



# Efficacy of Using Retro Games in Multimodal Biofeedback Systems for Mental Relaxation

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## ABSTRACT

Video games are used to increase the engagement of biofeedback systems. For cost-effectiveness, the original Nintendo Entertainment System (NES) games can be used. Therefore, a multimodal biofeedback system was developed to leverage the NES games for biofeedback. This study aims to test the efficacy of the developed system, the motivation of participants, and the usability of the system. A within-group design study was conducted with 16 participants followed through four interventions: deep breathing, stress-test, non-biofeedback game (control), and biofeedback game (experiment), where their HRV was recorded. Participants showed significantly different HRV during interventions ( $F(1.60, 23.93) = 11.94, p < 0.001$ ) and reported higher HRV when using biofeedback game than the non-biofeedback game ( $t(15) = 9.14, p < 0.0001$ ). The motivation was reported to be the same with biofeedback and non-biofeedback version of the game, and the overall system was reported as usable. The results of this study support the efficacy of using original NES games in biofeedback for mental relaxation.

## KEYWORDS

Biofeedback System, Graphical User Interface, Heart Rate Variability, MATLAB, Mental Relaxation, Nintendo Entertainment System Games, Open-Source Software, Physiological Signal Acquisition

## 1. INTRODUCTION

Mental stress has detrimental effects on one's mind and body (Lupien et al., 2009), and in the long run may lead to chronic diseases like cardiovascular problems (Larkin, 2005) and diabetes (S. Cohen et al., 2012). In developing countries like India, for the productive population, stress from the number of contributing factors is responsible for mental disorders which contribute to greater morbidity and is a matter of serious concern (Murthy, 2017). Besides traditional interventions for stress management like Cognitive Behavioral Therapy, technological intervention like biofeedback is also becoming popular (L. Kennedy & Parker, 2019). In a biofeedback session, the physiological parameters (like heart rate)

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of an individual are shown in real-time and one can learn to better manage them by following some specific protocol (like paced breathing) (Schwartz, 2010).

However, the routine of a traditional biofeedback session can be quite monotonous and may offer a lesser appeal to the young participants (Pope & Palsson, 2001). One way to increase engagement with biofeedback sessions is to use video games as a biofeedback delivery mechanism (Bersak et al., 2001; Mandryk et al., 2013; Pope & Palsson, 2001; Wang et al., 2018; Zafar et al., 2020). In this case, the individual plays a game specially created/modified for biofeedback application. The physiological state of the individual is shown as a change of in-game elements or game-mechanics, instead of directly showing the physiological measures (Wang et al., 2018). In this way, the participant/player aims to control the game state by following the biofeedback protocol and thus have an engaging and fun experience during the biofeedback intervention.

There are some challenges with using video games for biofeedback. The lack of use of the same game or game genres across various studies creates difficulty with the replication and comparison of results. The non-availability of the game in the public domain and proprietary source code of the study further add to the challenges. Moreover, there is a higher cost associated with game development and maintenance which reduces the appeal of biofeedback research to groups with limited funding support.

The retro games developed for Nintendo Entertainment System (NES<sup>1</sup>) (Nintendo, Kyoto, JP) can address these issues. These are 8-bit games that run on NES hardware or NES emulator and are popular among people. The simple gameplay and meticulous level design of these games makes them excellent candidate for delivering biofeedback. Therefore, the authors have developed an open-source system to leverage NES games for multimodal<sup>2</sup> biofeedback. The system consists of data acquisition (DAQ) hardware (H/W), software (BioNES<sup>3</sup>), and a game system, which can be used to deliver heart rate (HR) and/or heart rate variability (HRV) biofeedback via any NES game. The player has to follow biofeedback protocol (like deep breathing) to keep the HRV deviation from baseline value at a minimum while simultaneously playing the biofeedback-enabled game. The in-game feedback continuously shows the current deviation of HRV to the player. Failing to keep up with the biofeedback protocol triggers additional game mechanics (like warning beep, change in player life) which brings about enhancements to the original gameplay of the NES game. The appeal of the system is that one does not need to know the proprietary source code of the NES games and the game mechanics can be modified and feedback can be displayed by using the support of the NES emulator. In this way, any available game created for the NES platform can be leveraged for delivering biofeedback.

In this paper, an attempt is made to understand the efficacy of the developed system in inducing mental relaxation. *Super Mario Bros.* (SMB) (*Super Mario Bros.* - *Super Mario Wiki, the Mario Encyclopedia*, n.d.), a popular NES game was used. The purpose of this study can be summarized in two steps.

- Firstly, to find the engagement of SMB, and what game mechanics of the game can be used for biofeedback. Authors have used Octalysis, a popular gamification analysis tool to disseminate the engagement core drives in the SMB game. Based on the results, the feedback delivery modality of the biofeedback is decided.
- Secondly, to test the hypotheses about the developed system. It was hypothesized that the biofeedback game (BF-Game) in the experiment group/intervention induces more relaxation than the non-biofeedback game (NBF-Game) in the control group/intervention. This will attempt to explain the efficacy of the developed system as well as the game used for biofeedback. Next, it was hypothesized that the participant's motivation towards playing the BF-Game is the same as towards the NBF-Game. Here, the intrinsic motivation to play the BF-Game is important, failing which defeats the purpose of using video games for biofeedback. It was also hypothesized that the participants find the overall biofeedback system usable, which is an important criterion for the continued use and acceptability of the system.

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