A Formal Approach to Distinguish Games, Toys, Serious Games and Toys, Serious Repurposing and Modding, and Simulators

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***Abstract*—While the serious game concept has considerably evolved in the last two decades, it still needs to be clearly differentiated from other types of artifacts. Thus, there is a degree of confusion about the relationship between serious games and other related applications, such as simulators or the repurposing of entertainment games within educational practices for most outside the domain. This article proposes a formal approach toward classifying games, toys, serious games, serious toys, serious repurposing and modding, and simulators. The aim of this theoretical work is twofold. First, on a practical level, this approach aims at helping actors from different ecosystems, such as health, to differentiate between these various devices and use them to their best advantage. Second, from a research perspective, based on a formal approach, our work aims to contribute to developing a taxonomy for gamified intervention with serious purposes. This formal approach demonstrates that unique combinations can be proposed to distinguish each kind of application. In this context, serious games can be seen as a specific purpose and not as a synonym for other existing applications.**

***Index Terms*—Formal definition, health, health game, serious game, serious modding, serious repurposing, serious toy, simulator, taxonomy, video game.**

I. Introduction

SERIOUS games (SGs) have been defined as "games whose first purpose was not mere entertainment." [1], or "A mental contest played with a computer following specific rules, that uses entertainment to further government or corporate training education, health, public policy, and strategic communication objectives" [2]. We propose that an SG could also be summarized in equation form as: "Serious Game = Utilitarian function(s) + Video Game"; where utilitarian functions could represent a range of activities, such as broadcasting messages, training, and collect data [3]. Besides, SGs are not exclusively focused on the entertainment market but also target other areas, such as schools, advertising, ecology, politics, and health [3]–[5]. In the context of a growing industry and interest, SG developments are now common in many markets, such as health, defense, education, policy, training, and ecology [6]. According to Manne and Williamson [7], we can define the market as "a collection of products and geographic locations, delineated as part of an inquiry to make inferences about market power and anticompetitive effect." In the case of the health field, a serious game can be designed for several different purposes (i.e., supporting diagnostics, prevention, and training) [6], [8] and target a wide range of user profiles (i.e., health professionals, learners, researchers, patients, parents and children [9], and the community).

Previous work highlighted that SGs aimed at patients and the general public often relied on metaphors to frame their interventions [10]. We define metaphor as the substitution of a game universe for a context of reference, in which it is possible to use fantasy and abstraction to motivate or immerse the player. This universe of substitution becomes a metaphorical universe through which purposeful content is communicated. However, the use of metaphorical universe is very rarely used in SGs targeted at students and health professionals [10]. Their applications are often based on virtual environments that replicate real-life models or situations with high fidelity. For instance, *InsuOnline* [11] uses a realistic environment to teach students how to use insulin to treat diabetes [12]. However, some might use the term "Serious Game" to describe these applications, while others might refer to them as "simulation" or even mix the two terms [13], [14]. This remark adds confusion in distinguishing these different objects.

In addition, leading companies from the video game industry, such as Namco-Bandai propose to repurpose existing games and assign them purposeful aims in the health domain. For

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example, in Japan, arcade games, such as *Gator Panic* [15] were adapted to senior citizens to keep them healthy [16]. We propose the term "repurposed game" to define this form of "catachresis," a term first used in linguistics to refer to misuses of words (e.g., "alibi" instead of "excuse") or to figures of speech that use existing expressions and give them a new meaning. The concept of catachresis can also be applied to objects. For example, using an adjustable spanner to hit something instead of a hammer is a form of catachresis [17]. This notion has also been transferred to ergonomics to describe the difference between initial technological conceptualization and its deployed usage [16], [17]. The presence of leading game development studios, such as Namco-Bandai in the health field further blurs the line between video games and SGs and raises the question of their differentiation.

For the stakeholders in this domain, whether serious games or related products (i.e., simulators, serious toys), it is essential to distinguish between these different objects, their definitions, and their boundaries. At the same time, sponsors, clients, and institutions may be unclear in their requests by confusing the various objects, fields of application, and respective perimeters. It is also necessary for research to start from a clear basis to study an object. If this is not the case, then how can we give credence to the very existence of the serious game for example? Thus, it is advisable to distinguish between them to understand them better and improve communications in the domain, both academically and commercially.

Thus in this article, our main research question is as follows:

> *Does the term "serious game" represent an object in its own right, or is it simply a synonym for other existing applications?*

Answering such a question implies a deep analysis and reflection on the nature of other objects, such as toys, simulators, etc. Providing answers is essential for two reasons. First, on a practical level, it should provide information that can help practitioners in health ecosystems select the kind of application best suited to their needs. Second, from a research perspective, it should enable researchers and designers to accurately determine a taxonomy for SGs and health games [3]. In cases where the terms "serious game" and "simulators" are used interchangeably, one should question whether it is legitimate to continue using either in taxonomic research. Indeed, if some of these objects can be linked by the presence of a scoring system or challenges, it is essential to know if we are facing the same kind of scores and objectives. For example, in *SimCity* [18], the values displayed on the screen correspond to variables, such as the population living in the city, the remaining budget, the satisfaction rate of inhabitants. But such data are not associated with objectives set by the application to win. Indeed, it is impossible to win in *SimCity* [18]. This will be different in the context of a game, where the score is usually associated with variables related to the objectives to be reached to win. For example, one must exceed existing scores if one wants to be ranked in the high scores table in a game like *1943* [19]. Such subtleties are likely to escape most stakeholders who confuse simulators with games.

Additionally, we think the boundary between toys and simulators is probably weak. As we try to distinguish SGs from simulators, we also have to explore the boundary between toys and simulators. We propose to investigate the exact nature of object definitions through a formal approach. We previously used a formal approach to game classification, inspired by Vladimir Propp's work [1], which used functions to classify Russian fairy tales for the first time in 1928. We propose extending this approach to the serious games domain and relevant pedagogical practices. The study presented in this article aims to define clear boundaries between games, toys, serious games and Toys, serious repurposing and modding, and simulators. We believe it would benefit professionals and the general public in efficiently determining the adapted technology that best fits their needs. To define these artifacts formally, we will identify criteria specific to each term. We will then compare these criteria and look for term-specific signatures to improve on existing SG taxonomies (i.e., [2], [6], [20]–[22]), including a preliminary approach proposed for the health domain [3].

II. Definitions and Concepts

Each of the seven following sections presents a definition, formal approach, and examples concerning: game, toy, serious game, serious toy, serious repurposing, serious modding, and simulator.

A. Game

In the context of this article, it is essential to define what constitutes a game formally.

1) Definition: To avoid the type of subjectivity generally associated with genre-based game classifications (first-person shooter, shoot'em up, adventure games …), we positioned our approach within a formal system advocated by Salen and Zimmerman [23]. This allows our work to be contextualized outside of games' perception, genre, or other cultural factors [23]. As such, this article is not dealing with whether or not applications like *Her Story* [24] or *Proteus* [25] are games or which genre they might belong to, but on a formal analysis of their elements, components, and functions [26].

Previous work in this domain by Djaouti and colleagues [26] has led to identifying gameplay bricks to deconstruct gameplay and player activity within a game.

They identified a total of ten gameplay bricks (Fig. 1) related to 1) game rules, objectives, and primary mechanics (bricks A - objective) or 2) elements of the game or secondary mechanics that facilitate the fulfillment of objectives (brick B – means). Through their analysis of more than 580 games in the *Video Entertainment and Games Studies (VEGaS)*,[1] researchers have discovered that gameplay bricks are often paired with one another as part of the game design exercise to form specific game mechanics. These are referred to as Metabricks [26]. For instance, AVOID and MOVE are often combined to implement the type of collision avoidance mechanic generally observed in racing (e.g., *Gran Turismo series* [27], *Project Cars* [28], *Mario Kart* [29]) or arcade games (e.g., *Pac-man* [30], *Sonic* [31], etc.). Metabricks are named to reflect the purpose of their association and, as such, the gameplay bricks Avoid and Move from the Metabrick DRIVER. Similarly, the bricks DESTROY and

Fig. 1. Gameplay bricks. (a) Objectives (Yellow). (b) Means (Blue).

SHOOT combine to form the KILLER Metabrick, a common and recurrent element of the first-person shooter (e.g., *Call of Duty* [32], *Doom* [33]) and shoot 'em up (e.g., *Space Invaders* [34], *Ace Combat* [35]) genres. Metabricks always combine an objective brick [Fig. 1(a)] representing primary aspects of the game (Game) with a means brick [Fig. 1(b)] representing aspects of the game related to the player activity (Play). Consequently, to describe the basis of any game, gameplay, or mechanic, it is necessary to identify a minimum of one *Metabrick* that combines both Game and Play [26]. As a concept, *Metabricks* are defined according to the following rules [26].

1) Metabrick combines two complementary gameplay bricks and describes a challenge.
2) Adding a gameplay brick to a Metabrick adds variations to a challenge without altering its fundamental nature.
3) When adding several gameplay bricks to a Metabrick, point 2) applies as long as the Gameplay bricks do not form another Metabrick.
4) Combining Metabricks results in the association of their respective challenges.

Based on Propp's Morphology of the Folktales methodology [1], one can use gameplay bricks and *Metabricks* to document video games and their gameplay structures [26]. Thus, it is possible to document the game's main challenges and elements by considering a set of Metabricks and their gameplay bricks components in relation to the main game objective. As the game carries this objective, it is qualified as *intrinsic*. This is in contrast to an objective of an *extrinsic* nature. The latter is proposed by someone outside the game. For example, to win at *Pac-man* [30], you must eat all the pac-gummies. This is an intrinsic objective demanded by the game. On the other hand, if a friend asks you to eat all the ghosts before you finish the level, this is an extrinsic goal. Therefore, it is not required by the game itself to advance to the next level.

From a structural perspective, the main ensemble of Metabricks describes challenges at the game level, while other gameplay bricks or Metabricks represent more minor local challenges

$$[\text{Metabrick}\,(n) + \text{Metabrick}\;(n+1) + \ldots] \\ +\text{Metabrick}\;(p) + \text{Metabrick}\,(p+1) + \ldots \quad (1)$$

When describing a game with additional gameplay bricks and features challenge variations, we propose using upper cases to describe the main bricks and lower cases for the elements that relate to variations as

$$[\text{KILLER} + \text{GOD}] + \text{DRIVER} + \text{Random} + \text{Write}. \quad (2)$$

A complete game can be described at a generic level as

$$[\text{Metabrick}\;(1) + \ldots + \text{Metabrick}\,(n)] \\ + \text{Metabrick}\,(1) + \ldots + \text{Metabrick}\,(m) \\ + \text{GameplayBrick}\,(1) + \ldots + \text{GameplayBrick}\;(q) \quad (3)$$

where n is the number of global objectives, m is the number of local objectives, and q is the number of gameplay variations possible in the game [26].

In this context, objectives can also be described formally. An objective contains a game brick, an instance, and a variable list (1 to v). The instance represents the elements controlled by the player in the game. For example, in *Pac-man* [30], the player controls a single instance, *Pac-man* [30]. In a game, such as *Warcraft III* [36], a player controls units of soldiers and villagers, mages, orcs, etc. The variables for each instance represent its associated characteristics; for instance, in *Warcraft III* [36], a junior soldier does not have the same variable value as an upgraded soldier. As such, an attack on an enemy camp with a unit of junior soldiers does not have the same impact as if it was conducted with heroes and upgraded soldiers.

When formally considering the cases of *Her Story* [24] or *Proteus* [25], we only really need to identify the nature of the bricks that these applications contain (objective bricks, Metabricks). The presence of objective or Meta bricks would indicate that we are dealing with a game. Their absence would suggest that these applications are probably something else as no intrinsic objectives are associated with them. For instance, *Her Story* [24] is about finding keywords for identifying and unlocking hidden videos and conducting an investigation throughout the experience. According to the Gameplay Bricks model, this is indeed a game since we can identify a Metabrick comprising of the CHOOSE and MATCH bricks. In the case of *Proteus* [25], an experience based on exploring places through computer-generated music and landscapes, the user can only navigate the space. The absence of objective bricks (e.g., MATCH, AVOID) suggests this is not a video game but a video toy as characterized in Section II-B.

An objective can be represented as

$$\text{Brick} \sum \text{Game}\,(\text{Instance})\,.\,[1..v] \quad (4)$$

where v is the number of variables and

GAME = ACHIEVE and/or AVOID and/or DESTROY.

These formal writings were used to test the gameplay bricks from a computational point of view by using *Gam.BAS* application for "Gameplay Bricks As Switches" [26]. This application allows designers to activate or deactivate the different gameplay

bricks within the same game, and thus, modify the gameplay on the fly. Taking the case of the game *Snake* [37], it could be shown that the activation and deactivation of some gameplay bricks generated different gameplays. Moreover, the experiment proved them globally conclusive as gameplay variations generated through *Gam.BAS* could be observed [26].

Artifact Categories: The artifacts described in this article can be applied to several different types of games in the following categories:

1) *Digital:*

A game is a digital game when its gameplay is deployed through computing or electronic means. For instance, video games are digital games.

2) *Analog*:

A game is an analog game when its gameplay is deployed without the use of computing or electronic elements. For instance, traditional card games or board games are analog games.

3) *Hybrid*:

A hybrid game combines both digital and analog gameplay. For instance, a card game that features Q.R. codes linked to URLs and allows access to video games represents a hybrid form of gaming. Likewise, transmedia games are typically hybrid.

2) Formal Approach of Game: Assessing the definition of game and its components (cf. Section II-A.1), we can formalize games as follows.

1) Games are artifacts that must be created.
2) An artifact has one or several properties (digital, analog, or hybrid).
3) A game proposes an intrinsic objective.
4) Games operate within the pure entertainment market.

Use considering the following sets.

The set GOAL of goals: GOAL = {Avoid, Match, Destroy}.

The set MEANS = {Create, Manage, Move, Random, Select, Shoot, Write}.

The set ARTIFACT = {Digital, Analog, Hybrid}.

These three sets are included in the set named formal system (FS).

Considering:

The set MARKET = {ENTERTAINMENT, HEALTHCARE, EDUCATION …}.

The set UTILITARIAN FUNCTION = {F1, F2, F3} (described in Section II-C.2).

These two sets are included in the set named cultural system (CS).

A GAME is defined by

$$\begin{aligned}\text{Game} = \{g \in \text{GOAL} \mid g \\ = \text{Intrinsic}\} \times \text{MEANS} \times \text{ARTIFACT} \\ \times \{x \in \text{MARKET} \mid x = \text{ENTERTAINMENT}\}.\end{aligned} \tag{5}$$

3) Example of Games in the Health Domain: Three examples of games are given as follows.

1) *Digital example:*

Trauma Center: Under the knife [38] or *Theme Hospital* [39] are examples of video games based on the health theme. But, for both of them, the creators target only entertainment purposes. As a result, the players have simplified and fun objectives that do not consider all the constraints real actors could have in connection with the jobs mentioned.

2) *Analog example:*

The board game *Operation* [40] proposes that players operate on a patient by removing organs from the body without touching some areas. It is a game dedicated to the entertainment market, where the challenge lies mainly in the sensory-motor aspects.

3) *Hybrid example:*

Escape games challenge a group of players to flee from a given place within a given time. There are several types of escape games. For example, *Serious Escape Cards -Naisscapegame* [41] combines card games with a smartphone application to solve puzzles. This serious game is dedicated to French 2nd year midwifery students. This is where we can observe the hybrid aspect of this type of approach, as the game uses both analog (cards) and digital (smartphone application) elements.

B. Toy

1) Definition of Toy: If we refer to Frasca's approach [42], the application *SimCity* [18] does not offer intrinsic objectives toward a "win" condition. According to Salen and Zimmerman [23], Sim City could be regarded as a software devoid of "quantifiable outcome." This essentially means that it does not provide an end state and does not offer any assessment of the player performance or heuristics. This means that Sim City is a toy or more precisely a video toy.[1]

Considering this approach, we can define a "toy" as an artifact with no objective gameplay brick. According to the approach described in this article, the definition of "toy" is therefore: artifact, digital, or not, aiming at the only entertainment market. It presents no objective gameplay brick, namely, "Match," "Destroy," or "Avoid" (see Yellow Bricks in Fig. 1) but only Medium Bricks among Create, Manage, Move, Random, Choose, Select, Shoot, or Write (see Blue Bricks in Fig. 1).

2) Formal Approach of Toy: From the definition of the Toy (cf. Section II-B.1), we can formalize "Serious Toy" as follows:

1) Toys are artifacts that must be created.
2) An artifact has one or several properties (digital, analog, or hybrid).
3) Toys have no objective.
4) Toys operate within the pure entertainment market.

Considering these four main items, the Toy can be defined by

$$\begin{aligned}\text{TOY} = \text{MEANS} \times \text{ARTIFACT} \\ \times \{x \in \text{MARKET} \mid x = \text{ENTERTAINMENT}\}.\end{aligned} \tag{6}$$

3) Example of Toy in Health Domain: In the Toy category, there is a multitude of health-themed artifacts. For example, a

[1]Conversely, *Pac-man* [30] proposes explicit goals (eat all the dots while avoiding the ghosts) that are used to assess the performance of the player, a positive return (points score gain) or negative (loss of a life). We face, in this case, a game or more precisely a video game.

whole range of objects, such as stethoscopes, syringes, physician, or nurse costumes are dedicated to children. Besides, there are *Playmobil* [42] or *LEGO* [43] characters, buildings, cars, and helicopters based on the health theme.

C. Serious Game

1) Definition of Serious Game: "A Serious Game is an artifact, digital or otherwise, for which the original intention is to combine with consistency, both serious aspects, such as nonexhaustive and nonexclusive, teaching, learning, communication, or the information, with playful elements from the game. Such an association is made by embedding the utilitarian functions within the game's story, graphics, and audio elements, which no longer only focuses on pure entertainment" [3].

From this definition, Alvarez *et al.* [45] have extracted three conditions as follows.

1) Serious games combine utilitarian functions and game.
2) Serious games operate outside of the pure entertainment market.
3) Serious games are artifacts, digital or otherwise.

This definition mentions the concept of utilitarian function in the first condition (as follows).

2) Utilitarian Functions: However, assessing a designer's authorial intent when analyzing an SG is not trivial. The game's purpose is often described regarding intervention domains, such as advergames, edugames, exergames, datagames, news games, edumarket games, health games, military games, etc. In our opinion, these categories are not necessarily more relevant because they are devoid of formal criteria, and we propose establishing a more synthetic categorization [46]. When describing an SG in terms of purpose, "Edugames" (and their equivalent "Games for Education" and "Learning Games") or "Advergames" (and their equivalent "Advert Games") are often used. An "Edugame" carries an educational message, while an "Advergame" promotes a product or a service and provides a deliberately positive message about specific products or services. While they differ in focus (commercial or educational), these two categories of SGs appear to share the purpose of "broadcasting a message." A similar observation can be made regarding other categories where information is broadcasted through "Newsgames" and political messages through "Political Games," etc. We could argue that the different categories of "purposes" are used to differentiate the broadcast message's nature through an SG. When classifying these categories with regards to the nature of the messages broadcasted, we observe that: the informative message is generally used to broadcast a neutral point of view; the educational message serves to transmit knowledge or education; the persuasive message aims to influence, and the subjective message is used as a means to broadcast an opinion. However, the purpose of all SGs is not always to broadcast a message. Indeed, games belonging to the "Training and Simulation Games" or "Games for Health" categories have a different purpose: to provide training. For instance, *Pulse!!* [47] is used to train emergency physicians to handle crises, while *MoSBE* [48] has been developed to prepare soldiers for military operations. This central concept for training applications is the development of physical or cognitive skills through in-game practice. Finally, a less common purpose is for games to be designed to facilitate the exchange or collection of data. For instance, *Foldit* [49] was developed by the University of Washington to solicit Internet users to fold proteins to reveal their properties. These applications are often referred to "Datagame" [3]. It is not quite as widespread as other SG activities but shows great potential.

To avoid confusion, our taxonomic and structuralist approach focuses on the serious games' initial authorial intent and their intended utilitarian functions. Thus, we avoid relying on the observations or opinions expressed by users to determine these functions as they are not necessarily objective and are a potential source of contradictions [3].

In summary, we, therefore, propose to classify SG purposes according to three main categories.

1) *F1 - To broadcast a message:* the SG is designed to deliver one or more messages. The type of message can be educational (e.g., some Edugames), informative (e.g., Newsgames), persuasive (e.g., some Advergames), or subjective (e.g., Activist Games, Art Games). One game can combine several types of messages [3].
2) *F2 - To provide training:* the SG is designed to improve cognitive or physical player capabilities (e.g., Exergames).
3) *F3 - To enable the sharing of data:* the SG intends to facilitate the exchange, manipulation, or collection of data (e.g., Datagames) a) between players; b) between the game publisher and players; and c) between researchers and players.

It is essential to specify that these utility functions can be associated with games in two distinct ways: either internally or externally.

1) Internal means that the utility function(s) is/are built into the artifact. For example, a serious game like *Pulse!!* [47] provides the user with the ability to solve clinical cases. This is a training function that the application provides internally.
2) External means that the utility function(s) is associated with the artifact through activities or uses. Let us now take *Pulse!!* [47] as an example to explain to students how an operating room is organized. Something not foreseen by the application designers, the utilitarian functions of the application are modified by its usage. We are then in an external approach.

These functions are essential for SGs.

3) Formal Approach of a Serious Game: Assessing the definition of the SG and its components (cf. Section II-C.1), we can formalize SGs as follows.

1) Serious cames are artifacts that must be created.
2) An artifact has one or several properties (digital, analogic, or hybrid).
3) Serious games combine utilitarian functions: (F1: to broadcast a message, F2: to provide training, F3: to enable the sharing of data) and game (at least one goal, at least one means to achieve the goals).
4) A serious game proposes an intrinsic objective.
5) Serious games operate outside of the pure entertainment market.

Including the sets previously defined, the definition is

$$SG = \{g \in \text{GOAL} \mid g = \text{Intrinsic}\} \times \text{MEANS} \times \text{ARTIFACT} \times \{(a,b) \in \text{MARKET} \mid a \in \text{ENTERTAINEMENT} \Rightarrow b \notin \text{ENTERTAINEMENT}\} \times \text{UTILITARIAN FUNCTION}. \quad (7)$$

4) Examples of Serious Games in the Health Domain: Taking into account the three main categories of utilitarian functions, we identified examples of SGs in the health domain as follows.

a) *To broadcast a message:*

An example of a serious game broadcasting a preventive message is *Out of Time* [50]. This health game is designed for Type 1 diabetic patients treated by insulin pumps and using functional insulin therapy. The gameplay is based on a point and click adventure game. The goal is to help the main character resolve a murder mystery while managing a chronic disease. Hospital doctors created this game to target adolescents who have just been recently diagnosed with diabetes. The game's purpose is to deliver the positive message that they can have an active life even when living with a chronic disease.

b) *To provide training*:

Voracy fish [51] is a serious game designed for functional rehabilitation of the upper limbs. The patient is placed in front of a camera and a video display. The player movements move a fish in a marine world according to bimanual motions performed by the patient. The aim of the game is to eat small fish and avoid being eaten by bigger ones. This game is a good example of integrating a software-based approach within a caring environment.

c) *To enable data-sharing*:

Foldit [49] allows the general public to contribute to scientific research by presenting protein folding problems. Players must propose solutions by trying to solve this puzzle game. The proteins used in the game are used to develop new drugs for diseases, such as HIV or cancer. The solutions developed by the players are then sent to a laboratory in charge of developing new medical treatments. SGs can also be used to collect live data [52]. *Play to Cure: Genes in Space* [53] allows players to analyze real genetic data to beat cancer.

D. Serious Toy

1) Definition of Serious Toy: The G/P/S (Gameplay / Purpose / Scope) classification model dedicated to serious games proposes to use as structure either a "game" or a "toy" [3]. This implies that both serious toys and serious video toys could have utilitarian functions, such as broadcasting a message, providing training, and enabling data sharing. The serious toy does not offer explicit objectives to be accomplished to "win." Thus, just as a toy differs from a game in the absence of a goal, a serious toy differs from a serious game according to the same criteria.

A toy can perform utilitarian functions without presenting a goal to the player. For instance, a simple marble is a toy. It does not provide the player with an intrinsic goal to win. On the other hand, it can be set extrinsically by stating that the marble must be placed inside a circle drawn on the ground from a certain distance. Setting a goal in this way leads us to create a game. But the marble remains a toy. The game objective is not intrinsic to the marble but an external factor or proposition. Suppose we put a written message or a logo on the marble. In that case, we potentially allow it to broadcast a utilitarian message (e.g., to promote a brand, a political or any other kind of message to the player). Thus, this message is to be distinguished from the objective of the game (Goal) that could be proposed extrinsically but still associated with the marble. We created a serious toy by adding a message to the marble since the marble carries a utilitarian message without offering an intrinsic game objective.

2) Formal Approach of Serious Toy: From the definition of the SG and its components, we can formalize "Serious Toy" as follows.

1) Serious toys are artifacts that must be created.
2) An artifact has one or several properties (digital, analogic, or hybrid).
3) Serious toys combine utilitarian functions: (F1: to broadcast a message, F2: to provide training, and F3: to enable the sharing of data) and toy (at least no goal, but only means dedicated to playful).
4) Serious toys proposes no objective.
5) Serious Toys operate outside of the pure entertainment market

With the sets defined above, we can offer the following definition

$$ST = \text{MEANS} \times \text{ARTIFACT} \times \left\{(a,b) \in \text{MARKET} \mid \begin{matrix} a \in ENTERTAINEMENT \\ \Rightarrow b \notin ENTERTAINMENT \end{matrix}\right\} \times \text{UTILITARIAN FUNCTION}. \quad (8)$$

3) Examples of Serious Toys in the Health Domain: The Free Hugs application (French Ministry of Health, France, 2007) is a digital serious toy inviting Internet users to give hugs virtually. The idea was to raise awareness of discrimination against the HIV positives.

E. Serious Repurposing

1) Definition of Serious Repurposing: Previous work concluded that an SG does not possess intrinsic characteristics differentiating it from a video game from a formal system perspective. The distinction between these two types of artifacts only occurs in cultural or pragmatic systems [26]. By "formal system" means a purely computational level, where standards are binary and respond only to mathematical logic. When analyzed at this level of abstraction, there is no component that distinguishes a video game from an SG. This means that an SG only differs from a video game when considered from a user perspective, user perception, and associated purpose. The distinction between video games and SGs should thus be made in relation to how these are perceived culturally and pragmatically. As such, the video game is only positioned in the entertainment market, while the SG addresses areas and domains outside the pure entertainment market (health, education, defense, etc.). *Trauma Center Second Opinion and Dark Cut 2* [54] are video games that enable the user to interact with a patient in a more or

less realistic manner. The game's goal is to provide appropriate care within a time limit, and the player scores points according to the speed and finesse of execution. Should these videogames titles be included in the corpus of SGs targeted at the health domain? While these two examples are firmly set within the pure entertainment domain, they also have a health theme and feature existing therapeutic techniques currently in use. Hence, nothing prevents one from playing *Trauma Center: under the knife* [38] *or Trauma Center Second Opinion and Dark Cut 2* [54] from a "serious" perspective. This is also true for any video game from the entertainment industry that can potentially be used for serious purposes [55]–[57]. The work of Michael Stora, for instance, is a good illustration of entertainment games repurposed for healthcare [58]. As a clinical psychologist, he used a specific section *ICO* [59] in therapy sessions with children. The player is asked to hold a princess's hand (by holding down a button) to lead her to the exit. Once the destination is reached, the player must release the button and allow the princess to leave. When children refuse to perform such an action and become disoriented, the therapist stops the game and looks at investigating a dialogue by linking the child's family experience with the in-game situation.

However, a fundamental difference remains between Stora's [58] approach and SGs as previously defined. While the result appears similar (a game used for serious purposes), an SG is intently designed for a specific purpose and use. We should then distinguish between repurposing entertainment games and purposely built SGs. We propose using the term "Serious Game" for games explicitly designed for purposes other than entertainment. "Video Game repurposing" approaches, which allow a game to serve serious purposes not anticipated by its designer, should be referred to by another term. We propose the use of the "Serious repurposing" (aka "Serious Diverting" [17]) term to refer to the action of taking an existing game or toy, digital or otherwise, and assigning it a utilitarian function. In this context, we propose the following distinction; an SG is an artifact, while serious repurposing is an activity.

2) Formal Approach of Serious Repurposing: We summarize this approach as follows.

1) We consider one existing game or toy.
2) Serious repurposing is (this game or this toy) with external modifications as a consequence at least to make appear one new function (F1, F2, F3).
3) A serious repurposing from game proposes both intrinsic and extrinsic objectives.
4) A serious repurposing from toy proposes no objective and extrinsic objectives.
5) Serious repurposing operates outside of the pure entertainment market.

Formally, we can also summarize serious repurposing as

$$\begin{aligned} \text{srp} \in & \{\text{GAME} \cup \text{TOY}\} \times \text{UTILITARIAN FUNCTION} \\ & \times \{(a,b) \in \text{MARKET} | a \\ & \in \text{ENTERTAINMENT} \Rightarrow b \notin \text{ENTERTAINMENT}\}. \end{aligned} \tag{9}$$

3) Examples of Serious Repurposing in the Health Domain: In the United States, since 2006, *Wii* [60] games have been used in Riderwood retirement homes to stimulate older people, while offering something that is both occupational and social. This approach has since been observed in similar establishments around the world. In Japan, Namco-Bandai, which notably produced the *Pac-man* games [30], now also offers senior citizens in their eighties the chance to visit their offices and play with different arcade games to maintain their health capital. The game aims to hit crocodiles or frogs with a rubber mallet and stimulate blood flow to certain parts of the brain and body (arms, legs). It is worth noting that some of these games have been adapted to correspond with the target audience's physical needs.[2]

F. Serious Modding

1) Definition of Serious Modding: Serious modding implies transforming an existing game, digital or not, to assign it a utilitarian goal. The modifications can concern its design (sound, graphics), functioning, objectives, game mechanics, ergonomics, and scenario [17].

Another approach halfway between the design of SGs and the serious repurposing of games is software modification. Known as "modding," it consists of modifying an existing game to create a game variant. This is a well-known practice in the computer gaming culture. A mod designer is generally not linked with the original game's creators, and the practice is, in most cases, confined to entertainment purposes and fan-based community activities. However, in some cases, mods have been used to adapt an entertaining game for a serious purpose. For instance, *Escape from Woomera* [61] was a modification of *Half-Life* [62] and developed to raise public awareness about the harsh living conditions in refugee camps in Australia. There, we can observe the presence of both playful and serious dimensions. When modding is performed to a utilitarian end, we propose to include it in the SGs domain. To differentiate it from games designed specifically for serious purposes, we suggest using the term "Serious Modding" when describing this type of approach.

2) Formal Approach of Serious Modding: We propose to formally define the serious modding approach as follows.

1) We consider one existing game or toy.
2) Serious modding is (this game or this toy) with internal modification with a consequence at least to make appear one new function (F1, F2, F3) with or without a goal.
3) A serious modding from game proposes no objective or an Intrinsic objective.
4) A serious modding from toy proposes no objective or an Extrinsic objective.
5) Serious modding operates outside of the pure entertainment market.

Formally, we can summarize the serious modding approach as

$$sm \in \{\{\text{GAME} \times \text{GOAL}\} \vee \text{TOY}\}$$

[2][Online]. Available: https://www.straitstimes.com/asia/as-japans-population-greys-video-games-now-target-silver-generation (Last link accessed: 30/03/2022)

TABLE I
FORMAL COMPARISON OF THE STUDIED ARTEFACTS

Artifacts / criteria	Game	Toy	Serious Game	Serious Toy	Serious Re-purposing from game	Serious Re-purposing from toy	Serious Modding from game	Serious Modding from toy	Simulator
NEW: Create a new artefact (C) or Adapt an existing artefact (A)	C	C	C	C	A	A	A	A	C
GOAL: Intrinsic (I) / Extrinsic (E)	I	""	I	"" or E	E and I	E	E and/or I	E and/or I	"" or E
MEANS: interactivity mean(s) proposed to user (M)	M	M	M	M	M	M	M	M	M
MARKET: Pure Entertainment (E)	E	E							
UTILITARIAN FUNCTION: Linked to the artefact (L) or Joined to the artefact (J)			L	L	J	J	L and/or J	L and/or J	L and/or J

$$\times \text{ UTILITARIAN FUNCTION} \times \{(a,b) \in \text{MARKET} | a \in \text{ENTERTAINMENT} \Rightarrow b \notin \text{ENTERTAINMENT}\}. \quad (10)$$

3) Examples of Serious Modding: The game *Asthma 1,2,3…Breath!* [62] provides an example of serious modding. This title is based on a previously existing game: the *Parcheesi game* board game. *Asthma 1,2,3…Breath!* [62] uses the board game structure of Parcheesi but modifies it to include health-related content. In this case, each game board square refers to a question created by the game authors. *Asthma 1,2,3… Breath!* [63] targets teenagers aged 15 to 17 to raise awareness of problems associated with asthma, people who have asthma, and its impact on younger members of society [64]. The player moves pawns around the game board using virtual dice in the game's universe. Depending on the pawn's color, the game features activities about four themes: asthma and prevention; triggering factors; asthma and allergies; and asthma control. The modding approach used in this particular example is based on the "game framework" concept developed by Stolovitch and Thiagarajan [65].

G. Simulator

1) Definition of Simulator: A simulator is "a piece of equipment that is designed to represent real conditions, for example, in an aircraft or spacecraft" [66]. Besides, the concept of a simulator varies greatly depending on application domains. In the IT domain, a simulator can be characterized by 1) a numerical model, a data abstraction and/or a real or hypothetical system, and 2) the opportunity to carry out experiments where modifying inputs affect the outputs generated by the system. From this perspective, a computer simulator can be defined as a software program offering a model representation and enabling the simulation of its behavior and evolution through its execution and the proposed interactivities [67]. For example, Lebrun *et al.* [68] offered a road traffic simulator on an interactive tabletop allowing tangible interactions with real objects. The simulator aims to test hypotheses for reducing waiting time in an intersection, crisis management (e.g., in the event of an accident), and infrastructure modifications. In the health domain, the definition of a simulator can be associated with the use of a material (dummy or procedural simulator), computer software (digital simulator), a virtual reality device [69], or a standardized patient to reproduce situations or care environments. Chiniara categorized the most used simulation methods in the health domain. She identified different interactivity degrees, ranging from simple content representation to complex manipulations via haptic or neural devices with varying degrees of overlapping digital and reality representations [70]. Haptic feedback can help practitioners learn and practice a task [71]. Milgram and Kishino [72] defined the term mixed reality as a combination of virtual reality and reality. When transposing Milgram's reality continuum diagram to simulation practices, we can identify three types of simulators: nonnumeric simulators, digital simulators, and mixed simulators.

2) Simulator versus Serious Game: For illustration, a *Barbie* doll [73] is a toy because no instructions are provided to tell the user what rules should be followed to win. It is just playful with a *Barbie* doll [73]: this is paidia [74]. A video toy offers a similar approach. In *Monopoly* [75], there are rules to follow to win, and the underlying objective is to eliminate all opposing players by ruining them financially.

This is ludus and accurately fits the definition of a video game. Note that the difference between "paidia" and "ludus"

is equivalent to that found between "play" and "game" in the English language. "Play" is close to the idea of freeform fun (*Barbie* [73]), while "game" is closer to the notion of game rules (*Monopoly* [75]). We propose to make a similar distinction between "serious toys," based on a "paidia/video toy" structure, and "Serious Games," based on a "ludus/video game" structure.

From a marketing perspective, the term "simulation game" is also used for "video toy," a term used to describe tangible objects which feature near field communication (NFC) technology [76], such as Activision's *Skylanders*, Nintendo's *Amiibos,* or Disney's *Infinity*. In this article, a video toy is a virtual sandbox, as described by Natkin [77]. Now that we have explained the difference between "serious game" and "serious toy," we can revisit our formal definition for simulators (above). It is generally very similar to a video game in that it can incorporate a model for the player to experiment with. Games, such as *Minecraft* [78] or *Grand Theft Auto* [79] are good illustrations of this concept. However, games differ from simulators regarding play objectives and underlying logic. A game defines a set of goals and uses them as referencing points to evaluate whether a player has won. This is an intrinsic aspect of game design and game interaction. Conversely, a simulator will generally involve a third-party relationship to achieve a similar outcome. In most cases, an instructor will define goals for the user and determine whether the player has completed the challenge or not.

For example, with *Flight Simulator* [80], users are free to switch from paidia (play) to ludus (game). For example, they can fly freely (paidia) or set themselves objectives, such as passing under a bridge without crashing (game) [42]. We can also mention the notion of context which can influence both paidia and ludus aspects [67]. For example, an instructor can propose a destination to the learner pilot, weather conditions, and a time limit to respect. The instructor can then set up the simulator accordingly and observe the abilities of the learner pilot in managing the situation. We will not consider this situation as a play. If the *Flight Simulator* [80] now intrinsically proposes such objectives, which would amount to proposing a virtual instructor associated with the simulator, then we are moving into a serious game [67]. The real-world instructor cannot propose a situation to the learner as this would amount to duplicating the virtual instructor from the serious game.

We can, thus, differentiate a serious game from a simulator through the representation and mapping of player goals and assessment mechanisms. However, such differentiation is more difficult when comparing a simulator to a toy or a video toy.

3) Simulator versus Toy: Simulators are not necessarily games because they offer no intrinsic goals, unlike a game. The goals of a simulator are usually provided by an instructor or by the user. However, a simulator accurately represents a reference model (i.e., operating procedures, physical laws, and explicit modes of representations). From this perspective, it is possible to regard simulators as akin to toys. For instance, even when their representations borrow from the imaginary, toy cars or dolls have for reference existing models (i.e., cars and humans). Moreover, like simulators, toys do not set goals, and there is no explanation given to the user as to what to do to win. However, when provided with a manual, its content explains how to operate the toy. Last but not least, it is possible to use a toy to do an activity in a context other than entertainment (e.g., using a doll to teach future midwives how to bathe a baby). This brings the discussion back to the serious repurposing concept discussed earlier.

Conversely, a simulator can be used as a toy. If a child is placed in command of a *Flight Simulator* [80], she will likely start playing with it like a toy. However, this will not be the case for an apprentice pilot monitored by an instructor in an assessment context. Thus, if one seeks to differentiate a toy from a simulator formally, it quickly becomes complex when solely focusing on the artifact. Settings and contexts play a crucial role in how to use the same artifact in the same way a doll used as a toy by a child in a domestic context can also be used to train midwives in a hospital setting. The doll, in this case, thus acts as a simulator or toy, depending on the situation [67]. Based on this observation, we believe that the boundaries between toys and simulators are close or nonexistent. We would argue that it is possibly the targeted market for the artifact that determines whether one is dealing with a toy or a simulator. A simulator does not target the entertainment market, whereas a toy only targets the entertainment market. If an artifact is aimed at both entertainment and another type of market (e.g., health), we propose the term "serious toy." Finally, when a toy is repurposed to target utilitarian goals, we again face the serious repurposing activity previously discussed.

4) Simulator and Utilitarian Functions: We have reviewed several cases toward distinguishing SGs from simulators. However, an important aspect remains to be clarified: can simulators perform all three utilitarian functions identified earlier? Namely, broadcasting a message, providing training, and enabling the sharing/collection/manipulation of data. In previous work [17], we identified "serious toys," defined as serious video games using a "paidia" play structure (see Section III-B). Examples of serious toys are *September the 12th: A toy world* [81] (Message broadcasting), *Moo-o* [82] (Training), or *Second Life* [83] (Data sharing). Since serious toys can be compared to simulators, we deduce that these artifacts are also able to broadcast messages, provide training and promote the sharing of data. The utilitarian functions previously identified as part of SGs are not specific and can be found in all the artifacts studied in this article.

5) Formal Approach of a Simulator: We propose to formally define a simulator as follows.

1) A simulator is an artifact.
The simulator has one or several properties (digital, analogic, or hybrid).
2) A simulator operates outside of the pure entertainment market.
3) A simulator has no objective or an extrinsic objective.
4) Simulator presents utilitarian functions.

Formally, we obtain

$$\begin{aligned}\text{SIMULATOR} = \{g \in \text{GOAL} \mid g \neq \text{intrinsic}\} \\ \times \text{MEANS} \times \text{ARTIFACT} \times \{(a,b) \\ \in \text{MARKET} \mid a \in \text{ENTERTAINMENT} \Rightarrow\end{aligned}$$

$$b \notin \text{ENTERTAINMENT}\}$$
$$\times \text{UTILITARIAN FUNCTION}. \quad (11)$$

6) Examples of Simulator in the Health Domain: Virtual anesthesia machine (VAM) [84] is a simulator for Health. VAM is used to show future practitioners how the internal structure of an anesthetic machine works and help them learn how it should be used. We also see *SimForHealth* [85] as a simulator to represent a virtual respiratory clinic.[3] The player uses an *HTC Vive* [86] to incarnate a doctor who has to take charge of a patient for chest pain. This virtual clinical case perfectly illustrates the possibilities opened by new technologies for initial and continuing health training.

While this type of tool has a utilitarian purpose, it has no game-playing scenario or predefined rules and relies on an instructor to set goals for the user. Thus, as seen above, this is not an SG but a simulator. Finally, as the market is not entertainment but health, VAM [84] is a simulator, even if nothing prevents users from playing with it as a simple toy.

III. Synthesis

In this article, we reviewed the following concepts: Game, toy, serious game, serious toy, serious repurposing from game, serious repurposing from toy, serious modding from game, serious modding from toy, and Simulator. Then, we summarized the characteristics of each artifact in Table I. This table shows how formal criteria apply (or not) to each artifact. With Table I, we can now use the different letters C, A, I, M, E, L, and J to define the combination of each artifact; "" means: none.

We obtain the following results.

1) Game = CIME.
2) Toy = CME.
3) Serious Game = CIML.
4) Serious Toy = CML or CEML.
5) Serious Repurposing from game = AIEMJ.
6) Serious Repurposing from toy = AEMJ.
7) Serious Modding from game = AEML or AIML or AEMJ or AIMJ.
8) Serious Modding from toy = AEML or AIML or AEMJ or AIMJ.
9) Simulator = CML or CMJ or CEML or CEMJ.

As we can see, all the artifacts present a specific combination except serious repurposing from toy, serious modding from game, and serious modding from toy (two possible combinations for each). Indeed, these three artifacts can switch and present AMJ or AIMJ combinations. Everything depends on the nature of the uses or transformations carried out.

This analysis allows us to answer our initial research question: *Does the term "serious game" represent an object in its own right or is it simply a synonym for other existing applications?* Indeed, we can observe that SG offers a unique combination: CIML. It means that a serious game has a specific purpose. Thus, in the study's context, we can conclude that a serious game is not a single synonym of another existing application. Instead, it is an object in its own right.

[3][Online]. Available: https://simforhealth.fr/en/projects/virtual-reality-virtual-clinical-case-in-pneumology/

IV. Conclusion

In this article, our research question was to determine if the "Serious Game" term is tied to a specific purpose or used as a synonym for other types of applications, such as simulators. To investigate the question, we were inspired by the methodology used by Vladimir Propp [1] to analyse Russian fairy tales by a formal approach. By using five criteria (#1 Object Utilitarian functions, #2 Object = Artifact, #3 Can include the entertainment market but not exclusively, #4 Intrinsic objective proposed, #5 Based on an existing game or toy Artifact), we concluded that the SG term was related to a specific artifact and was not a synonym for simulator or serious repurposing. However, as innovative practices emerge and new artifacts are introduced, the terms used to refer to them will likely evolve and change over time (including "Serious Game"). This underlines one of the limits of this study; since the definitions and criteria used in this work are based on cultural considerations, these would need to be periodically revisited. Meanwhile, for future work, we should investigate whether or not the missing combination in Table I could be related to other types of artifacts.

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