

Knowledge Assessment: Game for Assessment of Symptoms of Child Physical Abuse

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ABSTRACT

Using serious games as a form of training and education has been a growing trend. While there has been research into the adaptation of games for training, assessment of user knowledge as a whole for the purpose of creating tailored training content has not been closely examined. In this paper, we propose a general framework for creating an assessment game and show how Knowledge Assessment can be used to guide the focus of subsequent training modules. Using our framework, we address the frustration and anxiety expressed by medical and nursing professionals about their lack of training regarding indicators of child physical abuse (CPA) in the United States. We develop the Computer Simulated Interactive Child Abuse Screening Tool (CSI-CAST), which contains scenarios in a serious game and uses assistive AI technologies to assess a group of users and discover features that are important in indicating the users' collective knowledge identifying CPA. A user study is conducted to show that CSI-CAST is easy to use and it functions to discover specific training needs.

CCS CONCEPTS

• Applied computing → Computer games • Software and its engineering → Interactive games • Human-centered computing → User studies

KEYWORDS

Video game, serious game, educational game, game design, knowledge assessment, child physical abuse

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1 Introduction

Child physical abuse (CPA) can be defined as “any non-accidental physical injury to the child” and can include striking, kicking, burning, or biting the child, or any action that results in a physical impairment of the child [33]. According to the U.S. Department of Health and Human Services Centers for Disease Control and Prevention, 117,772 U.S. children had a substantiated case of CPA in 2015; 1,650 (or 2.25 in every 100,000) children died as a result of CPA [4]. Epidemiological studies suggest that 28% of children (approximately 20 million) experience CPA during their lifetime [4]. These data suggest that many incidents of CPA are not being reported to child protection services.

Before starting school, healthcare settings may be the only setting children encounter staff who are mandated to report CPA. Medical and nursing students have expressed frustration and anxiety about their lack of training regarding indicators of CPA and procedure for responding to suspected abuse [1]. When properly trained, students and staff can better recognize signs of CPA and make appropriate referrals. Lack of trained professionals represents a missed opportunity for preceptors and mentors to educate students to identify and respond to CPA.

To tackle this issue, we propose a framework for a game-based assessment and training system. Using this framework, we create the Computer Simulated Interactive Child Abuse Screening Tool (CSI-CAST). It consists of a serious game simulating a healthcare setting to assess users' ability to diagnose and respond to CPA. In the simulation, users conduct virtual examinations where multiple contextual cues related to CPA could be present. We collect user choices during the simulation. A feature selection technique is then

used to automatically identify the most important contributing factors in the group of users correctly identifying sentinel injuries or injuries likely caused by CPA or missed opportunities in identifying or reporting these injury patterns. Training modules can then be tailored to these identified contributing factors. The end goal is to disseminate training to improve competence in assessing and responding to suspected CPA.

2 Related Works

In this section we discuss previous work both in the area of game-based training and adaptation, and the area of our application, training for students and professionals in the knowledge of CPA.

2.1 Educational Games and Games for Training

While game-based education has had a long history [26], using serious games in educational settings for learning and training has recently become a fast growing trend [6,11]. Previous studies have shown that students' previous gaming experiences and their attitude towards educational games do not influence their learning [22], making educational games a suitable method to augment existing teaching pedagogy.

Many researchers have examined the use of video games as a resource for teaching computer science [20] and computational thinking [19]. Teaching computer programming is a popular topic in educational games, especially towards novices without prior coding experiences [36]. Foster et al. [23] developed a game specifically for the purpose of introducing programming logic to novices. The core component of this game requires the player to utilize programming logic, but the game presents it in a graphical interface where the execution flow is personified as a character going through a game map. Melcer and Isbister [37] have also examined the effects of using visual blocks and collaboration between players in learning programming.

Educational games have been used to teach various non-computing subjects, such as biological engineering [18] and sustainability [24]. As hardware evolves and new technology comes into existence, so does new innovative use of these technology in educational games. In PlayScope, the use of augmented reality to add game elements to a smartphone app gives students a better experience learning biology [21].

Adaptation and personalization have been utilized in the context of games. Adaptation refers to the continuous adjustments of game content based on the actions of the player, whereas personalization is often used to refer to a one-time adaptation of some aspects of a game to suit an individual player's needs or preferences [35]. Past research has shown that providing an adaptive experience for each player increases enjoyment for certain players [27]. These adaptive experiences are often enabled by creating a model of the player as the player goes through the game [30]. Previous research has addressed adaptation in many components of games, such as interactive narrative [28,29] and the adaptation of game missions and difficulty [31]. Mavromoustakos-Blom, et al. [12] developed

personalization on training with crisis management, where the system provides personalization in the form of tailored feedback and scenarios using a player model. The player model is built using physiological sensors and in-game events.

While assessment often comes up as an important topic in educational games, researchers have addressed assessment methods for the design of educational games [25], the assessment of players' learning outcome after playing the games [19], as well as the assessment of the learning experience and time/cost effectiveness [32].

The framework we propose in this paper examines Knowledge Assessment, a phase in which the users' knowledge is assessed, before the actual game-based training occurs. Previous work on knowledge assessment has experts manually analyze answers to written questions and oral interviews [34]. While these methods are effective at gathering information about intermediary knowledge and cognitive reasoning, we show that we can use an automated machine learning method in this pre-training phase to direct game designers to focus on specific knowledge areas that might otherwise be overlooked, when designing subsequent training and testing material.

2.2 CPA Training

Doctors and nurses have more frequent contact with CPA victims than most other mandated reporters [13]. However, healthcare professionals often do not follow the mandate to report [14,15]. In fact, medical and nursing students have expressed frustration and anxiety about their lack of training regarding knowledge of and procedures for responding to suspected CPA. Improved training for healthcare professionals in CPA assessment and reporting may facilitate accurate reporting and save lives [16,17].

With the exception of the Child Abuse Pediatrician, education for healthcare professionals on CPA usually includes didactic information, medical chart reviews, and case studies [10]. While effective, these methods are time consuming, often do not address misconceptions about CPA, and do not lead to long-term change [9].

Training in CPA reporting should include behavioral rehearsal. The use of a virtual simulation game and tailored training modules to train healthcare students in the accurate recognition and reporting of CPA would allow for the use of behavioral rehearsal without the need to use child actors. Adaptive virtual learning environments have a strong, positive effect on learners' level of knowledge, self-regulation, efficacy, and performance [2]. When reflective problem solving and explanatory feedback are included, learners show increased knowledge, a reduction of misconceptions, and greater transfer of training.

Frutos-Pascual and Zapirain [5] reviewed research on serious games and found that AI techniques have been used in the assessment of users, among others. Bellotti et al. [3] proposed a formal design methodology for serious game. However, none have examined the use of a serious game to train healthcare professionals to recognize CPA. McEvoy et al. [8] reported the use of live-action

interactive videos showing a simulated hospital environment to provide training in child abuse recognition and management. The results of this study found that the virtual simulation increased healthcare professionals' knowledge and confidence in recognizing and reporting CPA. However, this study did not examine if the participants' choices during the simulation were consistent with approved protocols for the assessment and reporting of CPA, nor did it link to appropriate training resources when participants made errors.

3 Framework

In this section we describe a framework for a game-based tailored assessment and training system, its three components, and the technique used for the assessment of group user knowledge.

3.1 Overall System

We break down an assessment and training system into three main components (Figure 1). The first component is the Knowledge Assessment phase, where a user is given game-based scenarios that simulate real-life situations. The main purpose of Knowledge Assessment is to gather information on the knowledge of a group of users for a particular knowledge domain. The aggregate data from the users are then used to determine the areas in which users are most likely to make mistakes or knowledge areas in which users are most likely to overlook. Game designers can then use this information to tailor the training modules.

The second component is the Training phase, where a user is given a set of training modules to complete. Through the training modules, a user is given the required knowledge on the subject matter. The training modules are tailored to the users based on the user' responses in the Knowledge Assessment, while ensuring that the most likely mistakes or most likely overlooked knowledge areas are especially focused.

The third component is the Testing phase. After the user completed a training module, the user is given a quiz on the corresponding knowledge. If a user does not pass the quiz according to the requirements set by the trainer, then the user is asked to go back to the Training phase and review the parts, tailored to the mistakes. When the user passes all quizzes, the Testing phase is considered completed.

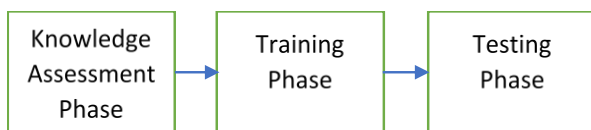


Figure 1: Game-based tailored assessment and training framework.

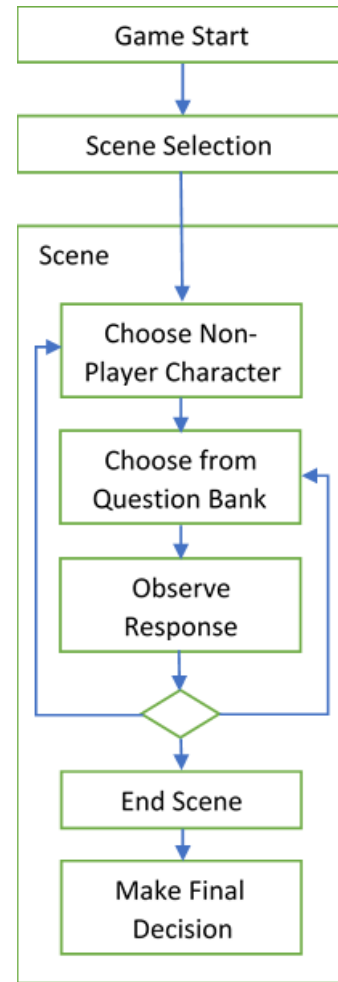


Figure 2: The Knowledge Assessment phase of the tailored assessment and training framework.

3.2 Knowledge Assessment

In the Knowledge Assessment phase (Figure 2), a user is asked to select from a set of simulated scenarios. Since the goal is for the system to become familiar with the user's knowledge, this phase does not contain any structure for teaching the user. In each scenario, the user assumes a role (such as a doctor) preset by the game designer. In the scenario there are other non-player characters (such as a child patient seeing the doctor), each with their reasons for being in the scenario. The user can interact with the non-players characters and engage in conversations with them. Users are given the freedom to interact with the non-player characters in the environment for as much or as little as they want. No directions should be given to the users on what they should be looking for, to ensure the user is not biased in the responses. Once a user determines that they have obtained all the information they need, they can choose to exit the scenario and make one final decision. This final decision, however, has a right answer that is preset by the game designer based on the scenario. Whether the user makes the

right decision at the end will be an important indicator of the user's knowledge.

In each scenario, as the user interacts with the non-player characters, the user can choose from a set of questions and interactions. These are created by subject matter experts. The non-player character responds appropriately according to how they would in real-life situations, as determined by subject matter experts. We call this set of potential questions and interactions a question bank. For each question in the question bank, there could be a set of zero or more preconditions. Each precondition is set by another question in the question bank. A question only becomes available for the user to choose if all its preconditions are met, that is, all the required precondition questions have been asked by the user. For example, a doctor's question about what can trigger a patient's asthma will only be available when the doctor has already asked the patient about having asthma and received an affirmative response. Preconditions can also become disabled causing a question to become unavailable. Interactions are used in the same way. An example interaction is for the doctor to examine the patient's abdomen and the patient responds by showing a bruise on his abdomen. The user is allowed to choose the same question multiple times.

When the user decides that all required information has been gathered, the user can end the scenario. At this point, the user has to make a decision, for example, "do you have concerns about this child's safety or well-being?" There is a correct response depending on the preset situation in the scenario. The user's response is then recorded. The user is also asked to enter any additional notes regarding the scenario and responses.

3.3 Analyzing Knowledge with Feature Selection

Each user choice is recorded in the scenario, and each choice becomes an independent variable. The user's final decision is also recorded, which becomes the dependent variable. The power of the Knowledge Assessment phase lies in the analysis of group user responses. After a group of users have gone through the scenarios, we can then analyze the areas in which users are most likely to make mistakes or knowledge areas in which users are most likely to overlook. Did the user, in the role of a doctor, ask the right questions? Did the user overlook an important clue in this situation? What clues did the users believe were the most influential in their decision-making?

Treating the choices as binary features (they have either chosen it or not) in a machine learning problem, we can find out which of the features are the most important in determining the users' correct responses. This is done through a technique in machine learning called feature selection. Feature selection is the process of choosing those features (independent variables) which contribute most to the prediction (dependent variable).

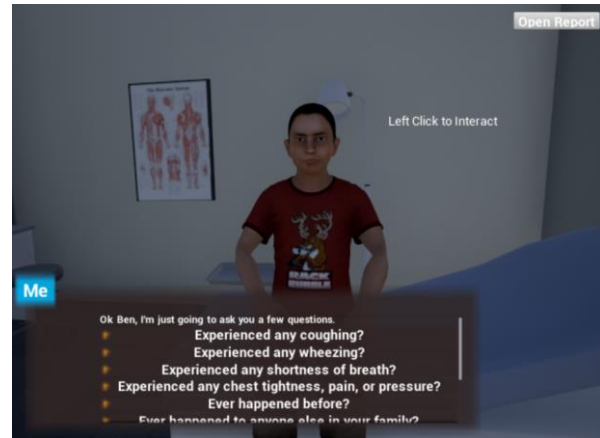


Figure 3: A sample set of questions a user can choose to ask Ben.

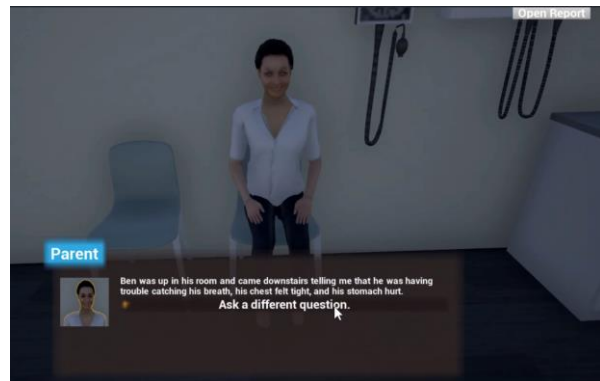


Figure 4: A sample response by the mom. Responses were provided by subject matter experts.

There are many existing feature selection techniques: wrapper methods such as recursive feature elimination, filter methods such as univariate feature selection, or embedded methods that perform feature selection and classification at the same time [7]. Since in our case, the features are binary, a recursive feature elimination method with a penalized logistic regression estimator is used to identify features that have the strongest relationship with the dependent variable. In recursive feature elimination, least important features are pruned from current set of features, one by one, and the algorithm recursively considers smaller and smaller sets of features.

We use a penalized logistic regression estimator to calculate the importance of a feature with regards to the final decision. This analysis shows the important questions and interactions in the question bank according to the group of users. These questions have a strong relationship with the result that the user made the right decision at the end. This information is useful for game designers in tailoring training modules for users.

4 Simulation Game Prototype

As part of the Knowledge Assessment, we built a serious game to assess the training needs of healthcare students and professionals regarding CPA in an interactive format. The scenario presents a simulated scene of an examination room with an adult guardian (mom) and a child patient (Ben) that speak realistically in such a scenario. The user assumes the role of a doctor. At various points in the scenario, the user makes decisions on what questions to ask based on the user's own judgement. In certain situations, signs and symptoms of CPA are visible on the child and during the interaction, but it will be up to the user to make the correct inference and follow protocol to report.

The game is created using the Unreal game engine. The two main programming languages used are Blueprints and C++. Blueprints is a visual scripting system by the Unreal Engine using an event-based interface to create and connect different interactive elements. C++ is used in conjunction with the Blueprints system to create additional capabilities such as file access.

As a user plays through the game, user interactions are collected and encoded in a trace file. In the scenario, the question bank contains 27 questions the user can choose to ask the mom and 23 questions for the child patient Ben. Each question is a binary choice for the user: ask the question or not. After the user chooses to ask a question, the responding character replies with answers written by our subject matter experts who are familiar with these scenarios. Some questions are unlocked according to questions already asked, based on preconditions. Figure 3 shows a subset of questions a user can choose to ask Ben at a particular instance, and Figure 4 shows a response given by the mom when asked by the doctor to describe the situation. There is also one interaction choice for the user (whether to conduct a physical examination on Ben with parent in the room). In total, there are 51 binary choices in this scenario.

5 Pilot Study and Results

We conducted a user study of the game prototype in an undergraduate population to evaluate the usability and functionality of the current user interface and the use of Knowledge Assessment to gauge user knowledge of CPA and mandated reporting procedures. The system should be:

1. Intuitive and easy to use.
2. Able to provide useful information on the knowledge of the groups of participants on the subject matter.

5.1 Participants

We recruited 100 undergraduate students as participants. They were asked to complete the game and a post-game survey. Participants were predominantly male (62.0%), between the ages of 18 and 37 ($M = 19.82$, $SD = 2.70$). The detailed breakdowns of the participants were 72.0% White, 6.0% Multiethnic, 15.0% Asian, 5.0% Black or African American; 2.0% Hispanic. The

majority (58.0%) of the participants were freshman (first year), with 22.0% sophomore (second year), 7.0% junior (third year), 8.0% senior (fourth year), and 5.0% other (beyond fourth year).

5.2 Results

From the post-game survey, we asked the participants to rate their comfort level with using the game interface, from 1 (not at all comfortable) to 10 (very comfortable). The result is a mean of 8.60 with a standard deviation of 1.64, showing that most participants had no issues with the interface. When asked to note down comments about the game, participants noted on the level of detail (e.g., branching question paths, patient chart, realistic), interactivity and ease of use as positive aspects of the game. Participants spent an average of 6.8 minutes in the scenario. In total, 80 participants (80%) correctly made the decision to "concerns about the child's safety or well-being."

We performed analysis on the user choices. From the question bank, the most frequently chosen questions to ask included:

- Asking mom "Does Ben have asthma?" (56 participants).
- Asking mom "Has this ever happened to anyone else in your family?" (47 participants).
- Asking mom "Do you have any pets at home?" (37 participants).
- Asking Ben "Do you have asthma?" (46 participants).
- Asking Ben "Has this feeling been getting better or worse?" (39 participants).

We compared the most frequently asked questions to an analysis using feature selection. We applied feature selection based on the responses of the 100 participants, and by recursive feature elimination, ranked the features by their importance (Figure 5). These most important features correspond to the questions:

- Asking Ben "Do you have asthma?"
- Asking mom "Do you know why he is having trouble breathing?"
- Asking Ben "Have you ever been to the ER before for breathing problems?"
- Asking Ben "How long have you felt this way?"

While the participants' interests in enquiring about asthma is a most frequently asked question, feature selection also provides new insights: this group of participants believed that asking detailed questions about the child's specific conditions were important, as these questions affected their final decision. This analysis is helpful for trainers in the creation of the subsequent training modules, as asthma was seen as a topic of concern for this group of students and the training modules should address the perceived differences in engaging with the child compared to the mom. For a different group of users, the resulting emphasis could be different. That is why conducting Knowledge Assessment is important.

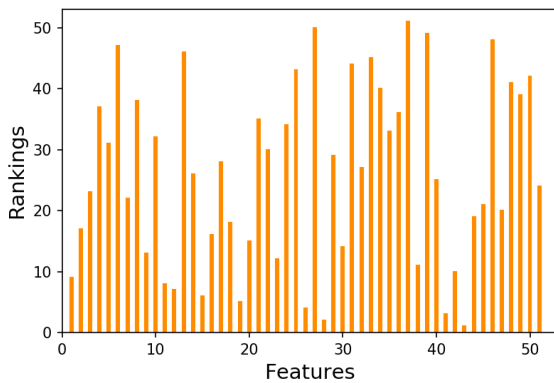


Figure 5: A visual representation of the rankings of the 51 features based on recursive feature elimination. Feature 37, which has the highest ranking on the graph, represents the question “Do you have asthma?”

6 Discussions

The Knowledge Assessment phase was completed in a short amount of time by participants. This suggests that a brief pre-training assessment likely would not negate the time saved by tailoring training to address areas of CPA weakness versus an untailored training.

Users reported a high degree of overall comfort with the use of the game. The resources needed to create the Knowledge Assessment game, such as the non-player characters and the environment, could be reused in the subsequent training modules, reducing the need for additional work.

CSI-CAST has a potential for having a broader impact beyond the current project to include national implementation with learners from various contexts (e.g., schools, social services, and child welfare). It could be distributed to all mandatory reporters in the U.S., and could be used worldwide in healthcare settings. The structures created could be used with alternative content or choices to serve different audiences (e.g., healthcare workers, teachers, university employees). The results obtained will contribute to broader knowledge domains of tailored learning and serious games as a proven model for online behavior change. CSI-CAST could also be useful in any industry that requires critical analysis and just-in-time decision-making such as child welfare.

For future work, we will examine the convergent validity between user decisions in the simulation and self-report measures of knowledge regarding CPA identification and mandated reporting procedures. Additional CPA scenarios will be created to foster a more intensive assessment and training simulation experience. The simulation prototype could also be improved with more realistic animations and voice acting to provide a more immersive experience. Future user studies will involve medical and nursing students.

The proposed game-based tailored assessment and training framework can be adapted to a broader range of educational games and be used to create new training programs, e.g., identification of child sexual abuse or intimate partner violence.

7 Conclusion

In this paper we present a framework for the process of creating tailored training aimed at specific groups of learners. By using a Knowledge Assessment phase, information about a group of users can be gathered and analyzed, and trainers can use this information to create training modules to address the users' specific knowledge deficiencies in the subject area. We create a serious game to simulate scenarios in which a doctor is in contact with a potential victim of child physical abuse. Through Knowledge Assessment, we identify important features in the group of participants that correlate with their final decision. This project has great potential for having a broader impact beyond the current context. It could have impact worldwide in healthcare settings. The results obtained will contribute to broader knowledge domains of tailored learning and educational game as a proven model for online behavioral rehearsal.

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