], which monitored the players' behavior to adapt *Amazon* marketing campaigns to them. This business model is particularly hazardous for younger users, its main target.

In academia, especially in psychology, experiments have been conducted using games (*regular* and *serious*) for

research, but primarily focusing on analyzing how the player's personality is projected in the gameplay patterns [112], [113], [114], [115], [116]. Nevertheless, studying psychological characteristics or phenomenology using serious games seems to be an up-and-coming field, especially when introducing AI techniques into the equation.

V. CHALLENGES AND NEW HORIZONS

In the previous sections, we have discussed the main applications of serious games and the current trends in their synergies with data science and AI. In this section, we argue about the great potential of serious games together with AI to serve as research tools, particularly in CSS research, examining the most critical challenges and promising new lines of work. This section aims to answer RQ3.

As discussed in the INTRODUCTION, games allow research to be entertaining, provide high levels of empathy, and have a disinhibition effect that is highly sought after in social science investigations. Games can evoke dynamic and complex emotions in players [101]. Besides, these complex reactions are difficult to capture with the traditional approaches. Therefore, using serious games as research tools, supported by novel AI techniques, can contribute to advancing many social science fields in an entertaining and non-invasive way [117].

We can already find some splendid examples of the use of games as large-scale social research tools, such as *The Moral Machine Experiment* [118], which uses a gamified environment to explore the moral dilemmas surrounding autonomous cars. To do so, they use the framework of the classic trolley problem and study participants' responses to variations in different parameters (e.g., number of people who would die, age, gender, etc.) and the cross-cultural differences in this decision-making [119]. We can also find some noteworthy examples that use serious games to explore collaborative and trusting behaviors [120], [121], understand preferences for charity donations,[4] or even fight cybercrime [122].

On the other hand, the latest advances in AI allow us to analyze vast amounts of data and find patterns or behaviors that would be very difficult to observe with traditional methods. So far, the main application given to large AI models that study our interactions through social networks and personal data is for marketing purposes [123]. This practice has been done almost since the beginning of social networks without considering the negative social consequences it could have, particularly for children and adolescents [124], [125]. We firmly believe that AI has the potential to help us live better lives and to understand ourselves and our society better. We need to start thinking about the applications of AI that can bring the most benefit to society. Moreover, to achieve these goals, it is essential to join forces between different branches of science (e.g., sociology, psychology, engineering, computer science, AI, etc.), and games are an excellent vehicle for this purpose. With this paper, we also hope to contribute to the "AI for Good"[5,6] movements.

A. CHALLENGES

To achieve these important goals, serious games must overcome several critical challenges. Through our research, we have identified the following:

- *Game design*: Game design is a creative process that involves a wide range of artistic and technical skills. Game designers must consider factors such as story, character development, game mechanics, user interface, graphics, sound, and more. The harmonious integration of these elements is necessary for creating a compelling game experience that engages players. However, game design is not a purely scientific process but often relies on the intuition and creativity of the designer. It is challenging to quantify and standardize design elements, making it difficult to predict the success of a game or to identify what makes a game genuinely engaging. Therefore, the success of a serious game as a research tool depends largely on its design and playability.
- *Validation and generalizability*: The use of serious games as a research tool is becoming increasingly popular in a variety of fields, including education, health care, and social sciences. However, one of the biggest challenges researchers face when using serious games is demonstrating the validity and reliability of their findings. Unlike traditional research methods, serious games involve complex interactions between players and the game environment, making it challenging to ensure the consistency and accuracy of data collection. While some areas of serious game research have shown promising results, such as game-based ASSESSMENT or in-game moral dilemmas [126], [127], it is still necessary to establish standard validation procedures for each game and its intended purpose. Each game is unique, and the research questions and hypotheses behind it must be carefully designed and tested. This necessitates a personalized validation approach, which can be time-consuming and resource-intensive.
- *Data scarcity*: Training and enhancing AI models require a large amount of high-quality data. However, academic experiments in serious games often rely on small, biased, and heterogeneous data sets, which limits the effectiveness of AI models. Consequently, research outcomes and findings may be inaccurate, prejudiced, or biased, hindering the research process. To overcome this challenge, researchers must find ways to increase the number of participants, collect diverse and representative data, and optimally utilize the available data. This may involve partnering with the industry to access larger data sets, using synthetic data generation, or devel-

[4] MyGoodness! https://www.my-goodness.net/

[5] AI for Good Global Summit https://aiforgood.itu.int/

[6] AI for Good https://ai4good.org/

oping standardized data collection and management methods. Moreover, researchers must establish appropriate methods for sharing sensitive data while ensuring the anonymity and privacy of participants. This practice can be immensely beneficial for social science research [128].

- *Explainability*: The increasing complexity and opacity of many AI tools pose significant challenges to their use in studying human and social behavior. These AI models are often regarded as ''black boxes'' since their inner workings are not transparent or understandable. Computer science has historically emphasized prediction over explanation, further complicating the use of AI tools in social research. Understanding the results produced by AI models is crucial for studying human behavior. Although progress has been made in developing explainable AI techniques such as LIME or SHAP, many challenges remain. One significant obstacle is the trade-off between model complexity and explainability. More complex models may provide better predictions, but they may also be more difficult to interpret. Furthermore, explainable AI techniques' suitability must be evaluated for specific research contexts, especially for small or highly heterogeneous data sets. Addressing these challenges requires interdisciplinary collaboration between AI researchers and social scientists. This includes developing best practices for incorporating explainable AI into serious game experiments, evaluating the appropriateness and accuracy of different techniques for specific research contexts, and balancing the trade-off between model complexity and explainability.
- *Ethical considerations*: Using personal data in serious game experiments raises significant ethical considerations that cannot be overlooked. Clear and unambiguous ethical guidelines are necessary to ensure that the potential benefits outweigh the risks, and to prioritize the safety and well-being of participants. This is especially crucial when dealing with sensitive data of children or marginalized populations. To establish these ethical standards, it is necessary to develop interdisciplinary collaboration between computer scientists and social scientists, who often have different approaches to research ethics [129]. While computer scientists often prioritize technical aspects of privacy and security, social scientists are more concerned with the impact of research on human subjects and communities. Developing ethical guidelines for serious games experiments involving AI requires a deep understanding of the specific ethical concerns associated with this area of research. For instance, researchers must thoughtfully consider how to obtain informed consent from participants, ensure the privacy and security of personal data, and mitigate potential harm resulting from using AI models in research.

B. NEW HORIZONS

Despite the challenges mentioned above, we can also find promising new horizons and future lines of work regarding the interaction between serious games and AI:

- *Synthetic data*: The AI field has extensive experience developing agents that can play games at a high level and even outperform human players [130]. However, in recent years we are experiencing a wave of generative AI techniques that can create new and diverse content such as images, music, or text. These techniques have shown remarkable potential in creating data mimicking human behavior and preferences. Combined with data augmentation techniques (e.g., agent-based *imitation learning* [131]), they can enable us to produce large volumes of diverse data that closely mimics real-world human behavior to train other AI models and improve their performance. This opens up the possibility of exploring new research questions and hypotheses that were previously difficult or impossible to address due to limitations in data availability. As such, this is a promising line of work in which we can make the most of the limited data available, build models that help us better understand players' motivations and decision-making processes, and create new forms of content for serious games.
- *Data sharing*: The emergence of serious games and their potential to address social issues and promote learning has opened a new avenue of research for CSS. Unlike traditional social science research, which often relies on surveys or experiments with human subjects, serious games offer a unique opportunity to collect data from many participants in a more controlled and interactive setting. This has several advantages, including the potential to address the small sample sizes that often plague traditional social science research. One of the challenges that CSS has faced is finding and sharing open data, especially from private companies [132]. However, serious games research is in a much more advantageous position in this regard, as it typically does not involve collecting sensitive data. As such, fewer ethical and legal barriers exist to sharing and collaborating on data collected from serious games. In addition, the use of anonymization and privacy-preserving algorithms has proven very useful in recent years, allowing researchers to extract meaningful insights from data while protecting participants' privacy. This approach has the potential to help researchers overcome one of the significant obstacles in social science research: the need to balance ethical considerations of participant privacy with the scientific need for large, diverse data sets.
- *Causality*: The social sciences have traditionally focused on providing interpretatively satisfactory explanations of human behavior, with randomized controlled trials being the gold standard for establishing causal relationships. In contrast, computer scientists have tended to

prioritize the development of accurate predictive models that do not necessarily represent the underlying causal mechanisms. In recent years, however, there has been a growing interest in computational causality techniques [133], [134], even for observational data [135], that can help us estimate the workings of systems with greater robustness and generate more plausible alternatives. Computational causality techniques allow us to make explicit the assumptions of the model and the scientist building it. This approach can help us better understand individual and collective human behavior, especially in the context of serious games. By combining predictive and explanatory approaches to scientific research, we can build more comprehensive models that account for the complexity and nuance of human decision-making in serious games. In addition, integrating explanatory and predictive approaches can help us better understand individuals and society through serious games. Explanatory models can help us identify the mechanisms by which behavior is reflected in serious games and account for biases in the data, while predictive models can be used to make accurate predictions when explainability is not a critical constraint. Integrating predictive and explanatory approaches to scientific research is critical to advancing our understanding of individual and collective human behavior in serious games. By developing more comprehensive models that account for both causal mechanisms and predictive accuracy, we can generate insights that can inform the design of more effective and impactful research in CSS [136].

VI. CONCLUSION

Gaming, as a form of leisure and functional tool, has been an integral part of human and animal evolution for millennia. With the advent of AI, there is a unique opportunity to utilize serious games as a valuable instrument for social research, given the enormous amount of data that can be harvested, as well as other inherent benefits, such as disinhibition and engagement.

This paper has identified research gaps and promising work areas at the intersection of Serious Games, AI, and CSS. To contextualize the research, we have examined the principal application domains for serious games, including education, training, science, and recruitment, among others, and reviewed the literature on AI applications in serious games with the potential to generate new insights and knowledge in the realm of CSS research. However, due to the dizzying speed at which the field of AI is changing, it will be necessary to continue to conduct research that explores the potential applications of AI to social research.

This paper aims to encourage researchers to pursue these areas of work and help them identify potential applications of serious games for positive social research objectives. Furthermore, we advocate for interdisciplinary research, which is crucial in this field of science. The potential of serious games for understanding human behavior and society is enormous and requires further and deeper inquiry.

AI is a game-changing technology that has the power to either benefit or harm society significantly. Therefore, it is time to utilize these tools for the greater good, and there is no better way to do this than through gaming. If gamified research continues to enable substantive scientific discovery, the results will speak for themselves. In conclusion, serious games, coupled with AI and CSS, can provide a unique window of opportunity to investigate social phenomena in more sophisticated and nuanced ways.

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