User Performance Tweaking in Videogames – a Physiological Perspective of Player Reactions

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ABSTRACT
The videogame industry has suffered significant modifications in the last years, broadening its horizons towards a more casual market. This market expansion not only brings new opportunities from an interaction point-of-view, but also new challenges with the inclusion of users who are not accustomed to these games. This paper presents part of an ongoing study which aims at providing a better understanding of player behavior both from an interactive and a physiological standpoint. The experiment addressed here assesses different gameplay mechanics influence not only a subset of the players' physiological signals, but also their performance and interactive behavior.

Categories and Subject Descriptors
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Experimentation, Human Factors, Performance.

Keywords
Physiological Assessment, User Performance, Videogames.

1. INTRODUCTION
Videogames are an increasingly important part of our society: not only it is one of the fastest growing entertainment industries, but also they are being applied in domains as diverse as therapy [14] or rehabilitation [19]. Regardless of the domain of application, individuals desire to achieve a certain degree of satisfaction when playing games, although the motivation behind this may differ between areas of application [2][[7][10][14]. This state of satisfaction is often referred to as *flow* [8]. There are several features or mechanics used to control flow [6] such as providing rewards, attempting to gather the attention of the user by exploring emotionally engaging gameplay sequences, etc. While some of these provide a positive experience to users [7], others may detract them from having an enjoyable time [10] and, ultimately, forfeit playing the game.

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We are undertaking a research on user reactions and behaviors when they are confronted with determined interactive features and constraints (e.g. performance display, temporary boosts, displaying rewards, etc.) in single-player games. The goal is to understand the effects of these features on players and capitalize on these reactions to pro-actively maximize user performance in videogames. The presented study focuses on analyzing how different mechanisms can provoke positive or negative effects on the players' performance and a subset of their physiological signals. The main contribution is the empirical results which can be used by developers to create content which can actively regulate the player's performance.

2. RELATED WORK
The study of user levels of enjoyment while playing games is not a novel trend in the HCI area. Mandryk [13] has presented work on user reactions while playing cooperatively with persons with different acquaintances, showing that individuals tend to enjoy a game more if playing with their friends rather than with strangers. Other authors have performed studies on emotional reactions to games [10] or particularly stressful situations [14]. Namely, Chumbley's research [7] has provided empirical evidence on distinct emotional responses to alternative types of content. These two research examples focus on two important aspects of videogames: Mandryk explores how environmental variables affect how users play, during the playtime; on the other hand, Chumbley and Hackbarth [10] investigate how the game's content (e.g. story, genre) can affect a user's emotional status, despite analyzing pre and post playtime emotional responses.

2.1 Game Feature Assessment
The assessment of gameplay features and how they affect players is not a novel research area [11]. There has been some investigation on features used to balance gameplay across all players in order to avoid frustration or a sense of inferiority from one player towards the others [15]. Typical approaches to balance user performance rely on a sole assumption: the difficulty being too steep for the player. There is some research on how to adapt difficulty by adjusting the number of enemies and obstacles on screen [16] or adapt the speed of on screen moving objects, such as a tennis ball [12]. Applying such mechanisms must be carefully considered, as opposing players may sense unfairness [15] in the way the game is progressing and ultimately fail to be satisfied with their achievements [5]. A recent work from

Bateman [3] also addressed the issue from sense of balance and fairness when using target assisting techniques to help novice users play against more skilled players.

2.2 Usage of Physiological Assessment Mechanisms

Physiological interaction is a trend within the broader unconventional human-computer interaction domain, which focuses on the use of the body's biological signals and stimuli as an alternative or complement to traditional interaction mechanisms [2]. This interaction paradigm can provide information which is paramount to determine and understand user satisfaction and usability issues in different settings. Traditional assessment approaches (e.g. post-experiment questionnaires, observation) are considered highly subjective and possess an interesting set of drawbacks [14]: they typically fail to address complex interaction patterns; questionnaire responses may not relate to the actual user experience. In fact, Wilson and Sasse [20] state in their research that results stemming from subjective and physiological measurements are sometimes conflicting, as users may not be aware of (or try to hide) their true feelings or simply are not able to recall their experience in post-interviews. Rowe [17] also provides a report on the advantages of physiological assessment mechanisms.

Most of the existing work in the area is related with the use of physiological signals as a mean to adapt or reflect content according to the user's emotional state or in the usability assessment field. For instance, in [13] the authors apply galvanic skin response in combination to button-pressure detection to adapt the difficulty of a game according to emotional state of the user. Shi [18] has also performed a correlation between galvanic skin response and the cognitive load associated with interacting with a game in order to adapt its difficulty.

2.3 Our Research

Our work is focused on analyzing player interactive behavior and physiological changes when confronted with certain gameplay elements. Elucidative examples include the usage of faulty interactive controls (e.g. button requiring more than one press to activate), displaying incentive messages, displaying performance metrics (e.g. accuracy), among other.

3. EXPERIMENTAL PROTOTYPE

We decided to employ an arcade style game with simple rules and in which users are capable of maintaining a steady performance throughout the interaction period. For these reasons, we decided to use a version of the popular Whack-a-Mole game.

3.1 Whack-a-Mole

Whack-A-Mole (Aaron Fechter, Creating Engineering, Inc. 1971) has maintained its popularity throughout the years since its beginnings in arcade saloons and the later versions for mobile devices. The goal of the game is to stop an invasion of moles in a field – the gaming area is typically populated by various holes from which the moles emerge for a brief period of time. The players need to hit them using a plastic tool (arcade version) or clicking / tapping the mole.

3.1.1 Our Design

Our version of Whack-a-Mole – denominated *Ctrl-Mole-Del* (Figure 1) respects the rules and gameplay mechanics of the original game. We did extend its features to include some assessment features, providing support to the recording of interaction data as the player progressed through the game (e.g. where the player clicks, hits and misses, etc.).

3.1.2 Interface

The game screen is composed by four main panels: a menu panel (lowermost area of the screen), the title area (topmost section), a status panel (below the title panel) and the main gaming field occupying the majority of the screen. The status area displays the player's score and some of the feedback elements used in the experiment. The main game field contains the typical layout of Whack-a-Mole game.

Figure 1 – Ctrl-Mole-Del early prototype and final version.

3.1.3 Rules

Players are rewarded 2 points for hitting active moles. On the other hand, they are penalized in 1 point for missing to hit the moles or idling (at the rate of 1 point each half second, after not taking any action for 3 seconds). The main objective is to score 500 points in 240 seconds.

3.2 User Performance & Status Feedback Mechanisms

These mechanisms are informative feedback labels which convey game status or user performance information. For this study, we identified two different mechanisms recurrently found in videogames: a performance indication label and a timer display which shows the remaining time to complete the game.

3.2.1 User Performance Feedback

Different games and applications measure distinct features in a user's performance. Ranging from the number of enemies defeated, to the completion percentage in a determined level, these metrics are a constant in today's games and a simple yet effective way of measuring and comparing our performance with peers. We decided to include a metric measuring the accuracy of the user in the game. Accuracy stands for the number of correct inputs over the total number of inputs the user performed.

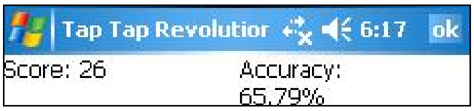

Figure 2 – Performance metric indicator widget.

3.2.2 Game Status Feedback

One of the most basic forms of controlling a user is imposing a limiting time frame to attain a certain objective. The existence of such a feature may have a double sided effect: on the one hand it may influence users to perform better to accomplish the task in time; on the other hand it may induce stress and anxiety and ultimately lead to a loss of commitment.

Figure 3 – Time constraint widget.

3.3 Temporary Bonus Rewards

In games, bonuses are, typically, items which appear at specific locations or occasions and boost the player's abilities and / or score. For this study, in addition to the feedback mechanisms, we designed a couple of bonus mechanisms which can help the players in attaining their goals. In *Ctrl-Mole-Del*, bonuses appear at an interval between 20 to 25 seconds and always at the same time as a mole appears. The bonuses are represented by a 'B' letter, sharing the same spawn points as the moles.

3.3.1 Hit-Window Dilation

One of the temporary bonus rewards we designed is called hit-window dilation. Based on slow motion techniques commonly employed in videogames to improve user accuracy (e.g. Red Dead Redemption), this bonus increases, during 10 seconds, the time frame users have to hit a mole. The down side is the slowing of the rate at which the moles appear during that 10 second period.

3.3.2 Time Extension

The second bonus is also commonly found in videogames and simply extends the player's available time to complete his / her task (e.g. Outrun). In *Ctrl-Mole-Del* the timer is extended by 5 seconds.

4. STUDY: PERFORMANCE TWEAKING MECHANISMS

We conducted a study to assess if certain feedback or gameplay elements are able to produce significant shifts in a subset of a player's physiological signals and on his / her performance. This study was divided in two parts and conducted in different time periods with distinct user sets: the first concerned the usage of specific feedback mechanisms, while the second was related with the usage of bonus elements capable of enhancing user performance. We will first describe the elements common to both experiments and then detail each one in particular.

4.1 Hypothesis

- ***H1*** – When confronted with different performance and status visual indicators while interacting with a game, subjects present significant shifts in a subset of their physiological indexes.
- ***H2*** – When confronted with different performance and status visual indicators while interacting with a game, subjects present significant shifts in their performance.
- ***H3*** – When confronted with different beneficial bonus items, individuals present a significant decrease in a subset of their physiological signals.
- ***H4*** – When confronted with different beneficial bonus items in games, there is a significant increase in user performance.

4.2 Metrics

We concentrated on a select set of metrics representative for the conclusions we intend to draw from the study:

- ***Average Heartbeat Rate (HBR)*** – this metric is capable of quickly reflecting changes due to stress or anxiety. We considered it relevant to be one of the main measures recorded for this testing period.
- ***Heart Rate Variability (HRV)*** – heart rate variability offers further insight of a user's emotional status [4]. By calculating the standard deviation of the former, we are able to achieve this measure [7].
- ***APM*** – actions per minute indicate the number of interactions an individual performs during 60 seconds. This is often related to user activity in a certain application or game.
- ***Score*** – players are awarded 2 points for each correct hit. Issuing an incorrect interaction (not hitting the current target) results in a 1 point penalty. Finally, idling for too long (more than 3 seconds) results in a point deduction each half second.
- ***Accuracy*** – accuracy stands for the number of correct hits over the total number of interactions triggered by the player.

4.3 Variables

The following subsections comprise the variables tested in this experiment, both controllable and not controllable.

4.3.1 Independent Variables

- ***Performance & Status Visualization Mechanisms*** – participants were confronted with variations of the *Ctrl-Mole-Del* game, differing between themselves in the mechanism displaying different performance metrics.
- ***Temporary Bonus Controls*** – subjects were confronted with the same game, but we provided different bonus rewards across different tasks.

4.3.2 Dependent Variables

- ***Physiological Metrics*** – as expected, physiological metrics (average heartbeat rate and heart rate variability) will be considered as dependent variable in light of the hypothesis for the experiment.

- ***Performance Metrics*** – given the experiment's fixed time to accomplish each task (explained in more detail below), the player's score will be taken into consideration. The subject's accuracy (number of hits over total number of interactions) will complement the former to provide a general overlook on his / her performance.
- ***Interaction Activity Metrics*** – we also assessed if the presence of the above mentioned mechanisms has any influence on the users' interactive behavior, by observing the interaction logs and delving into shifts in the subjects' APM.

4.4 Participants

Two different groups of 30 individuals (roughly 65% male; age 22~47) participated in each experimental period and all of them had proficiency in interacting with mobile devices (e.g. cell phones, gaming handhelds).

4.5 Tools & Equipment

Subjects were handed a Windows Mobile phone (HTC HD2), with the necessary test applications, and an AliveTec Heart Monitor [1] sensor, previously prepared with electro-gel for better signal acquisition. Sensors were placed 2 inch apart over the heart's location in the subject's chest. This device is capable of gathering the user's heartbeat rate.

4.6 Experiment I: Users VS Feedback Mechanisms

The first experiment assessed how players reacted to specific performance and game state feedback mechanisms. We were primarily interested in physiological shifts which resulted from the introduction of these features.

4.6.1 Procedure

- ***Pre-Task*** – users engaged in an interaction period with the smartphone using different apps (e.g. calendar, creating notes, etc.) in order to establish the baseline for physiological metrics on normal device usage. During this period they were briefed on *Ctrl-Mole-Del*'s mechanics and the bonus mechanisms effects.
- ***Task 1*** – subjects interacted with the game, having 240 seconds to achieve a score of 500 points. Similarly to the pre-task period, we used Task 1 as a baseline for all users when interacting with *Ctrl-Mole-Del* without the addition of any mechanism.
- ***Task 2*** – subjects interacted with the prototype including an active accuracy visualization control. The interaction period lasted for about 140 seconds or until the player reached 500 points.
- ***Task 3*** – in the third task the goal was the same, but we displayed the remaining time to attain a score of 500.

All subjects started by performing the pre-task. The remaining tasks were randomly ordered for each subject. A ten minute interval was inserted between tasks to eliminate any physiological bias stemming from the previous one.

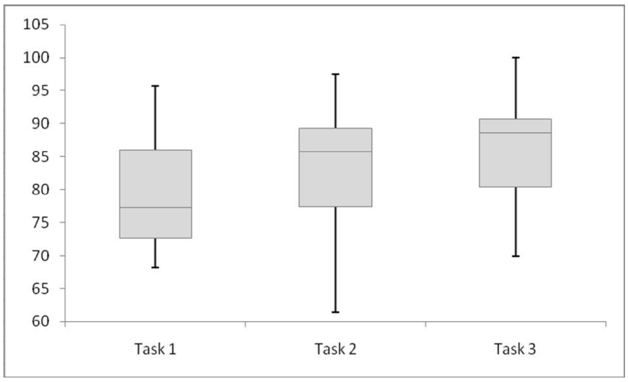

Figure 4 – HBR Box Plot.

4.6.2 Results

The results section will be divided in two parts: during the first we will present and discuss the results stemming from physiological metrics; the second part will deal with performance and interaction metrics

Table 1 – Experiment I results.

	Baseline	Task 1	Task 2	Task 3
Avg. HBR	76,34	78,49	86,82	88,15
HRV	8,47	13,33	15,51	16,51
APM	N/A	74	78	80
Avg. Accuracy	N/A	94	85,73	84
Accuracy St. Dev.	N/A	2,32	8,97	9,67

Physiological Analysis: the results for the physiological metrics can be observed in Table 1 and Figure 4. The introduction of a performance visualization widget (in particular, displaying the player's accuracy) resulted in an increase in the recorded physiological metrics (average HBR and HRV). Likewise, when users were confronted with time constraints to attain a certain goal in the game, there was an increase in the recorded physiological values (roughly a 12% increase in the average HBR value).

Table 2 – Statistical analysis for the physiological results.

	Task 1 – Task 2	Task 1 – Task 3
Confidence Interval	95%	95%
T value	2.2306	2.4928
Degrees of Freedom	58	58
Standard Error of Difference	3.734	3.876
Two-tailed p value	0.0296	0.0156

We assumed a normal distribution for our population. This led us to perform a couple of unpaired Student's t-test for this: one comparing the gathered metrics (mean HBR and HRV) between Task 1 and Task 2; the second comparing Task 1 and Task 3. The obtained result can be observed in Table 2. The differences between the sample values and the obtained value of P point that the obtained results are statistically significant for both comparisons. However, the differences and the value of P when comparing Task 2 to Task 3 point that there is no statistical significance.

Performance Analysis: results for the performance and interaction metrics can be observed in Table 1 and Figure 5. They show there was a slight increase in APM when comparing Task 1 with both Task 2 and 3. This increase is not very substantial in the case of the accuracy display, being more notorious when users were confronted with the time constraint one. The results for the accuracy metric are also in harmony with the remaining metrics: there was a decrease in accuracy comparing the absence of performance related widgets to their presence in the game. This means there was a loss of performance from the individuals comparing the different tasks of the experiment. While the difference is not significant, this loss of performance was even more noticeable when in the presence of a timer constraint.

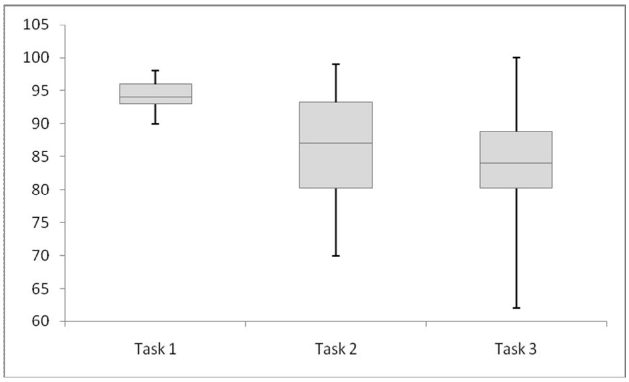

Figure 5 – Accuracy Box Plot.

Again, we performed statistical analysis for the collected performance results, in particular for the recorded accuracy levels. The setup for these tests was similar to those performed regarding the physiological data: we compared the average accuracy and its standard deviation between Task 1 and Task 2; we then carried out the same test, although comparing Task 1 to Task 3. Results can be consulted in Table 3. We applied a couple of unpaired Student's t-tests assuming a normal distribution for our samples. Regarding the accuracy metric, and the obtained values supporting it, our results are extremely statistically significant when comparing Task 1 to Task 2 and Task 1 to Task 3. No statistical significance was found when analyzing the results for the APM metric.

Table 3 – Statistical analysis for the accuracy results.

	Task 1 – Task 2	Task 1 – Task 3
Confidence Interval	95%	95%
T value	4.88	5.50
Degrees of Freedom	58	58
Standard Error of Difference	1.69	1.81
Two-tailed p value	< 0.0001	< 0.0001

4.7 Experiment II: Users VS Bonus Mechanisms

The second experimental period assessed the physiological reactions of players to the introduction of special bonus mechanisms. In this test period we used a previously assessed mechanic (i.e. the timer display) to put all subjects under stress during gameplay and analyze if the introduction of the bonuses had any effect on their emotional state.

4.7.1 Procedure

- ***Pre-Task*** – we conducted an approach similar to the one applied in the first experimental period, allowing subjects to freely interact with the device's applications, while we established the baseline for their physiological metrics.
- ***Task 1*** – in Task 1, subjects played Ctrl-Mole-Del using the variant which displays the remaining time to attain the 500 points goal.
- ***Task 2*** – similar to Task 1, but subjects were confronted with hit-window dilation bonuses.
- ***Task 3*** – following the same premise as Task 1, here subjects were confronted with time extension bonuses.

The second experimental period followed the same pattern as the first concerning intervals between tasks and order task randomization.

Table 4 – Experiment II results.

	Pre-Task	Task 1	Task 2	Task 3
Avg. HBR	78.36	85.89	81.77	80.71
HRV	5.34	8.11	8.27	7.46
Avg. Score	N/A	412.63	319.40	494.57
Score St. Dev.	N/A	85.39	95.29	17.36
Avg. Accuracy	N/A	87.98	82.12	84.76
Accuracy St. Dev.	N/A	9.42	10.24	6.53

4.7.2 Results

The results section will analyze the quantitative results according to the recorded metrics. Figure 6, Figure 7 and Figure 8 along with Table 4, Table 5, Table 6 and Table 7 detail the collected data.

Physiological Analysis: Table 4 and Figure 6 depict the results for the heart related metrics. As can be observed, the introduction of bonus rewards had a relaxing effect across tasks 2 and 3. This effect was slightly more evident in task 3, as its bonus diminished pressure from the time constraint present in the game.

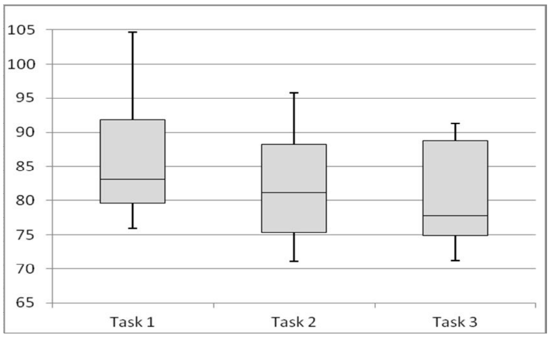

Figure 6 – HBR Box Plot.

Assuming a normal distribution for our sample, we proceeded to the verification of our results through the employment of a paired Student's t-test in order to assess any statistical significance.

Results can be consulted in Table 5. The values obtained for the comparison between Task 1 and Task 2 point that the results are extremely statistically significant. Following the same line of thought for Task 1 and Task 3, the two-tailed P value being lower than 0.0001 indicates the gathered results are extremely statistically significant. Finally, in the comparison between Task 2 and Task 3, the two-tailed P value for the test was equal to 0.1312 – pointing the gathered results are not statistically significant.

Table 5 – Statistical analysis for heart related metrics.

	Task 1 – Task 2	Task 1 – Task 3	Task 2 – Task 3
Confidence Interval	95%	95%	95%
T value	4.3261	6.6717	1.5531
Degrees of Freedom	29	29	29
Standard Error of Difference	0.953	0.777	0.685
Two-tailed p value	0.0002	< 0.0001	0.1312

Performance Analysis: Results for the score obtained can be observed in Table 4 and Figure 7. There was a severe loss of score performance when comparing Task 1 to Task 2. Between Task 1 and Task 3, we can conclude the time extension bonus had a positive effect on user score performance. Again we verified these results in order to assess statistical significance from them by employing a paired Student's t-test. Table 6 presents the results. Regarding the first test (between Task 1 and Task 2), the obtained values point the results are extremely statistically significant.

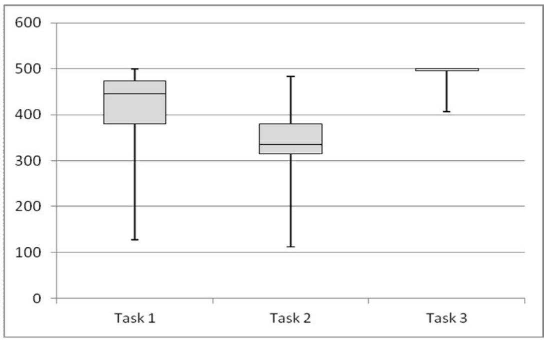

Figure 7 – Score Box Plot.

Taking into account the comparison between Task 1 and Task 3, the obtained two-tailed P value for this test is lower than 0.0001 – the gathered results are extremely statistically significant. Considering the comparison between Task 2 and Task 3, the two-tailed P value for this test was lower than 0.0001 –the gathered results extremely statistically significant.

Table 6 – Statistical analysis for score metric.

	Task 1 – Task 2	Task 1 – Task 3	Task 2 – Task 3
Confidence Interval	95%	95%	95%
T value	7.7237	6.1731	10.7505
Degrees of Freedom	29	29	29
Standard Error of Difference	12.071	13.273	16.294
Two-tailed p value	< 0.0001	< 0.0001	< 0.0001

Accuracy: The obtained accuracy results (Table 4 and Figure 8) present a slight contrast to the other performance metric (score). When comparing Task 1 to either Task 2 or Task 3, we can observe a decrease of accuracy. This decrease may, in part, be justified to the increased complexity and decision process introduced by the bonus mechanism. Again we verified these results in order to assess statistical significance from them by employing a paired Student's t-test (Table 7). Regarding the first test (between Task 1 and Task 2), the test indicates the gathered results are very statistically significant.

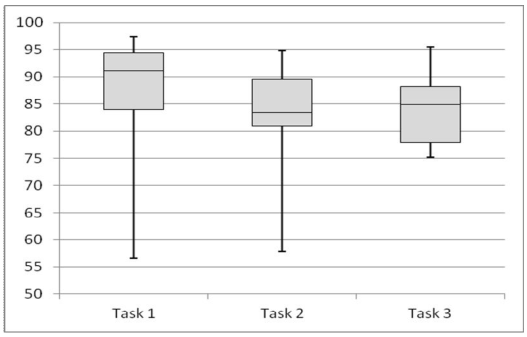

Figure 8 – Accuracy Box Plot.

Taking into account the comparison between Task 1 and Task 3, the two-tailed P value for this test equals 0.1044 –the gathered results are, thus, not statistically significant. As for the comparison between Task 2 and Task 3, two-tailed P value for this test was equal to 0.1373 – indicating the gathered results are not statistically significant.

Table 7 – Statistical analysis for accuracy metric.

	Task 1 – Task 2	Task 1 – Task 3	Task 2 – Task 3
Confidence Interval	95%	95%	95%
T value	3.4592	1.6764	1.5281
Degrees of Freedom	29	29	29
Standard Error of Difference	1.693	1.918	1.728
Two-tailed p value	0.0017	0.1044	0.1373

4.8 Discussion

The obtained results validate our four hypotheses. Summarizing, the two experimental periods supported our claims that certain elements introduced during gameplay period may have a beneficial or pejorative effect on a subset of an individual's physiological signals and his / her performance. Nevertheless, we can delve deeper into the results and discuss particular findings. The second experiment provided the most interesting results, particularly the case of the time-window dilation is interesting, since it resulted in significantly worse score and poorer accuracy. On the other hand, the inclusion of a time extension mechanism significantly increased score performance, as it provided more time to accomplish the game's goal. However, the accuracy recorded was even lower than the one registered for the time-window dilation. One of the most interesting remarks of the second experiment relates to the time-window dilation bonus. A significant portion of the subjects (roughly 65%) ignored the bonus after activating it the first time it appeared, mentioning it "disrupted their gameplay rhythm". However, despite results showing low or no apparent decrease of performance, they do present beneficial influences on the recorded physiological metrics. While, at the moment, we do not desire to draw early conclusions, we envision that bonus mechanisms may have an interesting "placebo" effect on user emotions. Further investigation will be undertaken from out part to assess this phenomenon.

The implication of such results for developers is the possibility of using specific game mechanics to relax or engage users in the playing experience and ultimately adapt the game accordingly. The results point that, again, it is possible to actively increase or decrease player performance by introducing different interactive features in a videogame. For developers, this means it should be possible to tailor gameplay experience to each user, based on their interactions and physiological metrics. In general, we believe it should be possible to pro-actively adapt a game's content and interactive mechanics based on a subset of the players' physiological signals and interactive behavior. The effects certain features have on these metrics should warrant the ability for developers to identify events in which key mechanics should be activated or introduced in order to maintain the players in a flow state.

5. CONCLUSIONS & FUTURE WORK

This paper presented a study which aimed at providing a better understanding of how certain gameplay and feedback elements affect user interactive behavior and a subset of their physiological signals. We carried out a couple of experimental periods to evaluate if these features impact on a player's performance.

Results have shown users present lower average heartbeat rate values and a lower hear rate variability when confronted with positive bonus rewards, while simultaneously showing a moderate increase in their performance. On the other hand, when certain feedback mechanisms are enforced, players showed higher values on the recorded physiological metrics, denoting more stressful periods. Complementing these findings, their performance was also poorer when in the presence of such feedback elements. In general we have showed the effects that different gameplay and feedback elements commonly used in videogames have in players. The contributions and implications of this study in the game development community relate to a more moderate and intelligent usage of these mechanisms to appease the players as well as hints on how to properly balance user performance over the course of a play session.

Our next endeavors will encompass performing focused tests on a lower number of users to assess the evolution of their satisfaction with a game over the course of several weeks and whether their physiological signals reflect changes in their perceived enjoyment or not.

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