Are you serious? – How serious games and abstract simulations can be useful when conducting security sensitive research

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Abstract - The worldwide gaming market is valued at an estimated $110 billion, eclipsing printed media, music and the combined movie and DVD industries. An increasing number of people use gaming as an interactive entertainment activity, therefore the next generation of military recruits are likely to be 'gamers' to some extent. A Serious game is defined as a mental contest, played whilst adhering to a set of rules, using entertainment for purposes of training, education, health or any other strategic objectives. It is a segment of the gaming phenomenon which offers players immersion within a replicated physical process, often for pedagogical applications, which allows skill development to manifest alongside entertainment. This presents a unique opportunity to train future military recruits using platforms they will be highly familiar with. Furthermore, there is potential for benefits afforded by such applications to be included in the design philosophies of future military systems (e.g. gaming controllers as input devices). By representing a process virtually, physical constraints on simulation and design are flexible, allowing for a serious game to function as a rapid prototyping tool for the evaluation of new technologies. If a serious game can be created for a process, the sheer size of the potential player base enables skill development, planning and evaluation to be undertaken on a vast scale, with the potential for extensive economic savings when compared to contemporary ways of training and evaluating future capabilities. The attainment of adequate immersion in serious games typically requires recognisable behaviours and appearances from the real world process. This can be problematic if the theme of the game is security sensitive in nature. This is particularly problematic in academia where a dearth of research related to the combat aspects of military operations is largely due to issues such as security. However, the development of abstract serious games may facilitate over coming such barriers. Abstraction, when applied to general design, is the process of separating functionality and representation. Isolation of these two components allows for encapsulation and the ability to map different functionalities and representations in various manners. Abstract functionality provides a template for bespoke representations, allowing the theme to be interchanged whilst maintaining the mechanics of a system across implementations. This provides benefits, such as the ability to test different interfaces and declassify sensitive information ('security through obscurity'). Abstract representation allows for a general controller or an interface to bestow multiple functionalities. This can benefit operators by reducing the need to learn new interfaces and could assist in a consistent user expectation. The Command Team Experimental Test Bed (ComTET) project is a program of work that has successfully utilised serious games to provide evidence based recommendations concerning the design, operation and ways of working for submarine control rooms of the future. The current work provides insights into the benefits that can be afforded to undersea defence projects by extending their simulator capabilities into serious games, and how this can be achieved.

1 Aims of the research

When conducting research in sensitive domains the risk of compromising security is a very serious challenge to manage. Segregation is a common approach, restricting authorisation to a limited set of resources (e.g. personnel holding relevant clearances). Whilst such exclusion criteria are necessary, they can limit how far research is extended. A pertinent example is human-in-the-loop trials, where reduced cohorts due to clearances can impede statistical power, leading to unreliable conclusions and ill-explored problem spaces. As authorised cohorts typically include specially trained operators and require usage of valuable resources it is likely that trials will be constrained further by cost and availability.

The aim of the current work is to demonstrate a working strategy which mitigates potential security risks in sensitive contexts whilst simultaneously minimising associated constraints on the research process. Specifically, how abstraction combined with augmented simulations and serious games afford research teams a significant advantage when conducting security sensitive research. A supporting case study is presented from the Command Team Experimental Testbed (ComTET) project on the evaluation of Remotely Operated Vehicles (ROVs).

2 Introduction

Despite being a relatively modern phenomenon, the prevalence of gaming in everyday life is substantial. Figure 1 shows the historic and projected size of the worldwide market, currently over $130 billion, eclipsing printed media, music and the movie and DVD industries combined [1]. An increasing number of individuals are volunteering their time for gaming as an interactive entertainment activity, with more choice than ever over narratives, themes and immersive scenarios [2, 3]. Therefore, the next generation of military recruits are likely to be 'gamers' to some extent.

Certain segments of the gaming market, specifically simulation and serious games, can offer experiences beyond entertainment. Both implement representations of physical processes with variable task fidelity, potentially allowing skill development to manifest alongside gameplay [4]. This presents a unique opportunity to develop and maintain the competencies of future military recruits by using recognisable gaming platforms, interfaces and hardware [5].

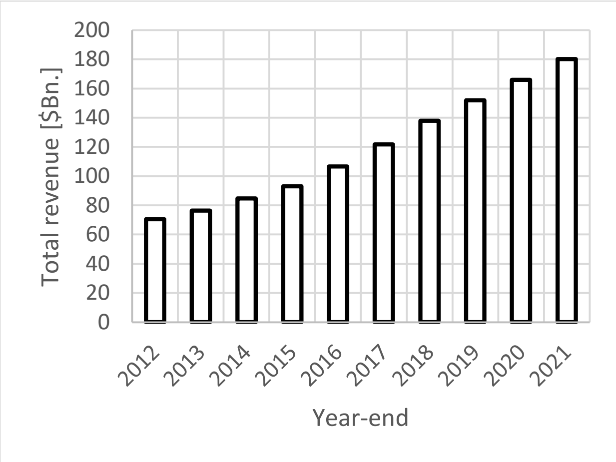

Fig. 1 Global gaming market revenue ($Bn.) (adapted from [1]).

Furthermore, the freedom of design offered by virtual training and testing environments allows for the narrative, theme and context of a game to be decoupled from the underlying mechanics. This separation of elements is realised through the use of abstraction in the design process [6]. By interchanging the user interface (audio, visual and hardware assets) and the contextual elements (narrative and theme) it is possible to obscure sensitive information and applications whilst retaining task fidelity [7].

Finally, if a collection of interface, context and mechanics can be suitably collated into a game, the overall product bestows considerable advantages to the research process. These include the ability to deploy worldwide and exploit large scale participation (similar to the distributed computation model), automate the experimentation process and leverage the emergent ‘gaming community’ for feedback and future development cycles [8].

2.1 Simulation and serious games

A simulation game is a replication of a process that incorporates a prescribed setting constrained by rules and procedures [9, 10]. Computationally, simulation games achieve replication by using a mathematical or symbolic model driven by a ‘game-like’ interface [11-13]. Entertainment is usually the key design criterion; therefore, the simulation is potentially of a reduced fidelity.

Fidelity itself is commonly separated into several types [14], which allows for computational resources to be allocated strategically towards different goals, allowing simulator designs to become more efficient. For example, fidelity in flight simulator software varies enormously between personal use and commercial training. To deliver professional flight training a simulator must be certified in accordance with various regulatory bodies, standards and aerodynamic testing procedures [15]. Crucially, the simulator must also bestow accurate, detailed and functional instrument panels to enable procedural training. In contrast, a generic flight simulation game can provide an entertaining challenge, but is not required to bestow the same levels of fidelity as the training counterpart [16]. In addition, development, running and purchasing costs are significantly lower when compared with a certified simulator [17]. Fundamentally, both implementations allow repeated observation of variables which may be difficult to measure on real hardware, whilst also eliminating the risk of losing a potentially expensive asset.

Serious games are similarly defined as a computer simulation where abstract gameplay mechanics coexist with a representative model of a physical process [18]. Unlike simulation games, the key design criterion for serious games is pedagogical applications, suggesting player experience manifests as both skill development and entertainment [4].

Typically, the extremely high overall fidelity and design for training approach bestow serious games with more controllability and observability than simulation games. Improved controllability enhances the enrichment of actions and scenarios a player can experience. For example, a serious game may have specialised scenarios driven by real-life events, live testing procedures (such as automated assistance, equipment failures or new goals and directives) and access to additional model data. Increased observability exposes more outputs, allowing for larger volumes and additional sources of live feedback data during gameplay. In addition to driving research outcomes, this data can be used to modulate and trigger automated events within the scenario, allowing for the automation of certain experimental protocol items (such as timings and interventions).

Curiously, a simulator can be augmented with increased information and improved outputs, blurring the differentiation between simulation and serious games. Ultimately though, in order to be considered a serious game, a simulation must provide a real-time training element, with ‘expert’ observation and feedback responses (either from the game or supported minimally by an expert agent), in order to ensure skill development [19, 20].

2.1.1 Applications of serious games

Serious games are an appropriate platform to develop training tools and provide excellent research platforms [21-23]. Pedagogical application examples can be found in several domains, such as musical tuition, computer programming and flight training [24-26]. The serious game training approach has been adopted by the United States of America (USA) from early simulations [27], to sophisticated, modern [28] and multi-branch warfare capabilities [29, 30]. At an appropriate maturity level, serious games have the potential to become self-contained teaching systems. As an example, the medical training section of 'America's Army' [28] enabled a player to stabilise injuries in a real-life incident [31].

Manufacturers have also turned to serious games to provide support for future operators, as well as demonstrations on platforms that are impractical for physical testing (such as large, expensive and/or security-sensitive assets). As an example, industrial ROV simulators [32, 33] have been augmented, creating industry-specific simulation games such as ROVSim[2] [32] - which could be adapted with a game challenge as a training scenario, fulfilling the premise of a serious game classification.

Alongside pedagogical applications, serious games have also been used for welfare applications, such as Post-Traumatic Stress Disorder (PTSD) therapy [34], phobias [35], Autism Spectrum Disorder (ASD) interactivity [36] and assistance with stroke recovery [37].

2.1.2 Benefits to research and development

Another important application of serious games is the evaluation of new technologies and feedback to the design process [38]. A well-designed game can virtualise future systems to permit repeatable trials with rich interactivity. By operating virtually, the risks and costs associated with manufacturing and commissioning an experimental asset can be avoided. In addition, well designed prototype simulation early in the design process can accelerate learning and potentially identify shortfalls before their impact becomes significant [39]. Case studies supporting this can be found in civil [40], electrical [41], automotive [42], and biological engineering [43]. Thus, it can be stated that serious games are an emerging rapid prototyping technique for the evaluation of new technology.

Furthermore, whilst a serious game design can be driven by the requirements of the application, the reverse case also merits exploration. That is, future design philosophies being driven by contemporary 'gaming' elements. An example of this is how gaming console controllers have influenced the input devices of other domains, such as aerial vehicles [5] and weapons systems [44]. The term 'gamification' is often used to describe this process and has been subject of increasing literature review in recent years [45-48]. Gamification is an emerging feature of sociotechnical design processes in many industry sectors, for example in-vehicle interfaces [49, 50] and healthcare training [51-53].

Overall, the serious game approach can be said to have a bidirectional influence on the design process - moulding anticipated game elements to the application for fidelity reasons and imbuing the application with additional game elements for a better player experience (be that engagement, skill development or both).

In addition to design philosophies, gaming platforms also offer the potential for distributed research on a global scale. The ease of deployment relaxes the constraint of conducting research at specific locations, especially when physical facilities are unavailable, unsuitable or unaffordable. A notable example of this technique (whilst not a serious game) was the rapid occurrence of distributed protein folding solvers on home PCs in the early 2000s, enabling biochemical research to be undertaken outside of controlled laboratories [54].

In conclusion, it is clear that if a serious game can be created for a process, the sheer size of the potential player base enables skill development, planning and evaluation to be undertaken on a vast scale, with the potential for extensive economic savings when compared to contemporary ways of training and evaluating future capabilities.

2.2 Abstraction as a design tool

Abstraction, when applied to general design, is the process of separating functionality and representation [6]. Isolation of these two components allows for encapsulation and the ability to map different functionalities and representations in various manners. Applied in reverse, combinations of abstract components are generally referred to as implementations, with some domains using the qualifiers 'specialised' or 'concrete' [55, 56]. When mapped to the design of a serious game, functionality and representations comprise the game mechanics and interface respectively.

2.2.1 Game mechanics and functionality

Abstraction of functionality generates a defined set of mechanics or behaviours, which can be used as a template to design interfaces. This is typically applied with the goal of reducing a large set of mechanics to a simplified model (potentially across multiple systems) through concepts such as the unification of common features or lumped element analysis [57]. The abstraction and subsequent isolation of the defined mechanics allows interface and contextual elements to be interchanged whilst maintaining the mechanics of a system across implementations.

A fundamental example of this technique is the creation and deployment of computer software. During development, programs must be constructed around the constraints of the hardware specification for each device. Thus, without standardisation, there is no guarantee of a program executing on a machine other than the one it was written for. This also mandates that software versions must be constructed for each combination of hardware in existence. To overcome this, development is traditionally through a set of language-based abstractions (for example, the 'C' programming language [58]), which are translated into machine-specific instruction sets (for example, the Intel 64 and IA-32 processor instructions [59]), themselves an abstraction of specific combinations of hardware components (typically specific processors and chip-set architectures). The standardisation of this approach has afforded modern software the capacity to execute identically across platforms providing there is sufficient compliance with the designated hardware abstraction. Furthermore, the abstractions act as a model of compliant machines, allowing testing and debugging interfaces to be routinely used in the development lifecycle, rather than confined to the commissioning of software on each device [60]. Finally, the standardisation of computer functionality through abstraction was key for the proliferation of more productive development interfaces (in this case, languages) – along with automated code production abilities and high-level design tools [61].

When applied to serious games, abstraction of functionality reduces interactive scenarios to their essential, intrinsic mechanics [62]. For example, games such as ‘Connect Four’, ‘Qubic’, ‘Go-Moku’ and ‘Renju’ exist as different representations of shared functions (connecting tokens to form a line). Therefore, they can be unified and abstracted into a collective set of mechanics [63]. The identification of the core abstract mechanics is a key step in defining the behaviours required for a serious game in order to both answer the posed research questions and provide player immersion appropriate for the proposed experiment design.

2.2.2 Interfaces

Abstraction of representation generates an interface specification, which can be used as a template to specify the required mechanics of a system design. When applied to multiple interfaces, abstraction also performs the same simplification as when operating on sets of mechanics. This creates generic interfaces which can operate across multiple devices that comply with the abstraction.

A physical example is the ubiquitous industrial Programmable Logic Controller (PLC) – which features an abstract input/output (I/O) interface [64]. An industrial PLC can control anything that complies with the I/O specification; hence, it is an abstract interface for the connected plant. PLC units can be bought in bulk for cost savings and pre-programmed before being installed. Utilising one unit saves maintenance and support costs when compared with utilising different controllers with different interfaces.

An example of how this applies to game interfaces can be seen in the universal chequerboard. This simple patterned board, can accommodate the functionality of several games such as ‘Chess’, ‘draughts/checkers’, ‘Lines of Action’, ‘Arimaa’ and ‘Kage’ [65]. Abstract interfaces such as these are vital for the ‘gamification’ process where gaming inspired interfaces can be used to improve upon traditional systems [5].

2.2.3 Benefits of abstraction

Whilst the benefits to the design process have already been outlined, there are also some additional advantages when using abstract modelling techniques. Firstly, because abstract representations map to real systems in a one-to-many relationship, developments on the abstraction can propagate to numerous real systems. For example, strategies, rule variants and solution algorithms for abstract versions of traditional games apply to all derived implementations [66-68]. This means that improvements in the design process, game product or application may add value to other / future operations if the abstraction model is appropriate.

Abstraction at the interface level specifically, could be employed to create universal interfaces for families of related systems. This can benefit operators by reducing the learning time, promoting a consistent user expectation and reducing the cognitive load when task-switching [69].

Finally, there are intrinsic security affordances leveraged when utilising abstraction as a design tool, these are described in the following section.

2.2.4 Implementing security with abstraction

Abstraction essentially supresses context and therefore can be used to remove sensitive information from a process. By removing context, abstraction provides security through obscurity – in that the intentions, detail and applications of an abstract model are not definitive. Obscurity works in principle, but as a *sole* method it is well documented as a poor security strategy [70-72]. Therefore, in order to conduct security sensitive research with a serious game, creating an abstract model (of a function or interface) is not satisfactory as a complete strategy. Fortunately, the abstraction process itself allows this to be rectified. As abstract models may represent multiple implementations, supressed context may simply be interchanged with a suitable alternative. This process is known as security through deception and provides a significant advantage over obscurity alone [73]. Deception as a strategy is also well documented and has been shown to be a prime design requirement in modern cybersecurity practices [74-76]. Therefore, the design process for a serious game in a security sensitive context must not only abstract context, but also replace it with a suitable alternative that satisfies classification protocols.

As a side note, when developing training packages for a serious game abstraction can also bolster security via the isolation of core skills and behaviours from a real process. This allows fine control of accumulated skills that may be sensitive if collectively trained, whilst ensuring participants are competent for experimentation.

3 Design for experimentation

In order to successfully deploy a serious game for research purposes, a design process is required that can leverage abstraction and gameplay elements effectively.

Once the research questions and objectives have been sufficiently defined, the initial outline design goal is to use abstraction to define security-sensitive system elements in simplified terms. Typically, a model is produced which removes qualitative context and sufficiently describes the physical process mathematically. After the system model has been generated, a review of successful published games should be undertaken, selected and filtered by similarity to the system behaviours (and context, if available). This review enumerates additional gameplay elements such as scoring mechanisms, scenario design and tutorial structure. Finally, an appraisal of the research requirements will reveal any other metrics and system functionality that should be added. The union of the abstraction model, publication review and research requirements builds the functional design specification for the serious game.

An identical process can then be used to form the user interface (UI) design. Specifically, abstraction reduces security-sensitive interfaces to discrete element descriptions (for example: buttons, indicators, text labels, check boxes etc…). This can be unified with a review of common game interface elements and the research requirements to form the UI design specification.

These specifications must be continuously refined in order to permit desensitisation and address two key fundamental issues in serious game design. Firstly, the adequate immersion of players into the given experiment and secondly, the enjoyment of the players. Thus, further strategies of design influence are required to finalise the specification.

Firstly, a theme and narrative must be chosen to replace the context which was suppressed by the abstraction process. The attainment of adequate immersion requires the implementation of recognisable behaviours and appearances available in the public domain. Ideally, these should be from commonly experienced phenomena, such that the user expectation is generalizable across large cohorts. Secondly, a review of the gameplay elements should be undertaken to determine their suitability. A universal method is to categorise the gameplay into core, alternative, enhancing and opposition mechanics [77]. Successful designs typically feature examples of each type, starting from a minimal core set. The set of alternative mechanics classifies unintended behaviours in the resulting gameplay. Enhancement mechanics derive from the combined core and alternative base in order to allow players to control and explore variations on the standard gameplay. Opposition mechanics derive from enhancement mechanics in order to define and control the difficulty level.

Finally, the construction of a training package completes the serious game design process. Participants must be competent at the task prior to experimental observation in order for a particular research question to be effectively investigated. As previously discussed, the abstraction process enables removal of task elements not relevant to the current research questioning which allows for a simplified, targeted training package to be developed. The training often requires multiple runs with scaling difficulty and task fidelity to allow participants to learn effectively. Figure 2 provides an overview of the design process from the inception of concept design through to the testing stages prior to experiment delivery.

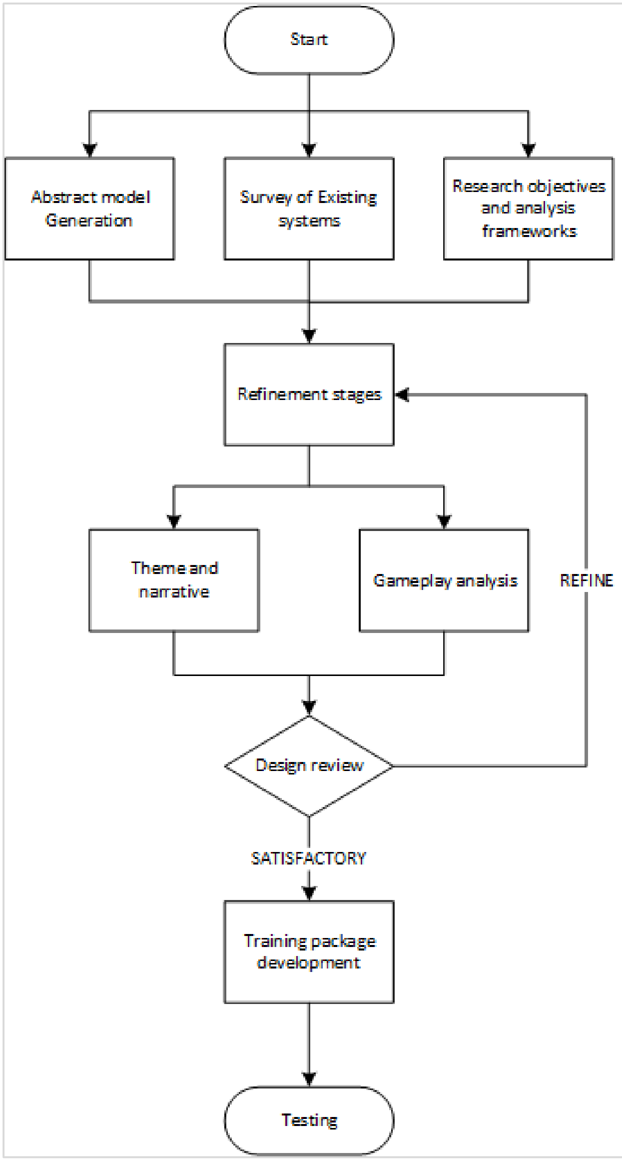

Fig. 2 Overview of the serious game design process from initial concept to testing stages

3.1 Generating an initial specification

In order to complete the initial specifications for the functional and UI elements which model a sociotechnical system it is necessary to harmonise the physical system and the human agents within the same process.

3.1.1 Physical systems and agents

Physical systems are often defined using analytical techniques which form a set of differential equations in continuous time. These are coupled with discrete logic to switch between modes of operation and provide certain methods of controllability. A lumped parameter or lumped element analysis is employed to reduce the system to its minimum degrees of freedom. Finally, a transformation to the discrete-time domain enumerates the atomic operations for implementation on computing hardware. During these steps, the qualitative properties and ability to identify the purpose of the mathematics reduces, allowing for sensitive calculations to be represented as an arrangement of elementary operations (both arithmetic and computational). For example, equation 1 is a difference equation enumerated from a time-invariant system.

$$x(k + 1) = 3x_1(k) + 2x_2(k) - 7x_3(k) \quad (1)$$

From the examination of this equation it is not clear whether it is an exact representation, a linearisation or a discrete transformation of a physical system. Whilst it may be possible to map an analytical formulation to equation 1, the reverse mapping is not guaranteed as one-to-one, meaning there are many possible answers for what the difference equation represented initially. Thus, the qualitative properties and functions that generated this model are shielded by the mathematical abstraction.

3.1.2 Human and social agents

Humans, as the other critical agents of sociotechnical systems, also require careful consideration for the completion of the general system model. Specifically, abstraction targeted towards describing the individual tasks and the interconnectivity between agents. Defining the tasks required by agents enumerates the functionality and UI elements required to operate the system. These may naturally overlap with the existing system design, but can also include new ways of working or other tasks and methods to be explored under experimentation. Cognitive Work Analysis (CWA) is framework for the analysis of complex sociotechnical systems. A particular stage of CWA analysis, known as Work Domain Analysis (WDA), is represented as an abstraction hierarchy that can be employed to discover information about a sociotechnical system [78]. By completing a Work Domain Analysis (WDA) the enumeration of the high-order goals through to the system objects ('top-down' analysis) ensures that all required components are discovered, as well as their respective feature sets and behaviours. This process can also be applied 'bottom-up' to predict and theorise the emergence of new behaviours and similar effects. An example of this is the usage of 'Bottom-up' propagation of simulated failures to demonstrate how alterations in service of singular physical objects affect the goals of the overall system [79]. An example of CWA in practice is the design paradigm of Ecological Interface Design (EID) where the output from a WDA contributes to the definition of required UI elements and their linkage to operator tasks [80]. Overall, the resultant abstraction hierarchy from WDA also helps shape the object architecture for the software design, as it bears resemblance to inheritance pathways in class hierarchies.

A complimentary technique is the Event Analysis of Systemic Teamwork (EAST) method which models complex collaborative systems through a network approach. Specifically, three networks are considered: task, social, and information [81]. Social networks analyse the communications taking place between the "agents" working in the team. Task networks describe the relationships between tasks, which may influence or depend on others in the network. Finally, information networks describe the information that the different "agents" use and communicate during task performance. This method is agnostic to whether agents are human or technological making it a powerful analysis technique for understanding and documenting complex sociotechnical systems [82]. The Social Network Analysis (SNA) component of the EAST methodology defines the nature and structure of the communications network between agents. This can then be used as a template to construct appropriate design specifications for the networking components of the game. For example, application-layer messaging protocols, routing and topology [83].

3.1.3 Existing game reviews

Comparisons with existing games is an important step in the critique and generation of the initial design specification for two key reasons. Firstly, game design is often best defined as an open problem, with varying degrees of publication, consistency and rationale [77]. Secondly, most successful games have extremely large player-bases and will typically therefore have been through extensive trial and refinement usually unavailable to most serious games at this early stage in the design process. The objectification of success in this context is chiefly measured in the total number of active players, but may also consider the duration of players within the community. Revenue and sales figures as factors require careful consideration as the proliferation of differing release platforms, business models and income sources can make comparisons difficult.

After selection, it is also beneficial to utilise abstraction methods, such as hierarchical classifications found in CWA and network methods from EAST, to analyse the game features. This may assist greatly in the understanding of game design, especially for non-specialists, who may be looking to leverage the serious game approach for the inherent advantages outlined previously. In addition, such frameworks can provide a reliable output from the review process, when considering the freeform nature of game design.

3.2 Narrative and theme selections

After the completion of a suitable initial specification for the game, it is necessary to refine the design to target the needs of adequate immersion and enjoyment.

Combined, these concepts create a community that can critique and review a serious game on the merits of player experience and task fidelity. This is not just useful to large scale distributed games, but also research-based serious game applications - as pilot testing with expert operators can offer targeted review at where the game is either succeeding or failing to meet requirements. Task fidelity is important at meeting the 'serious' aspect of the game design, but player experience is also key to control. With a poor experience, repeated trials can suffer from an increased disconnect between the player and the task, impacting the reliability of the results. At this stage in the design process immersion and enjoyment (and the derived player experience) are best constructed by removing the 'barriers' between an engaged and non-engaged player.

These may be grounded as preference (matching the player with the type of narrative), control feedback (including appropriate responses), time investment, reward structures and detail levels [84].

Whilst preference cannot reasonably be controlled with public and/or uncontrolled cohort selection, a strategy of utilising everyday 'common' theme and narrative elements can help form a schema which matches as many players as possible. Usage of phenomena commonly experienced by players outside of the game also helps to assert the level of realism in the simulation. Recognisable behaviours and appearances can help players intuitively learn, confirm and perform tasks by supporting objective learning [85]. Whilst recognition appears to be at odds with the desensitisation goals, the previous abstraction processes allow for substitutions of sensitive elements with similar affordances. For example, classified wheeled-vehicle platforms may be simulated using a driving simulation game known in the public domain, with recognisable (public) controls allowing drivers to connect with the simulation and maintain a positive experience.

3.3 Gameplay review

Once an initial specification has been drafted, then refined with the development of a theme and narrative, a review of the gameplay mechanics completes the refinement stage. The classification of gameplay into multiple classifications of mechanics hints that a successful design has a characteristic signature of proportions of each type. Successful design for gameplay typically requires a minimised set of core mechanics which can be easily learned – therefore also simplifying the training package development post-design [77]. The set of alternative mechanics is likely to be driven by research needs (as additional effects or measures beyond the core research) but should be smaller than the core set to prevent distractions and ensure maximal engagement [86].

Aside from the core and alternative sets, players can derive enjoyment from optimising performance and reward structures (a previously mentioned barrier to engagement) provided by enhancement mechanics. By adjusting the frequency and impact of enhancement mechanics it is possible to adjust the player experience using feedback from pilot testing to ensure it remains positive [87]. Finally, opposition mechanics can also be suitably tuned to adjust the difficulty level to avoid extremes cases where an engaging challenge is absent and the challenges cause too much frustration.

To summarise, the general mechanics of a serious game are refined in the following strategy. Firstly, the core set must capture the research behaviours and objectives and be as minimal as possible. Alternative mechanics should then be checked against the requirements to ensure suitable design, then refined from player experiences in the pilot testing to verify there is adequate engagement in the expected tasks. Enhancement mechanics are then adjusted based on the player enjoyment, before a final adjustment on the opposition mechanics set to define the expected difficulty level.

4 Case study (Tethered ROVs)

The Command Team Experimental Test Bed (ComTET) project is a program of work that has successfully utilised serious games to provide evidence-based recommendations concerning the performance of tethered ROV operators.

To evaluate operators when controlling and monitoring ROVs, a bespoke serious game was developed and deployed to novice participants utilising a desensitised design. As the requirements of the work included evaluating commercially and security sensitive future technological functionality, the initial specification was developed within the design process as described in the previous section.

4.1 Functional and UI specification

A high-fidelity mathematical simulation engine was created to abstract the ROV dynamics. This replaced any sensitive elements with a simplified three degree-of-freedom set of dynamics, complete with non-linear formulations to account for hydrodynamic effects. Testing and development of the engine was completed by constructing a control interface abstracted from consultations with project stakeholders. Whilst no ROV serious games were available (or suitable) for review, comparisons were drawn with industrial ROV simulators to refine the design into a complete initial specification.

4.2 Theme and narrative

To obscure the nature of the research applications the narrative was redefined to a prospecting and resource collection mission within the theme of deep space exploration. A futuristic space environment was selected due to it offering almost limitless flexibility and convenient representation of limited communications and sensing. This theme also permitted a broader user expectation of how objects should move and interact, allowing for replication of arbitrary ROV platforms and scenario definitions. Anything unexpected could simply be waived under the guise of 'futuristic technology'. Furthermore, it allowed for artistic license on visual and audio cues, simplifying the search for required assets.

To frame the scenario, participants were briefed with a mining operation tasked to acquire precious metals from deposits drifting in space. The prospecting area was to be filled with intermittent radiation that would block sensors in certain regions of the playing area. This successfully obscured the underlying security-sensitive nature, enabling a wider pool of participation whilst complying with stakeholder security protocols

4.3 Refinements and review

A CWA and EAST analysis of the proposed technology being investigated was conducted as part of structured review sessions with SMEs. These review sessions also helped shape modifications to the game mechanics in order to both capture the research goals and provide appropriate data. Trial versions of the game were demonstrated and play-tested in order to configure the final specification. Critically, a major difficulty element of motion planning and dynamical control was removed and the automation assistance provided by the game was given more authority in order to more closely match the research goals.

4.4 Experiment deployment

The final specification of the game was used to generate a build for human-in-the-loop pilot testing. After the first session it was found that the training package was not effective and that player engagement was less than satisfactory. Additional material was incorporated into the training missions and several adjustments were made to the individual scenarios to reduce the overall completion time. Additional in-built analysis and extra output formats were also requested to leverage the advantages of using a serious game over manual statistical calculations. Ultimately, these automated formatting stages accelerated the transition between the experiment and eventual publication of the results – also reducing the lead time for the stakeholders. The repeatability offered by playback of recorded inputs also allowed for live analyses and tactical discussions in future works, without the need to repeat the study or recruitment process

5 Conclusions

The sheer size and influence of the gaming market in a modern context is impossible to ignore. As its effects on potential military recruits continue to grow, so do the advantages of utilising serious games as training and evaluation tools.

The ability of serious games to provide knowledge and learned behaviours has been clearly demonstrated for a wide range of domains. Much of this depends on the quality of the design process, crucially, appropriate matches in expectations between the user and the fidelity offered by the game (immersion) and the player experience (enjoyment).

Abstraction is a key component of the design process to expose the simplified elements of physical systems and interfaces. By creating a unified model comprising classified, public domain (existing) and research-driven elements both the functional design and UI specification can be authored to exist within relaxed security constraints.

To complete a suitable serious game implementation (i.e. for desensitised research), the abstraction must be given a suitable alternative theme and narrative. This permits desensitisation via the paradigms of ‘security through obscurity’ and ‘security through deception’. Both concepts can be leveraged, providing the original documentation of functionality and abstraction process has been thorough.

Finally, a desensitised serious game empowers the research process by opening experimentation to a wider range of participants, applications and locations. The increased control, observation and automation potential offered by transiting from traditional experiment operations to a serious game also enhances the evaluation of new platforms before they are commissioned by improving feedback in the design process.

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