

Septtris and SICKO: Implementing and Using Learning Analytics and Gamification in Medical Education

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March 2014

- » To investigate the viability and application of gamification and learning analytics in medical education, Stanford School of Medicine developed two educational games: Septtris and SICKO.
- » The reception of gamification by learners was largely positive and widespread, and instructors found that data from learning analytics offer many potential uses and opportunities for studies.
- » Gamification has significant relevance and potential in medical education, which is very receptive to the application of simulation and technology in learning.

In recent years, the video game industry has become the leading form of entertainment in terms of global total revenue. In the United States, it surpassed the movie and music industries in 2005 and 2007, respectively, and in 2013, it is expected to exceed \$76 billion globally.¹ More than half of Americans (58%) play video games, with an average of two gamers in each game-playing household.² Forty percent of all gamers are female, and contrary to popular belief that only teenagers play video games, 49% of gamers are between ages 18 and 49.³ Only 25% of gamers are under 18, and 26% of gamers are over age 50; the average gamer spends 13 hours a week playing video games.⁴ This represents a significant and diverse demographic within one of the largest markets in the world, with a large interest in simulation-type games.

To investigate and capitalize on the growth of gaming and learning analytics and apply it to education, Stanford School of Medicine developed two educational games: Septtris and SICKO. Septtris (see Figure 1) and its successor, SICKO (Surgical Improvement of Clinical Knowledge Ops), are web-based educational games developed by a cross-disciplinary team of doctors, web developers, and instructional technologists.

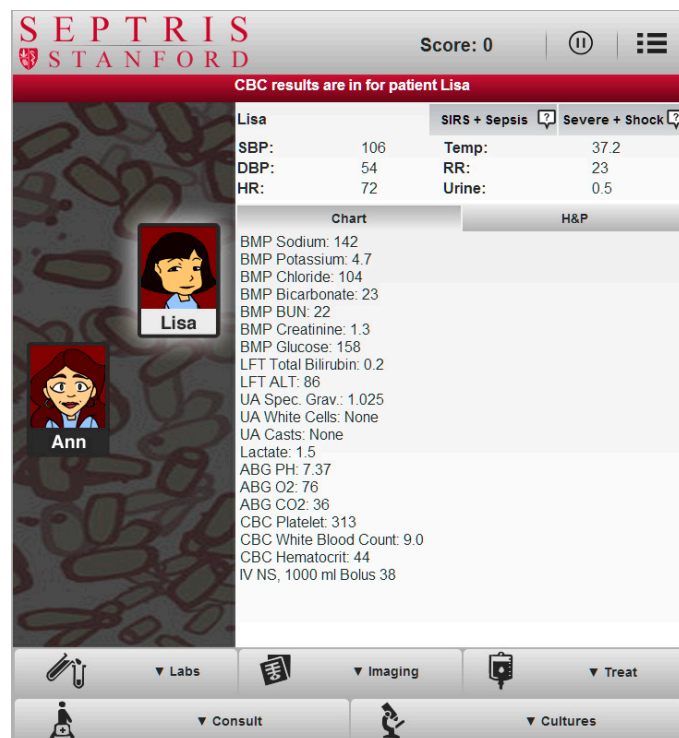


Figure 1. Screenshot of Septtris

The Educational Technology group at Stanford School of Medicine was initially approached by a group of physicians from the departments of medicine, surgery, and

emergency medicine to create a game playable on mobile devices to teach doctors how to identify and treat sepsis. Because 36% of gamers also play on smartphones⁵ (a number sure to increase), we chose to create a mobile-accessible game using the concept of a virtual patient simulator, which became Septris. We created Septris using JavaScript, HTML5, CSS3, and XML web technologies to ensure cross-platform compatibility and to reach as wide an audience as possible. Based on the success of Septris, a group of surgeons approached us to adapt the Septris platform—which became SICKO—to use for teaching and potentially assessing surgical decisions.

Septris was launched in January 2012, and SICKO was released in June 2013; both are freely accessible for anyone to play by visiting <http://cme.stanford.edu/septris> and <http://cme.stanford.edu/sicko>. Players also have the option of paying a fee to submit an application for CME (Continuing Medical Education) credit.

Implementing Gamification Concepts

Both Septris and SICKO feature a variety of gamification concepts, such as health points, damage points, actions/abilities, score points, a high-score board, levels, and real-time interactivity. In Septris and SICKO, learners (also referred to as “players”) play the role of a physician and must manage multiple virtual patients simultaneously. Each virtual patient in the games has dynamically changing vital signs based on a health level (health points, or “HP”) and an extensive case history. Patients have a continually declining health level (damage over time, “DoT”), and players must use their diagnostics to diagnose the patients and treat them accordingly (to improve the patients’ health levels—heal over time, “HoT”) before the patients die. “Attending physicians” Dr. Sepsis and Dr. SICKO provide feedback about the players’ actions, and lab results also have dynamically changing results depending on the patient’s health value.

In SICKO, the player has to complete three levels of cases with increasing difficulty, with more difficult cases worth more points. At the end of the game, Dr. SICKO may have a different expression of approval or disapproval depending on the player’s score, which can also be submitted to a high-score board.

Benefits of Applying Gamification Concepts

Because Septris and SICKO were built using web technologies, we were able to easily integrate player tracking and analytics. Games can generate an immense amount of player-specific data, which gives instructors the ability to study and analyze every decision and action that players make. This is conducive to studying the effectiveness of gaming in teaching⁶ and, for Stanford School of Medicine, allows for evaluating and investigating novel methods for ultimately improving patient outcomes in clinical and surgical care.

Whenever players perform an action, they have the potential to receive instant positive or negative feedback from Dr. Sepsis or Dr. SICKO, explaining why they should or should not have performed the action that they did. Players also receive bonus points for performing correct actions and for answering “pop quizzes” correctly; players lose points for incorrect or harmful actions. In SICKO, Dr. SICKO’s facial expression also changes depending on whether the action was correct or incorrect (with varying levels of incorrectness), which helps players form an empathetic connection with their virtual attending physician and also serves to reinforce the feedback and learning points (see Figure 2).

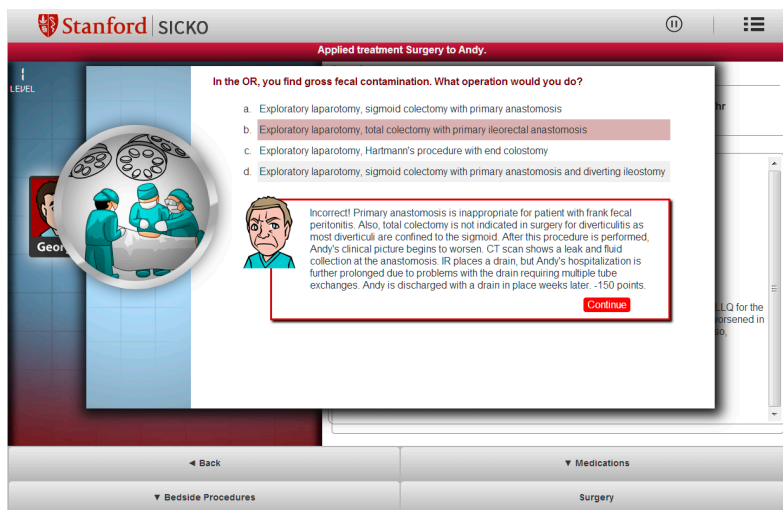


Figure 2. Screenshot of SICKO

SICKO features a new mini-game within the game itself, referred to as Surgery Mode. Surgery Mode is triggered when a player sends a patient to the operating room for surgery. While Surgery Mode is active, the rest of the game is paused to allow the player to focus on operating on one patient. The player is presented with a series of

multiple-choice questions that determine the fate of the patient. It can be likened to a case-based quiz, except that the player must have performed the proper workup and diagnostics to select the correct treatments. Immediate feedback is given to players after each answer they select.

Surgery Mode has the ability to support branching decision trees—the gaming analogue would be similar to a “Choose your own adventure” book/game. That is, depending on which initial decision the player makes in Surgery Mode, the subsequent choices can be very different. The fact that different diagnoses and operation choices can lead to very different operation sequences and outcomes is crucial to surgical decision making. We built this function into the game because we wanted to be able to support this level of realism and believed that it would also be a valuable feature to have when expanding the game to other disciplines. For example, an “ICU Mode” could be a potential expansion.

The most significant benefit of Surgery Mode is that the simulation can be customized for the actions of a specific player. In high-fidelity, real-life simulations, this can be difficult to do and almost impossible to scale. However, in a digital, gamified environment, the simulation can provide a personalized experience with competency-based feedback for thousands of learners.

In general, educational simulation games offer an immense amount of potential value, especially within medical education, which is very receptive to technology and novel ways of teaching. In traditional medical simulations, high-fidelity simulations can be labor-intensive and costly. Games like Septris and SICKO offer a less costly, lower fidelity type of simulation that can scale to reach larger audiences and be replayed multiple times. Furthermore, not only are they interactive and engaging, educational games offer a deeper insight into learners’ competency and decision making than does a traditional standardized test; that is, instructors can not only see what choice learners made but also what data they used to make their choice, as well as when they decided to make those choices.

Other Potential Gamification Elements

A few common gamification techniques were discussed but not implemented into Septris and SICKO due to project constraints. These include the concepts of badges/achievements and player levels. Septris and SICKO could

have improved “replayability” by adding player achievements—for example, an achievement for “Heal a patient before they reach septic shock” or for “Save Jack without using an ICU Transfer.” These achievements would encourage players to approach cases they have already solved using a different technique. And while SICKO introduced the concept of levels in that further progression in the game resulted in more challenging patient cases, there is no concept of a player level or rank. Introducing such a concept into the games would encourage players to try to maximize their scores, seek achievements, and replay the game to raise their personal player level. We plan to try to include these elements in potential future games.

Another gamification element discussed was randomly generated virtual patients based on a difficulty setting within the game (e.g., Medical Student level, Resident level, Attending level). This is an extremely complex feature that was discussed during the development of both Septris and SICKO, but it requires much further investigation, development, and testing before its viability can be proven. Proposed alternatives include crowdsourcing cases or setting up collaborations with other institutions to create cases.

Implementing Learning Analytics

We implemented player tracking using two different methods in Septris and SICKO. The first method was through Google Analytics (GA), which offered a quick and easy way to collect aggregate data on players and is built into both Septris and SICKO. The second, which was built into SICKO but not Septris, is a more comprehensive logging system that tracks players’ actions to a specific play session. This information is also visible to the users at the end of the game to serve as a “debrief” of their game-play session and can be saved for later analysis.

Google Analytics

By including a single line of JavaScript on the web pages of the games, we were able to collect a wealth of information about our players, including their location, their browser and system information, when they viewed the page, the device they used (e.g., iPad versus Android mobile devices), and more. However, we wanted to collect more specific detail about how our players were playing the games.

To do this, we used a feature of GA called Event Tracking, which can be used within the JavaScript to collect four levels of information: a category, an action, a label, and a value. We used all four levels for our event tracking data.

For Septris and SICKO, we set the category to patient names (and a general “Septris” or “SICKO” category for non-patient actions, such as starting the game, finishing the game, submitting an application for CME credit after finishing the game, etc.). We then set the action to the name of the treatment or diagnostic that they performed, and then we set the label and the value to the health value for the patient at the time that the action was performed.

By using event tracking, we were able to track which patient an action applied to, the action that the player took, and the health value of the patient (how “sick” the patient was) when the action was applied. This allows us to see in aggregate what kinds of actions players are performing on the patients, especially with respect to identifying common pitfalls (e.g., diagnostics/interventions that are given that are unnecessary or incorrect) and areas of improvement (e.g., diagnostics/interventions that should be given earlier).

Custom Action Log

While the GA tracking feature was quick and easy to implement, it lacked the ability to track an individual player’s decisions in chronological order. For example, you could see that players in aggregate gave 1L of IV NS to Jack 1,200 times, and that players ordered blood cultures for Jack 890 times, but with GA you cannot determine whether players ordered cultures first or gave fluids first.

Because the order of operations is especially crucial in surgery, we built a new feature for SICKO to track all of a player’s actions in what we call an Action Log, which includes several pieces of information: what action they performed, when they performed the action (in “game time”), which patient they performed the action upon, the health level of the patient at the time of the action, and their current score at the time of the action (see Figure 3).

Elapsed Time	Patient	Action	Health	Score
0	--	Level Started	--	0
12	Andy	Lab: Physical Exam	247	0
14	Andy	Lab: BMP	246	0
15	Andy	Lab: CBC	245	0
16	Andy	Lab: Lactate	245	0
17	Andy	Lab: UA	244	0
22	Andy	Lab: Abdomen/Pelvis CT	241	50
32	Andy	Treatment Applied: Surgery	237	50
35	Andy	Patient Fadeout	237	-100
52	--	Game Over	--	-200

Figure 3. Player Action Log

Furthermore, we added a tracking feature for all the decisions that a player makes during Surgery Mode. This feature tracks when the player answered the question, which patient they answered it for, which question it was, which answer they chose, whether it was correct, and how many points they received (or lost) by making that answer choice (see Figure 4).

Elapsed Time	Patient	Question	Answer	Correct?	Score
35	Andy	In the OR, you find gross fecal contamination. What operation would you do?	b) Exploratory laparotomy, total colectomy with primary ileorectal anastomosis	F	-150
37	Andy	What is the distal extent of your sigmoid resection?	b) Normal colon 5 cm beyond the grossly inflamed segment of sigmoid	F	-100
39	Andy	The inflammation is severe and halfway through the case, you realize that there is a 2 cm segment of the distal left ureter missing. What do you do?	c) Mobilize the kidney and perform a transuretero-ureterostomy	F	-100
40	Andy	Say you find a colovesical fistula while performing an elective resection for sigmoid diverticulitis. After taking down the fistula, there is a 1.5 cm defect in the bladder. What operation would you do?	c) Hartmann’s procedure and leave the bladder defect alone	F	-100
44	Andy	All of the following patients should undergo surgery except:	c) 81M hospitalized with new localized LLQ pain and CT scan revealing sigmoid wall thickening without perforation or abscess formation	T	200

Figure 4. Player Surgery Mode Answer Log

All of the information from the in-game actions and from the Surgery Mode are recorded continuously throughout the game and are made available to the player at the end of the game to review and debrief with an instructor. The data can also be submitted to the SICKO research team for further aggregate analysis and research.

Benefits and Applications of Analytics Data

The GA web interface allows you to drill down and filter by any of the levels, so you can easily see which actions were performed on which patients and at what health level the player performed the action (see Figure 5). This feature allows instructors to see which actions/diagnostics were most commonly used on specific patients and identify common mistakes that players make. These common mistakes can then be addressed with additional feedback built into the game or with other teaching methods (such as with a focused didactic lecture).

Because the games also include a score feature, instructors are able to approximate the skill and knowledge level of the audience playing the game (see Figure 6). GA allows you to filter data by date, so further analysis can also be done to study the change of scores over time, which may also be correlated with improvements in learner knowledge

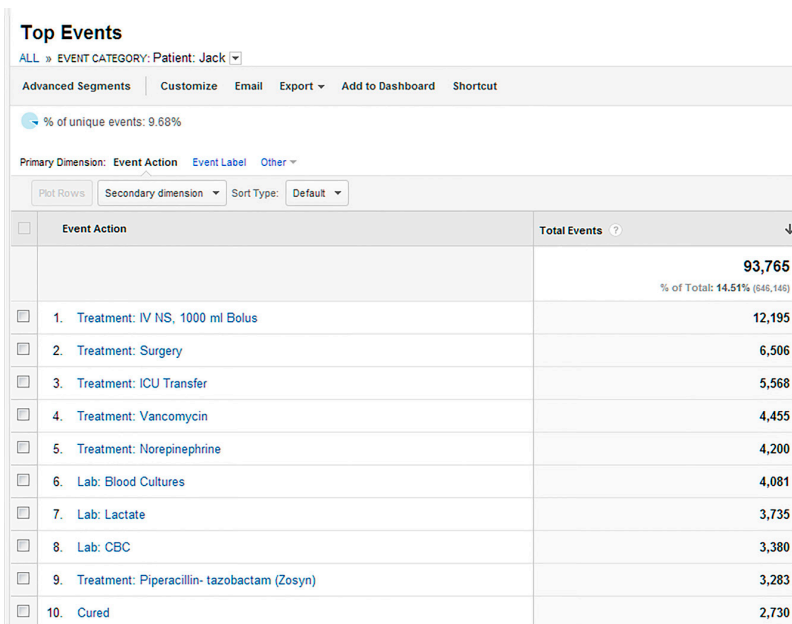


Figure 5. Google Analytics Interface

and potentially linked with improvements in mortality rates and patient outcomes.

For SICKO, we wanted to add tracking to players' performance on Surgery Mode because it uses Surgical Board-style questions relevant to the virtual patient's case. Thus not only does it serve as a study tool in preparation for surgical board exams, but it can also provide insight on how prepared individual learners are prior to the exams and help the instructors identify areas of weakness that the game can try to address via instant feedback within the game.

Learners are not only able to debrief on their performance by reviewing their action and answer logs, but they can also save and compare their logs to those of other players if they choose. Instructors can also review a player's logs to identify areas of weakness and

provide separate, personalized feedback to the learner.

Reception of Gamification and Analytics by Learners and Instructors

Reception of Septris was immediately positive, and usage was widespread. Within one year of its launch (January 2012 through January 2013), the game received more than 32,000 visits, with 16,700 plays and 2,500 completions of the game. Also, while 55% of hits were direct/organic, the other 45% of hits came from referrals. The most popular site for referrals turned out to be Facebook, which was responsible for more than 25% of all referrals, indicating that social sharing can be a significant driver of traffic even for an educational game. Septris was also positively reviewed on a variety of medical blogs, which helped drive traffic to the game.

Although the game was originally created with continuing medical education and current practitioners in mind, it was also trialed with pre-clinical medical students, clerkship students, and residents. Overall response from learners was positive, and further studies with other learner groups are pending. Learners especially liked the score feature, which induced natural competition between them and encouraged replay.

The value of analytics was readily apparent in Septris, but due to budget and time constraints, the functionality was not as complete as desired. For example, we were unable to track precise demographics on the players, such as their education level, profession or field of specialty, age, and other potentially useful data. While aggregate data on performance and usage is valuable, data on individual performance is much more so. SICKO was developed with these weaknesses in consideration and, along with the Action Log, players can submit personal demographic information (age, gender, role, type of surgical specialty, number of years of experience, and community vs. academic practice) to improve the quality of the data recorded. Although SICKO was released more recently than Septris (in June 2013), the SICKO team already has many use cases and research opportunities in mind for the personalized learner analytics.

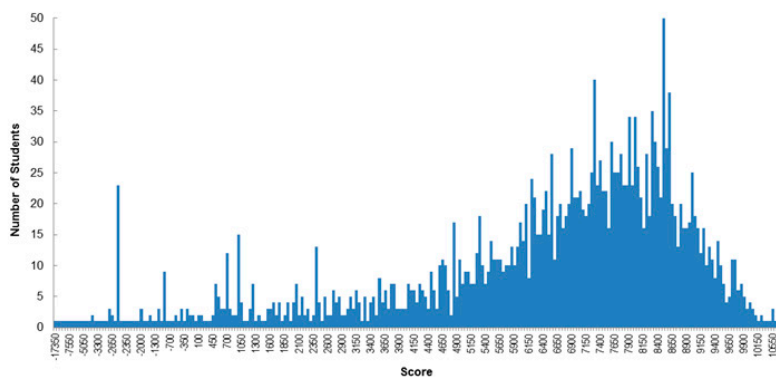


Figure 6. Distribution of Septris Scores upon Game Completion

Future Directions and Discussion

Based on the demand from learners for more interactive teaching styles from instructors, and based on improvements in technology and accessibility, gamification stands to be a potent and attractive tool in education, especially when combined with blended learning (or the flipped classroom model). Septris and SICKO were built with this type of customization and expansion, which should be thought of as tools for instructors and educational technology teams to apply to their own learning needs.

For example, at the most basic level, learners can play Septris or SICKO—as a counterpart to an online video didactic—in the classroom individually or in teams to work with each other on solving the cases. At a higher level, learners can discuss in the classroom how cases could be improved or changed, such as by adding or removing complexity by changing the list of available interventions or diagnostics. Discussion could be oriented around which interventions and diagnostics are necessary and which are optional, or about how the patient cases in the game would respond to new, different interventions. At an even higher level, learners could collaborate on designing cases that would be implemented into the game for their peers to play and critique. The course would partner with an educational technology team to translate the cases into XML to be added to the game. After these cases are played by peers in the classroom, the instructor can then facilitate a discussion on each group's experiences.

The original Septris/SICKO cases were constructed by experienced teams of practicing doctors and nurses from various specialties. As cases were debated, these clinicians learned about and debated the details of how these cases should work, relative to real-life scenarios, revealing differing best practices and knowledge that prompted discussion and learning. This demonstrated that even practiced clinicians can be both learners and instructors while working together to develop cases for the games.

Simulation games such as Septris and SICKO can also be applied to hospital risk management. Real-life patient cases can be re-created as a virtual patient in the game and then used by risk managers to assess service providers' performance on past or potential cases. Decisions made by service providers

in these scenarios can be deconstructed and analyzed to improve patient outcomes and reduce mortality and liability. These games can also be deployed institution-wide to test for compliance and consistency of institution policies and best practices.

Gamification combined with learning analytics can also stand to replace traditional exams and may potentially serve as a form of standardized testing. Gamified assessments can serve as an improved alternative to the typical multiple-choice assessment, which already faces much criticism over its tendency to narrow the curriculum and coerce students and teachers to study/teach “to the test.”⁷ Standardized testing has also been heavily criticized for being a poor measurement of educational quality,⁸ to which gamified assessments may provide insight as more data can be collected.

Demand for novel teaching methods that work in conjunction with blended learning is on the rise, and we expect to see gamification applied to more concepts, especially simulation. Furthermore, gamification is often conducive to producing valuable data, which can be readily used in research studies (in particular, “big data” studies). We will be exploring and conducting these studies in more depth in the future.

Notes

1. “Video Game Industry: Market Research Reports, Statistics and Analysis,” ReportLinker, <http://www.reportlinker.com/ci02073/Video-Game.html>.
2. Entertainment Software Association, “2013 Sales, Demographic and Usage Data: Essential Facts about the Computer and Video Game Industry,” http://www.theesa.com/facts/pdfs/ESA_EF_2013.pdf.
3. Entertainment Software Rating Board, “How Much Do You Know About Video Games?” <http://www.esrb.org/about/video-game-industry-statistics.jsp>.
4. Mike Sharkey, “NPD Group: Extreme Gamers Spend 48 Hours a Week Playing Videogames,” GameSpy, May 27, 2010, <http://www.gamespy.com/articles/109/1093408p1.html>.
5. Entertainment Software Association, “Game Player Data,” <http://www.theesa.com/facts/gameplayer.asp>.
6. Lisa Shieh, Eileen Pummer, Jamie Tsui, Brian Tobin, and Kambria Hooper, “Increasing Knowledge of Sepsis Recognition and Management through a Mobile Educational Game” (presentation at the 2012 AAMC Annual Meeting, November 2–7, 2012, San Francisco, CA), https://aamc.expoplanner.com/index.cfm?do=expomap.ssessAbstract&event_id=2&abstract_id=138&session_id=1582.
7. Louis Volante, “Teaching To the Test: What Every Educator and Policy-maker Should Know,” *Canadian Journal of Educational Administration and Policy* 35, (September 25, 2004). <https://umanitoba.ca/publications/cjeap/articles/volante.html>.
8. W. James Popham, “Why Standardized Tests Don't Measure Educational Quality,” *Educational Leadership* 56, no. 6 (March 1999): 8–15, <http://www.ascd.org/publications/educational-leadership/mar99/vol56/num06/Why-Standardized-Tests-Don%27t-Measure-Educational-Quality.aspx>.

Appendix: Google Analytics Implementation

Google Analytics offers an easy method for integration: simply add a snippet of JavaScript to the top of your page (the JavaScript snippet changes occasionally; see <https://support.google.com/analytics/answer/1008080> for the latest implementation), include your GA account ID number (it resembles “UA-#####-#”), and you are ready to begin tracking. The most basic feature is the simple page tracking, which we include on every page.

Page view tracking JavaScript snippet:

```
_gaq.push(['_trackPageview']);
```

We also track “Events,” which are typically triggered by a click on an element on the page.

Event tracking JavaScript snippet:

```
_gaq.push(['_trackEvent', 'Patient: ' + patient.name, 'Treatment: ' + name, 'Health: ' + patient.health, parseInt(patient.health)
]);
```

Custom “Action Log” Implementation

We also built our own analytics tracking functions to supplement the data recorded by Google Analytics. We wanted to track, in more detail, personalized player data specific to a play session.

Action tracking JavaScript snippet:

```
function PushLogEntry(patient, event_name, health, score ){
    var time = parseInt((prevTime-LogStartTime)/1000.0);
    _log.push(new Entry(time, patient, event_name, health,
        (score)? score : PointScore))
}
```

We also wanted to track players’ choices during Surgery Mode.

Answer choice tracking JavaScript snippet:

```
function PushORLog(patient, question, answer, correct, points)
{
    var time = parseInt((prevTime-LogStartTime)/1000.0);
    _orLog.push(new ORResponse(time, patient, question, answer,
        correct, points));
}
```