Introducing the Biometric Storyboards Tool for Games User Research

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***Abstract*—Evaluating and communicating affective user experience in games is an important component of the growing field of games user research (GUR). An important goal for the game industry and researchers alike is the successful unification of physiological measurements and player experience reports to generate meaningful insights, which is challenging due to the varying natures of the data. In this paper, we present a tool that facilitates GUR with a method called Biometric Storyboards (BioSt). The tool allows GUR professionals to visualize relationships between changes in a player's physiological state, a player's self-reported experience, and in-game events. This paper focuses on the BioSt development stages and the final BioSt tool that we present to facilitate the creation implementation of BioSt and its analysis procedure.**

Keywords— video games; user experience; affective evaluation; games user research; games design; physiological evaluation

I. INTRODUCTION

Games user research (GUR) traditionally relies substantially on self-report measures and behavioural observation to investigate player experience within video games. Novel methodologies, such as physiological signal recording during gameplay, have been introduced to provide more objective and covert indications of player emotions without interrupting the gameplay experience. Affective physiological player evaluation in GUR involves measuring the electric potential on the surface of the skin to make inferences about muscular activity, brainwaves, arousal, and general emotional activity [1, 2]. The problem that inhibits broad industry adoption of physiological measures is that – due to their high temporal resolution – they produce large amounts of data which are hard to analyse within the short iterative development cycles of game companies. If applied, the GUR methodology requires the use of physiological measures in conjunction with subjective measures such as player interviews or questionnaires, because the physiological data alone is often not meaningful enough to interpret a gaming situation.

A goal of our novel GUR tool, called Biometric Storyboards (BioSt), is to facilitate the analysis of physiological data and provide qualitative annotation capabilities that would allow players to comment on the physiological data gathered during a gameplay session. Together with a designer-drawn player experience graph, this allows a triangulation between designer intention, player experience, and player emotional responses to create and visualize a meaningful data set for improving game design. We use physiological measurement of players as well as their post-gameplay comments regarding game events to illustrate a meaningful relationship between changes in a player's affective state and their gameplay experience.

Since the volume of physiological data is hard to explore, because of the large amounts of data collected, we have chosen to adapt a visualization approach that allows a comparison between participant-created storyboard visualizations (from their post-gameplay comments) and physiological data visualizations (often using graphs that show the increase or decrease of physiological activity over time). In addition, BioSt uses this visual narrative to allow easier interpretation of the mixed-method data. Making meaningful connections between self-reported player experience narratives and measured arousal is an important step for increasing acceptance of physiological measures in the GUR field.

We have developed the BioSt visualization tool in four phases over the last four years:

1. We refined the initial idea in iterations while conducting three case studies in collaboration with game development studios. [20]
2. We presented the early BioSt prototypes to game developers and interviewed them about the advantages and disadvantages of this GUR technique. [21]
3. We evaluated the final prototype and improved the design based on the game designers' feedback [22].
4. We developed the final tool together with game programmers and independent game developers.

The key purpose of this paper is to describe how the BioSt method and **tool** were developed (phase 4). This an important contribution to the GUR field because it allows faster analysis of highly complex and interrelated mixed-method data from quantitative and qualitative sources suited for the short turnaround cycles of game development companies. After delivering a summary of related literature, we present an overview of results from the first and second phases in our design process (see [20, 21] for a comprehensive review of these stages). We then discuss our final prototype based on our

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evaluation results and provide in-depth development details on the BioSt visualization tool that supported the iterative design discussed in our previous publications [21, 22].

II. Related Literature

Storytelling is at the heart of the human experience. User experience (UX) researchers have leveraged the power of storytelling to drive observation-based and focus group research for improving website and interface design, which has been discussed in depth in the web development design community [3, 4]. In our approach, we use stories that describe and communicate player experience aspects to the game development team.

Within video game development, GUR uses traditional research methods from, for example, human-computer interaction (HCI) [5, 6, 7]. A classic approach involving the observation and interviewing of players is common, but recently, data logging and structural analysis have become essential parts of the GUR toolbox. For more information about this, Pagulayan et al. [6] provide an excellent review of GUR challenges that game development studios face. Physiological measurements are becoming more integrated in GUR and game development studios [8]. Common physiological measures include galvanic skin response (GSR), facial electromyography (EMG), cardiac interbeat intervals (IBIs), and electroencephalography (EEG). A comprehensive review of the current state of physiological game research as well as the advantages and limitations of physiological measures was chronicled by Kivikangas et al., [9]. Another comprehensive introduction to using physiological measures as part of GUR is available from Nacke [10].

Common physiological approaches distinguish analysis on a temporal dimension: Studying physiological and behavioural responses at game events (points in time) [11] and studying averaged physiological responses to variations in game variables (over a time span) [12]. For example, Mandryk [13] described experiments that tested the effectiveness of physiological measures for evaluating collaborative entertainment technologies by examining physiological responses to different interactive play environments. Hazlett [14] describes the use of facial EMG as a measure of positive and negative emotional valence during interactive experiences. In addition, Ravaja [15] measured facial EMG and IBI in addition to self-report ratings to index physiological arousal and emotional valence. Nacke et al. [2] created a real-time emotional profile of gameplay (with a focus on flow and immersion) by measuring EMG and GSR. Their results demonstrate the potential to provide real-time emotional profiles of gameplay that may be correlated with self-reported subjective descriptions. Yannakakis et al. [16] correlated psychophysiological and subjective measures of emotional components of the player experience. Tognetti et al. [17] used physiological data to recognize user enjoyment in a car racing game and Drachen et al. [1] report a case study on GSR and heart rate (HR) correlations with player gameplay experience in a First-Person Shooter (FPS) game.

Fairclough [18] provided an extensive overview regarding fundamental material for physiological computing systems and the development of physiological computing in HCI. Generally, the often-described ‘many-to-one’ relationship between psychological processing and physiological response allows for physiological measures to be linked to a number of psychological structures [10, 19]. As a caveat, it should be noted that players may potentially become emotionally aroused not because of specific in-game elements or events, but as a response to an external activity, anticipation, or as a result of something not otherwise observed.

III. Summary of the Early Prototypes

Early prototype development (phase 1) helped us in identifying several core features of the tool, such as which data we would aim to gather and our vision for the appearance of the tool and its associated graphical applications. Since game developers are the target users of this tool, we explored their requirements for the effective use of such a tool and their methodologies for interpreting data. Before we explain the final BioSt tool, we would like to discuss our earlier prototypes.

The initial idea for BioSt was to capture a player’s physiological measurements (we started by capturing GSR) and use the player’s post gameplay comments to annotate and explain changes in their GSR during gameplay. Initially, the point of these annotations was to reduce the danger of over-interpretation of the physiological data by researchers or game designers. This idea has been refined over three years of evaluation with game studios. The BioSt design went through three iterations based on three case studies with two game design studios and the feedback from two producers that used this technique during the development of their game. We developed our prototypes based on these case studies and the feedback we received from the game producers. BioSt uses a graphical annotation utility to juxtapose the player’s subjective experience with objective physiological measures. We drew the following graphs based on (1) a player’s physiological arousal signals (GSR), (2) player post-session interviews to explain why the change in their GSR occurred, (3) players’ self-drawn diagrams of their gameplay experience and (4) our own observations of gameplay behavior (or contextual influences).

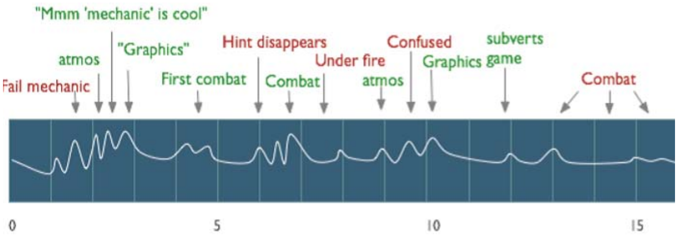

Fig. 1. BioSt first graph prototype [21].

In our first attempt, we divided the experience graph evenly over intervals of time to make the graph meaningful for game designers interested in pacing (Fig. 1). Each vertical block represents one minute of gameplay; positive comments are written in green and negative in red. Feedback from a game producer suggested that this design of the BioSt graph was difficult to compare between players. Standard time intervals are not always meaningful for games, and beats (or thematic game areas) were considered as more representative of level

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areas that a player encounters, shown in the example graph from the second prototype (Fig. 2).

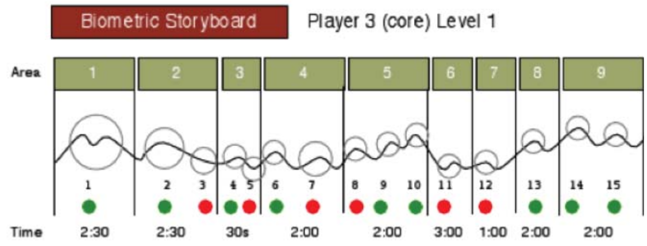

Fig. 2. BioSt second graph prototype [21].

The main differences in the second prototype are: 1) each level was divided into thematic areas, as this makes the key sections easier to compare; it also shows the amount of time taken by a player to complete that area. 2) Green or red dots show the positive or negative experience.

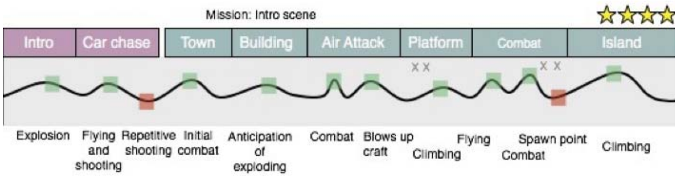

Fig. 3. BioSt third graph prototype [21].

The third prototype (Fig. 3) makes the diagram easier to read and connects behaviour (the text along the bottom) with the associated player experience graph. This iteration of BioSt was refined based on further comments from game producers. Their comments suggested that the experience graph should go down (negative gradient) to indicate negative player experiences, in order to better represent the emotional change, and in order to better draw attention to and isolate the negative experiences. Secondly, the game producers reported difficulty in pinpointing the exact moments highlighted by the red or green dots, which were key to providing context and establishing cause and effect in a game section.

IV. DESINING THE BIOST TOOL

In phase 2, we conducted semi-structured interviews to better understand our requirements and target group for future development of BioSt. We interviewed six game development professionals from midsize game design studios. None of the interviewees had seen BioSt before. The results from these interviews suggested the following major advantages and possible improvements for BioSt:

Locate and prioritize gameplay issues: Location of issues in each level is an important factor for the prioritization of their repair. By showing the exact location of the issues, BioSt helps developers to prioritize the revision process.

Identify a problem: The developers do not want user test (UT) reports to suggest a solution on the remedy of an issue. For them, the ideal report would be a combination of text explaining the nature of the problem as well as a brief gameplay video of the player experiencing the problem.

Facilitate discussion: Our interviewees were from different positions in game studios, yet they all felt that BioSt would be helpful for them. They also mentioned that BioSt would provide useful information to publishers and studio executives.

Trust: Trust is a vital matter for UT reports. Developers needed to trust the data from BioSt, so that they can act on issues that many players are facing. If they understand how the visualizations on BioSt are generated, they will trust the results.

Compare to intended experience: The interviewees mentioned that they already use some variety of storyboard depending on the game they are developing, for example, a sketched graph of intended emotional states for players. BioSt could make it easier for developers to compare the player's experience with the experience which they intended to design.

The prototype evaluation results helped us to better understand game developers' needs and requirements. We included these considerations in the development of the BioSt tool.

A. *BioSt Tool Feature List*

The developer feedback we received fundamentally allowed us to generate a necessary feature list (phase 3) for the BioSt tool.

Composite graph instead of individual: Our prototypes visualize how each individual player experienced a game. Based on our interview results, this can lead to two problems: (1) too many individual graphs for developers to look at and (2) showing how one individual player experiences a game does not convince developers to act on the issues. A composite graph addresses these issues by building a single graph which accumulates the information from all players.

Severity: The developers want a tool to help them to prioritize the resolution of game-related issues. While BioSt facilitates this in some ways (e.g., showing the location of an issue), it could also indicate the severity of each issue. For example, the skin conductance level among participants at a specific event could indicate severity.

Interactivity: The developers wanted BioSt to be interactive. For example, enabling a mouseover on each point in the graph to obtain a description, or the ability to click on each area to zoom in and see comments from different players or watch a clip of their gameplay video indicating the specific problem being examined by the developer.

Comparing Graphs: Developers want to see their intended experience graph in BioSt, or a graph that can show the difference between intended and actual experience. We have added a feature to the tool to enable the designers to create their intended experience graph.

Measuring different experiences: Our interviewees suggested that the high/low (green/red) arousal indicators on the current graphical design do not provide sufficient information. In order to produce a more complete picture of player emotion, we have added facial EMG to properly approximate emotional valence in addition to arousal.

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B. *Measuring Physiological Data*

In phase 4, we used a *NeXuS-10 MKII* (*MindMedia*) to record physiological signals and developed our own recording software using the *NeXuS SDK* to collect raw data from the device and display the recording timestamp on the computer screen (timestamp display enabled mapping between the physiological data and in-game events). Electrodermal activity (EDA), also known as skin-conductance level (SCL) or galvanic skin response (GSR), is a common psychophysiological measurement. EDA is regulated by production of sweat in the *eccrine* glands, where increased activity is associated with psychological arousal. Electromyography (EMG) describes the measurement of electrical activation of muscle tissue. Facial EMG is used in detection of emotional valence. Based on prototype evaluation, we recorded skin conductance level (SCL) changes (indicating changes in player's arousal level) and facial EMG at zygomaticus major (smiling) and corrugator supercilii (frowning) muscle locations as an indication of change in player's emotional valence level.

Once run, the program asks for a participant ID (to name the raw data file and analysis output file). The program then aims to connect to the NeXus. On successful initialization, the raw data file is created (and labeled), the device started, and the thread signalled to begin recording the raw data with its timestamp. At this point the raw data is being recorded into an array and written to the raw data file as the program runs (at 60Hz). For every recorded line of raw data, the counter variable is incremented by one, from 0 to (n – 1) where n is the number of raw input lines recorded.

As the data is recorded, the raw value of each channel in use (in our case C, D, and E) can be analyzed and compared to the previous minimum (min) and maximum (max) values where the starting min and max are the highest and lowest values respectively that a floating-point is capable of storing on the hardware. On a safe exit, the program will create the output file, run post-processing on the data, and save the results.

We measured SCL using passive GSR sensors attached to medial phalanges of the ring and little fingers on the player's left hand. The raw data collected from NeXuS Auxiliary Channel (E) are in millivolts (mV). These values have to be converted to microsiemens (µS) to reflect measurements comparable with the existing research literature. The listing below shows a formula provided by MindMedia:

```
GSR (kOhm) = output value (mV) * Amplification + Offset

SC (uS) = 1000/GSR

Amplification = 1.38

Offset = 4.3
```

Once the above signal conversions are completed, we can start analyzing our data. The next step is to normalize the SCL values [14]. Here is a sample MATLAB code used to calculate the normalized value:

```
MaxSC = max(SC);

MinSC = min(SC);

SC_Normalized = 100*(SC - MinSC)/(MaxSC - MinSC);
```

EMG activity was measured using passive EMG sensors attached on the player's cheek and forehead as well as a ground sensor on the ear lobule shown in (see Fig. 4).

Fig. 4. Application of EMG sensors [19,22].

The raw data was analyzed to indicate muscle activation in corrugator and zygomaticus muscles. We followed an analysis approach described by Hazlet [14], where we consider a muscle significantly active if the signal was above a threshold value of total sample average (M) plus total standard deviation (SD). After calculating the threshold values for both muscles, thresholds were compared to each sampled EMG value. If the sample value was above the threshold, the measuring muscle was noted as active at that moment. This was stored as a Boolean value for each time step. (If the current processed value is greater than or equal to the cut-off, then record `true`, else `false`, represented as `1` and `0` respectively.) Here is an example MATLAB code for this calculation:

```
[a b] = size(EMG_C);

for i = 1:a

if EMG_C(i) >= THRESHOLD

   EMG1(i) = 1;

else

   EMG1(i) = 0;

End
```

C. *Output Text File*

The post-processing described in the above section generates a text data file that is then imported by the BioSt tool (see next section). The output text file contains the frame counter and filtered data for the recording channels. Each frame counter is assigned a normalized value of SC data and a Boolean value for each of the EMG channels above the threshold. This is an example of the output text file structure:

```
SC (E), EMG1 (C), EMG2 (D), COUNTER

56.277, 1, 0, 4610

56.881, 0, 0, 4670

57.458, 0, 0, 4730
```

V. THE BIOST TOOL

The tool (phase 4) was developed in the Unity game engine for maximum portability and to allow the interfacing of game data collection in any game developed with Unity. The purpose

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of the tool is to visualize user test data collected during a GUR session and combine them. These data include: the game designer's intended player experience graph, a player's GSR and facial EMG measurements and a player's post-gameplay comments. The tool allows the designer to focus on aspects that they are looking to improve in their game. This is later compared with GSR, EMG, and player feedback for the GUR professional to create a graph that represents all of the information.

A. Designer's Intended Experience Graph

The designer's graph is where the intended user experience is drawn manually by the game designer. The tool allows designers to add beats (representing gameplay sections). These beats can be labelled with an appropriate name (see Fig. 5).

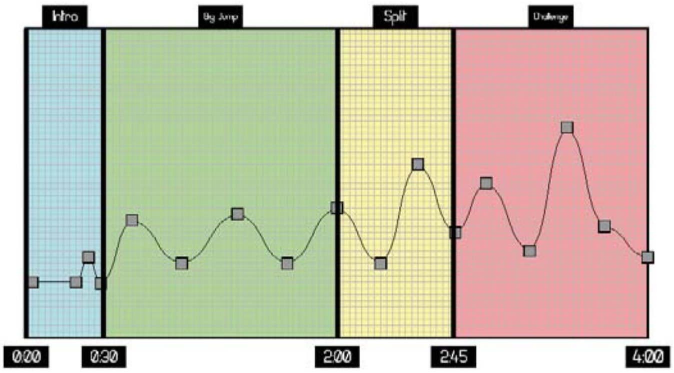

Fig. 5. Example of designer's intended experience graph drawn in the BioSt tool.

Time steps are indicated on the bottom of the graph. Graph nodes represent key points in the user experience, indicated as high or low to suggest a highly engaging or less engaging experience. When the designer is finished with their annotation, a save button allows storing the information for later use in the GUR view.

B. Player's Input

After a play session, the player's comments can be recorded. This information is entered by the Player in the input screen (see Fig. 6).

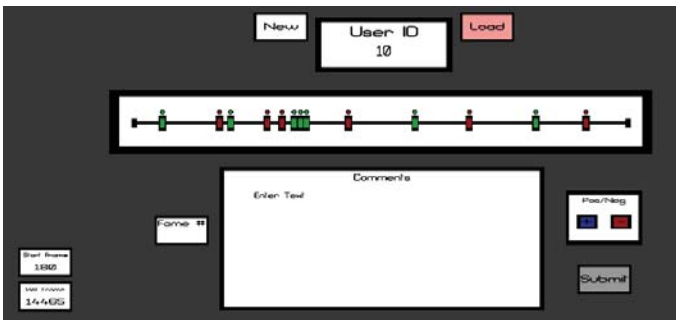

Fig. 6. Player's Input screen.

Here the player enters their unique ID, which will either load a previous session or create a new account. Then, the player reviews their gameplay footage and stops whenever they remember a change in their gameplay experience. To begin, the start and end frame of the recording are entered into the tool. This allows the triangulation of input data with the biometrics. Players then select the frame on the video where they would like to comment on their experience. They enter the comment and give either a positive or negative indication of their emotional state at the selected frame.

C. GUR view

The GUR view is where the BioSt tool triangulates the player's biometrics and comments with the designer's intended experience graph and allows the researcher to create a homogenized graph representing all of the data. Each player's data is viewed individually and is accessed by entering the player ID on the left-hand side. Here it displays the EMG (with percentages) and GSR data as well as the comments from the user (see Fig. 7). The middle of the figure shows a red/green bar indicating two different types (green = smiling and red = frowning) of EMG activity.

Fig. 7. GUR screen view. In the middle: green bars indicate periods of smiling EMG activity and red bars indicate periods of frowning EMG activity.

To facilitate quick data comparison, the designer's graph is always displayed at the top of the GUR screen. The researcher's graph (see Fig. 8) is located at the bottom and has the same functionality as the designer's graph, allowing the addition of beat nodes and saving capability.

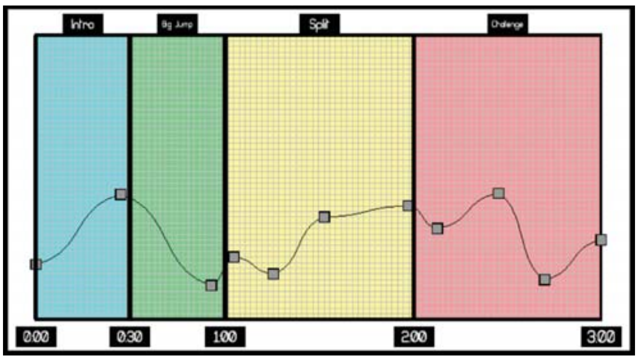

Fig. 8. Researcher's experience graph.

Analysed EMG data is loaded from a file and the placement of its visual indicator (the red/green bar) is determined if the Boolean value is 1 or 0 (based on passing an EMG threshold as done by Hazlet [14]). If the value is 1, its place and length are determined until a zero is read (meaning that the EMG activity

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is not over the minimum threshold) or the end of the file is reached. Two separate entries are used to determine positive or negative readings. Normalized GSR is read from the file as a value between 0-1. The y-value and the x-value are scaled to fit the width of the graph (see Fig. 9).

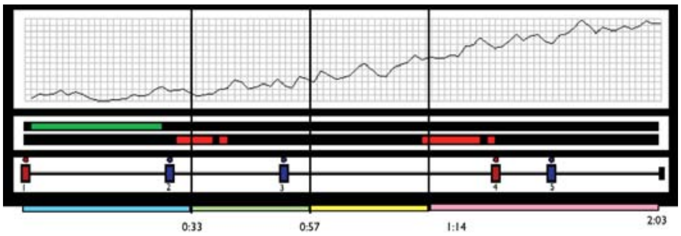

Fig. 9. GSR and EMG data.

The tool is also able to calculate the overall positive or negative feeling of each level and show it in the form of a percentage; this feature would be useful if we needed to compare an overall experience between conditions (such as different levels) (see Fig. 10).

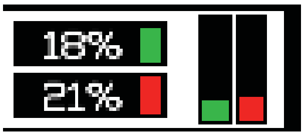

Fig. 10. Percentage of smiling (green) and frown (red) muscles activity over the course of one level.

VI. DISCUSSION

The BioSt visualization tool presented in this paper has the potential to make previously difficult-to-interpret physiological GUR data more accessible to the wide audience of the game industry. Some of the key strengths of the BioSt method and the presented tool are:

Correlation between physiological responses and gameplay events: Visualizations of players' physiological responses and gameplay events are helpful to understand and explore correlations of physiological responses and the corresponding gameplay events. For example, we saw BioSt being used to explore behaviour of several players during a single game event. Understanding how players are motivated to perform particular tasks in gameplay environments is a vital tool for game designers.

Comparison of players' behaviour: Once we have created a series of these BioSt analyses, we can compare the gameplay journeys of different players and use them to spot key trends in gameplay behaviour. Further studies may show that a player's background profiles and psychographics can reflect a regular pattern of behaviour and subsequent enjoyment in their corresponding BioSt. For example, we could visualize the experience of co-located players, such as collocated player vs. non-player (observer).

Whole session overview: By visualizing the whole gameplay session, BioSt analyses were able to provide an efficient overview across all events, levels, and missions, enabling the developers to quickly scan for key elements in level design, player performance, and player emotions.

Verifying the intended design decisions: We have observed producers using BioSt to compare how players actually felt during various game events to the designer's original intended experience. Suitably equipped to understand the effectiveness of the design process, these designers were able to verify the success of their game design environment, and judge whether the intended game experience matched the actual player experience. Therefore, in the future, BioSt can be used as an experience design tool.

Simplicity: BioSt has been formed and iterated based on the demands of our target users to deliver tools that are simple, easy to understand and interpret with an immediately apparent benefit.

User-centered Design: Our understanding of the game development process and relevant needs in the working environment has helped us to design visualizations which closely match the requirements and language of our target users, as well as supporting the level of detail necessary for the task.

Familiarity: Our target users (game developers and producers) are familiar with various data representation techniques and visualizations of game metrics. Similarity between BioSt and these existing models has helped to support communication with and between developers and effectively increased the acceptance of our new tools.

Support collaboration: BioSt enabled increased collaboration between game user researchers, game designers, game developers, and producers. We saw that producers and designers were able to more effectively discuss design strategy using BioSt as a tool to chronicle, represent, and analyse player behaviour.

VII. CONCLUSION

Through storyboarding we can visualize different player data in a single graphical representation. This can help GUR and game development teams to achieve a shared view on critical game design events. Biometric Storyboards are in our experience, not only a powerful tool to explain game design problems, but also provide a way to discuss their solutions. They can help the whole team to visualize the design problems, potential solutions, and gameplay areas that need improvement.

Creating data-driven storyboards supports design arguments, so that game designers can see the degree to which players experience their designs as they intended. These storyboards provide an analytical connection between players and game designers.

Game events and gameplay periods (referred to as "game beats") and the emotions resulting from those events are at the heart of creating a great player experience. Biometric storyboards will allow us to visualize events in gameplay where players' actions or behaviours lead to changes in their emotional states.

Biometric Storyboards facilitate the analysis of gameplay behaviour by visualizing designers' intended player experience combined with the comments and physiological measurements of players. Using our method and tool, GUR professionals

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finally have an accessible and fast way of analysing and triangulating physiological data, player reports, and game design intentions.

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