Bringing Tower Defense into the physiological study of flow in virtual reality

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1. Introduction

What is flow? The experience of flow in video games has attracted considerable interest in the recent years. Flow is a multi-faceted construct that emerges under sufficient challenge and through intense concentration. The players experience loss of time perception, loss of self-reflective thoughts, and a state of automation, during which their actions feel as being automatic [1]. Flow is considered a highly desirable experience during video game playing, and it is well documented that individuals are much more likely to replay a game if they experienced flow [2]. Hence, it is a state highly sought by game designers.
Measuring flow: Traditionally, flow has been mainly assessed with questionnaires [3] - the researcher aims to extract oral or written responses from participants. This is usually done by interrupting the participant at fixed or random intervals during playing, or by acquiring a retrospective report of the user's experience. Both of these approaches are inherently problematic. Interruption forces the participant to reflect on their most recent experience, thereby violating the loss of self-reflection dimension of flow. On the other hand, the retrospective report synthesizes a holistic impression of the game, thus it is insensitive to specific game events. Notwithstanding these drawbacks, the aforementioned approaches may be an insufficient practice for virtual reality (VR) experiments.
Game design: A growing body of literature has employed physiological indicators (e.g. brain activity, heart rate, electrodermal activity), offering an objective and passive way to detect the state of flow. A recent framework to assess flow in virtual reality concluded that responses of the autonomic nervous system (e.g., heart rate) might be efficient predictors [3]. However, a compatible VR game to facilitate physiological data collection and interpretation is still an open challenge. In this work, we present our own implementation using a custom-developed game from the Tower Defense (TD) family, which has been deemed a reliable genre for research [4].

2. Game design description

The TD-VR game was developed in Unity 3D (Unity Technologies) in collaboration with Sony Interactive Entertainment for PlayStation VR. The advantage of a TD game is that it is round-based; hence, we can demarcate when player interaction takes place, which resides at the core of the flow experience [5]. Physiological data are therefore easier to manage (Fig. 1). The variable subject to experimental manipulation is the challenge of the game. The default pacing is supported by a difficulty adjustment model that is tailored to TD games [6]. This is done to scale the game's challenge to the player's skills (flow rounds) and to adjust

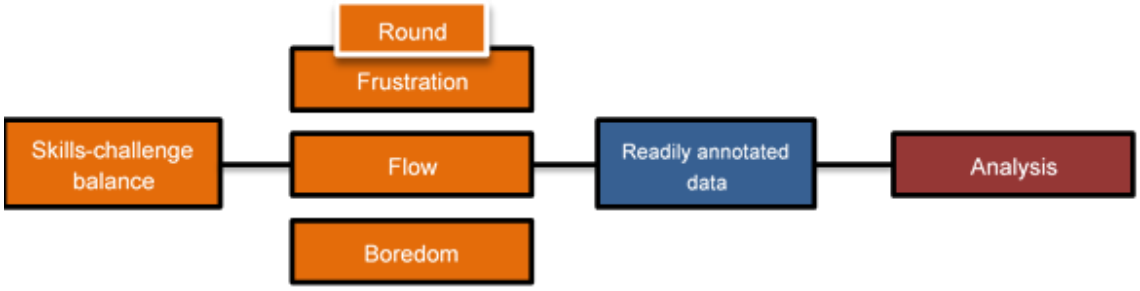

Figure 1: Brief illustration of a Tower Defense-based framework for physiological assessment of flow. Orange blocks reflect game modifications with the aim to induce different states.

the naturally linear difficulty scaling of the TD genre. For the frustration rounds, a great reward is promised to the player, but the enemies are programmatically modified to be invincible, thus instilling the illusion of a close win. This is a covert mechanic to prevent the possible suspension of player motivation. Finally, the boredom rounds always appear immediately after the frustration rounds and rely on repetition. The player faces a powerful enemy for multiple rounds, but with a low reward. Unlike classical TD games, we eliminated the lives system. This ascertained that every player would play all rounds in the game, irrespective of individual advantage in performance.

Other benefits include the use of a static virtual camera that disallowed player movement but maintained rotation from the head-mounted display. This was made to minimize the potential for motion sickness. Player physical motion is also minimized, because the game action takes place in a virtual game table in front of the player. The camera's field of view was adjusted to encompass most of the game table's contents when gazing at the center of the table. Thanks to this approach, the player should naturally maintain a constant posture throughout the game, thereby reducing motion artifacts in the signal. Furthermore, the player can perform a finite set of actions, each corresponding to a single outcome. Thus, we can guarantee sufficient consistency across player actions and effects – the absence of outcome contingencies minimizes random or unanticipated effects that could confound the interpretation of the physiological data.

Overall, this design adheres to experimental standards and facilitates annotation of virtually any physiological data. The way we handled the conditions for frustration and boredom are purely indicative – other mechanics may also induce these affective states. Currently, we are in the process of collecting physiological data to validate the design of this game as a reliable test bed for flow, frustration, and boredom detection in VR.

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