
Designing and Utilizing Biofeedback Games for Emotion Regulation: The Case of Nevermind

Adam Lobel, MSc

Radboud University
6525HR Nijmegen, Netherlands
A.Lobel@pwo.ru.nl

Marientina Gotsis, MFA

University of Southern
California
Los Angeles, California, USA
90089-0911
Marientina@yahoo.com

Erin Reynolds, MFA &

Michael Annetta, MFA
Flying Mollusk
Glendale, California, USA
Erin@NevermindGame.com
Michael@NevermindGame.com

Prof., dr. Rutger C.M.E. Engels

Trimbos Institute
Utrecht, Netherlands
REngels@Trimbos.nl

Prof., dr. Isabela Granic

Radboud University
6525 Nijmegen, Netherlands
I.Granic@pwo.ru.nl

Abstract

Biofeedback games have the potential to make gaming a deeply personal experience by linking the gamespace to each player's physiological state. First, this paper describes the psycho-educational potential of the horror-themed biofeedback game Nevermind. In Nevermind, players' heart rate is continuously read into the game which in turn adapts to the player's momentary levels of negative affective arousal. Greater negative arousal causes the game and its horror-themed settings to become more disturbing. As a result, Nevermind challenges players to improve their emotion regulation skills by encouraging them to healthily down-regulate their negative affective states in the face of stressful situations. Second, we share how Nevermind implements two valuable design principles to maximize player engagement. Finally, we describe a recent study conducted on 47 players. We discuss potential physiological metrics which may be useful for understanding how behaviors in the real world relate to those in biofeedback games like Nevermind.

Author Keywords

Biofeedback; Game Design; Psychology; Emotion Regulation.

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Heart rate variability as a proxy for stress

Heart rate variability refers to the extent to which the time between one's heartbeats vary. When calm, heart rate variability tends to fluctuate, demonstrating that the heart is in an easily adaptable state, ready to speed up or slow down depending on one's needs [1]. When under duress, however, heart rate variability narrows as the body focuses on self-control, performance, and on maintaining a fixed, high level of arousal. Figure 1, below, gives an illustration of heart rate variability.

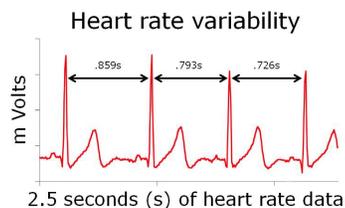


Figure 1: Heart rate variability demonstrated using hypothetical heart rate data.

ACM Classification Keywords

H.5.m Information Interfaces and Presentation (Biofeedback); J.4 Social and Behavioral Sciences: Psychology; K.3.1 Computer Uses in Education

1.1 The game: Nevermind

Developed by Flying Mollusk, Nevermind is a horror-themed biofeedback game played from the first person perspective [13]. The game casts players in the fictional role of a Neuroprober, a therapist of the future. As a Neuroprober, players enter the minds of Clients who suffer from life hindering psychological distress. Each Client serves as a self-contained level whose completion is achieved when players discover the root cause of their Client's distress. To do so, players must navigate each Client's nightmarish subconscious, solving puzzles to unlock fragmented memories. Players must think like a detective by attending to the game's details which help illustrate how these fragmented memories fit together to tell each Client's true story. Thus, at the conclusion of each level, players must identify and correctly order five of the Client's ten memories. Doing so reveals the root cause of their Client's anxiety, and brings closure for player and Client alike.

1.2 Theoretical background: Biofeedback and interoceptive awareness

While Nevermind can be played as a traditional video game, the game also prominently utilizes biofeedback. Biofeedback refers to a system whereby the player's physiology provides the game with input, and then reacts to this input, in turn providing feedback to the player. Supporting a variety of input devices (e.g.'s Intel RealSense cameras, Garmin Heart Rate Chest Strap; a full list is available on the Nevermind website's

support page [13]), Nevermind's biofeedback system utilizes players' heart rate. More specifically, by capturing heart rate variability, Nevermind continuously tracks players' degree of negative physiological arousal as a proxy for levels of player stress (see Sidebar). The more stress players experience, the more difficult the game becomes. Thus, increases in player stress are matched by the screen becoming progressively obscured by static; also, many environments in the game become hostile to the player, obstructing his/her movement or visibility, and sometimes dealing damage to the player (Figure 2¹).

Of course, being a horror-themed video game, Nevermind is designed to evoke stress, suspense, and even mild discomfort. In this way, the game challenges players to manage their physiology in the face of negatively arousing circumstances. Herein rests the promise of Nevermind to experientially teach players how to manage stressful situations in their everyday lives. In linking players' physiological states to the gamespace, Nevermind seems to engage players' interoceptive awareness.

Interoceptive awareness (IA) refers to the ability to recognize one's own physiological states [10]. This skill underlies our ability to determine things like hunger, muscle fatigue, or the accurate source of physical pain. But IA is also valuable in the domain of emotion regulation, that is, the conscious and unconscious means by which we manipulate our experience of

¹ The brightness and contrast of all screenshots in this document have been increased so that the relevant details described in the text are also visible in black-and-white printed versions. For color screenshots in their original form, please contact the first author.

Interoceptive awareness as a marker of healthy emotion regulation skills

In line with prominent theorists such as James [6], Damasio [3], and Niedenthal [11], several recent studies support the notion that IA is beneficial for emotional well-being: (1) IA has been positively associated with the ability to recognize one's emotions [15]; (2) IA has been negatively associated with Alexithymia, the inability to recognize one's emotions [5]; (3) IA has been positively associated with the ability to down-regulate negative affect by better reappraising negative emotional experiences [4]; and (4) people with a greater IA experience less negative affect when being socially excluded [12].

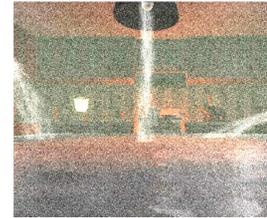


Figure 2: An example of Nevermind's biofeedback system. As the player's stress increases, the higher the milk rises. In this scenario, the player's character can drown, forcing him/her to restart the challenge. However, returning to a relaxed state causes the milk to subside.

emotions. This is because – as long argued by important theorists in psychology [7,3,11] – emotional states are inherently linked to physiological states. Increases in IA may therefore boost emotion regulation skills and therefore better equips individuals for dealing with negative emotional experiences [8]. Several recent studies support this (see Sidebar). Regarding Nevermind, because the game encourages players to recognize and healthily manage their physiological states, it may therefore be beneficial for IA, and by extension, for a player's ability to manage stress in their everyday life.

2.1 Design principles

Nevermind's biofeedback mechanic helps make the game feel like a personalized experience. How each individual player feels while playing the game makes for a unique experience. However, this design feature would likely not be enough to engross players and carry the gameplay on its own. Therefore, before we discuss the potential insights afforded by in-game data we collected in a recent study, the two following sections highlight the game's design principles which help make Nevermind a compelling experience. We call these design principles *thematic congruence* and *environmental storytelling*.

To concretely demonstrate these design principles, we draw on examples from the Client #251 level. In this level, players inhabit the subconscious of a middle-aged woman whose father passed away when she was very young – there was a fatal car accident, her mother told her. With the recent passing of her mother, however, the Client reports sudden feelings of guilt and anger. Related to this, she also reports anxiety coming from the belief that people stare at her, seemingly in judgment. In the Client's nightmarish subconscious, the idyllic suburban home from her childhood becomes a dark, dilapidated house of horrors. There are signs of financial insecurity and marital unrest. Over the course of the level, the player discovers that the story about Client #251's father dying in a car accident was a lie. [SPOILER ALERT / MATURE CONTENT WARNING:] In actuality, when Client #251 was a little girl, she mistakenly entered her parent's bedroom just as her father was committing suicide, and witnessed him firing a gun into his head.

In the following two sections, we discuss some ways in which the game uses *thematic congruence* and *environmental storytelling* to engage players by making the clues and themes of this level central to the gamespace in the Client #251 level.

Thematic congruence: Blank and blotched out faces



Figure 4: Blank or blotched out faces are a recurring visual motif in the Client #251 level. This motif reflects the Client's anxiety experienced when seeing people look at her.

2.2 Design principles: Thematic congruence

Thematic congruence means that there is an overlap between the themes of the game – for Client #251, these are things like social anxiety, domestic unrest, and separating fact from fiction – and the player's visual experience. This means that Nevermind's art, colors, and assets are meant to be in line with the messages which its designers want to convey. This creates a very singular design.

Some examples: The idea that Client #251's family unit corroded is depicted by a literally broken home (Figure 3). Also, Client #251 spoke about an intense guilt she feels when she is being looked at; so not only do family portraits in the home have blank faces, but in the nightmare version of the home, these faces are blotched out aggressively (Figure 3, bottom panel). These images recur throughout the game, and in some cases, blank faces follow the player, staring in judgment (see Figure 4 in Sidebar).

2.3 Design principles: Environmental storytelling

As consequence of Nevermind having consistent thematic congruence, the act of exploring the gamespace comes to have meaning for the player. The more players explore, the more they are rewarded with details that help tell a story. Moreover, because much of the exploration is voluntary, the things that players discover feel special. Players experience a sense of ownership. "Oh wow – I found this!" Nevermind was designed with this in mind; thus, because Nevermind's design strives for thematic congruence, Nevermind is also able to tell its stories via the game's world.



Figure 3: Client #251's childhood home. Players first experience a non-threatening version (left), before solving puzzles in the dilapidated nightmare version (right).

For example: Although not legible here, the bold red text "Past Due" is easily readable in-game on the envelope in Client #251's mailbox (Figure 3, top panel) – at least for those curious enough to attune to it. Also conveying domestic unrest, the titles of board games which are featured in the living room subtly change when players explore the home's nightmare version (e.g. "Family Games, Inc." becomes "Fractured Family, Inc."). Nevermind features a great many more of these subtle environmental clues for eager players to discover

Research materials

Pre-test (emotion regulation):

- Suppression and reappraisal, assessed with the **Emotion Regulation Questionnaire (ERQ)** [7]
- Instrumental social support, emotional social support, active coping, withdrawal, and acceptance, assessed each with a subscale from the **COPE** [2]
- Rumination, assessed with the **Ruminatory Response Scale (RRS)** [14]

Post-test:

- Interest/Enjoyment, Effort/Importance, pressure/tension, and value/usefulness, assessed each with a subscale from the **Intrinsic Motivation Inventory (IMI)** [9]

on their own initiative. Crucially, these instances of environmental story-telling not only compel players to explore, but with each discovery, these discoveries help players increasingly feel like they are cultivating their own personalized understanding of Client #251.

3.1 An observational study: Utilizing Nevermind's biofeedback and in-game data

We recently conducted an observational study to examine potential connections between Nevermind players' in-game and real world behaviors. This study was motivated by the observations that (1) Nevermind's biofeedback mechanic seems capable of engaging (and perhaps training) interoceptive awareness, and (2) Nevermind's design principles help make it a highly engaging experience. Forty-seven participants (38 males) aged 18 to 24 took part. The study was conducted at The University of Southern California, and was approved by the university's ethical review board. Below, we describe our procedures and showcase heart rate data collected in-game to discuss potential analysis strategies and potentially valuable insights that this data could afford.

3.2 Method

Participants completed an online questionnaire to assess how they manage their emotions in everyday stressful situations. Participants then came to the lab to play through Nevermind's Client #251 level while wearing a Garmin Heart Rate Chest Strap. Playtime was restricted to 45 minutes, with 34 participants (72.4%) managing to complete the game within the allotted time. Participants then completed an exit questionnaire assessing their experience when playing the game. See Sidebar for a comprehensive list of the measures used in this study.

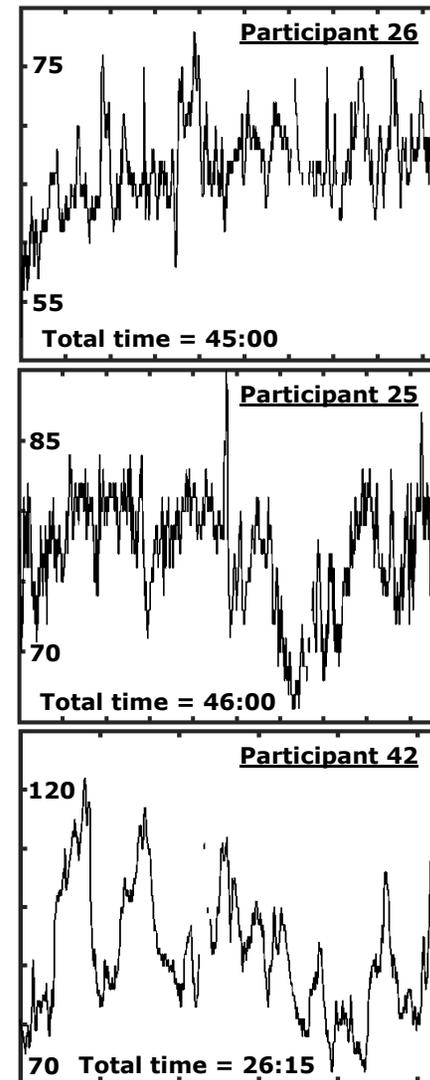


Figure 5: Heart rate data from three participants with heart rate in beats per minute on the y-axis, and time in minutes on the x-axis. Each graph plots a single play session from a single participant. While Nevermind utilizes heart rate variability for its biofeedback mechanic, heart rate is plotted here for ease of discussion and readability. Gaps in lines represent missing data. Participant 26 did not complete the level, Participant 25 did, and Participant 42 requested to end the session early due to duress. (This was the only participant in our sample to do so.)

3.3 Future steps and potential insights

Our next goal is to explore whether associations can be drawn between how participants regulated their physiology while playing Nevermind and how they manage their emotions during everyday stress. We therefore intend to extract a number of metrics from players' in-game heart rate (variability) data. The hope is that we can identify metrics that are informative with regards to how players deal with stress in their everyday lives.

Figure 5 (above) presents heart rate data from three different participants. While Nevermind utilizes heart rate variability for its biofeedback mechanic, heart rate is plotted here for ease of discussion and readability. The data from these participants were specifically selected to demonstrate the general variety in physiological reactions across participants, and to help illustrate the metrics we think may be informative:

- Frequency of spikes in negative physiological arousal – Comparing Participant 26 (P26) to P25, it seems that there is variability in the number of times which Nevermind caused players' heart rates to spike. This may be an indication of (over-)sensitivity to negative emotional stimuli.
- Speed of recovery – Perhaps more important than the number of times Nevermind evoked negative arousal, is the speed with which participants are able to recover from spikes in arousal. Thus, the slopes of the lines coming off of a spike may be important. This could be a metric of an ability to healthily down-regulate negative arousal after highly stressful experiences.
- Frequency of dramatic drops in negative physiological arousal – Again comparing P26 and P25, P25 seems to more frequently have dramatic drops in heart rate. These may be indicative of freeze responses, or perhaps to an ability to quickly regulate physiology when the situation requires it.
- Intensity of negative physiological arousal – Finally, negative arousal may vary in intensity across participants. For example, P42 seems to show a resting heart rate of about 80 beats per minute, while her heart rate exceeded 110 beats per minute on a number of occasions. This too may be an indication of (over-)sensitivity to negative emotional stimuli.

4 Closing remarks

This work describes the biofeedback game Nevermind, and argues for its potential to help train emotion regulation skills. It is our hope that Nevermind becomes just one of many interactive experiences to engage users' emotion regulation capacities. To that end, we have recruited established psychological research to argue for the value of its biofeedback mechanic. We have also highlighted design characteristics which may be beneficial for future like-minded projects. Finally, we have discussed some of the various ways in which physiological data recorded in-game can be of value for understanding human behavior outside of the game. We invite others to think together with us about how biofeedback games can be of both value and entertainment, and how physiological data from such games may be of value.

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