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Developing a triangulation system for digital game events, observational video, and psychophysiological data to study emotional responses to a virtual character

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ABSTRACT

Game researchers are currently lacking comprehensive data analysis tools that triangulate game events, event-related survey data, and psychophysiological data. Such a tool would allow a comprehensive analysis of player engagement in digital games. The development of this tool was motivated by an experimental psychology study that asked whether emotional reactions to congruent and incongruent emotional stimuli within an intrinsically motivated game task are the same as within the traditional experimental picture-viewing paradigm. To address the needs of our study, we used the Source SDK (Valve Corporation) for creating a system that automates event logging, video management psychophysiological data markup. The system also allowed recording of self-report measures at individual play events without interrupting the game activity.

1. Introduction

Digital games are now employed in many research, science and technology areas. For example, games are suitable stimuli for experimental psychology, since virtual gaming environments allow experimenting with vicariously experienced situations that would pose ethical problems in real life or would be difficult or expensive to carry out. These studies use different methods of investigation, such as behavioral observation (often with video), psychophysiology, and psychometric questionnaires, and an automated solution for combining the different data sources in an easy and functional way is currently lacking.

Our system is an analysis tool created for the study of physiological responses to emotional expressions outside the regular picture-viewing paradigm. The tool creates time-framed video clips of relevant game events and presents them after an experimental session to the participant for recreating their memory of the experience at the event point in the game. The participant is then prompted to answer a questionnaire regarding this specific game event. This allows a triangulation between game events, phasic physiological responses, and self-report measures without interrupting the gaming activity.

To better understand how this experiment motivated the development of this system, we briefly describe the background and related work regarding this experiment. Since this paper focuses on the triangulation system, the experiment is presented as the motivation and as an example, but we do not present results from the study. Finally, we discuss how the system fit our needs for the experiment, and its potential and limitations in a larger context.

2. Background of the experimental study

The research setup for the study had players meet realistic but virtual human non-player characters (i.e., NPCs) in a virtual gaming environment and react to the artificial facial expressions and assumed action tendencies of these characters. Prior psychological research suggests that viewing an affective facial expression elicits – automatically and mostly unconsciously – a similar expression and emotion in the viewer [1]. Furthermore, it has been shown that complex stimuli of congruent (i.e., similar valence) or incongruent (i.e., opposite valence) emotions either intensify or dampen elicited emotions, respectively [2,3].

These basic results are based on controlled experiments where participants looked at pictures without any confounding factors. We wanted to study if the effect can be detected in virtual characters, but also in more ecologically valid situations (e.g., when players meet characters while doing intrinsically motivated tasks). To be comparable to earlier research, our experiment needed to include the recording of physiological responses to, and self-reports of, game events without disturbing gameplay.

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3. Related work

Incorporating different data streams is most advanced in game evaluation, as making sure a game system works flawlessly is vital to its success on the market [4]. A number of regular software testing approaches are used in the game industry, such as unit testing and bug tracking. Another popular game user research method is direct observation. For example, playtesting, where participants play the game while their gameplay behavior is being observed either by video or by a game user researcher directly [5]. Open-ended tasks allow participants to play the game as if they were at home without any instructions. The experimenter takes notes during the observation procedure and later discusses his observations with the game's designers so they can use this information to shape the design goal of the game [6]. A more research-oriented approach is the extended playtest, which collects survey data at time intervals over several hours of playtime. Recently, playtests have been automated at larger companies such as Microsoft Game Studios, where the TRUE (Tracking Real-time User Experience) instrumentation system makes the triangulation of player feedback data with videos possible [7]. However, this system falls short of integrating physiological data in this analysis, which could provide potentially important data for the evaluation process [8].

In human-computer interaction (HCI) research, various approaches within the area of affective computing [9] show promising approaches for user sensing and prediction of user emotions. Some of these machine learning approaches are becoming accurate at identifying emotional states, detecting a user's facial expressions [10], analyzing non-verbal behaviors, distinguishing pressure patterns [11], sensing body temperature [12], and discovering emotion from keystroke typing patterns [13]. While these approaches are likely to be helpful for automatically adapting games [14], affective information, especially psychophysiological inference, is seldom used in game user research. In a similar vein, physiological measures have only recently become more popular for assessing game engagement [15–17]. However, physiological measures are employed commonly in basic psychological research [18,19]. Self-report measures, common in game research, are traditionally administered at a different time than playing the game. Thus, they are separated from the experience of playing the game (e.g., in focus groups), happen after an experiment (e.g., interviews), or are administered after a certain time period in the experiment representing an experimental condition (e.g., session questionnaires). Therefore, the capability of self-reports to pinpoint particular responses to events in the game is limited because they rely on recall without visual aids to memory. Since it is difficult not to affect gameplay experience when interrupting the game, researchers have recently proposed game logging triangulation systems that are suitable for real-time, in-game physiological data logging [20] and in-game gaze [21] data logging with an eye tracker. Triangulation in these cases means the cross examination of three or more data sources for being more confident in the experimental result. Based on these prior systems, we designed the tool for our study.

4. Experiment background and game system development

4.1. Congruency experiment

The full details of the experiment and the study can be found elsewhere [22]. To understand how this experiment motivated the system development, it is described here in brief. The experiment was implemented as follows. The experiment had the participants (volunteers, $n = 40$, 21 male, age of 18–31, active game players) rescue captured non-player characters (NPCs). The NPCs had facial expressions that prompted a player to decide whether the NPC was positive (i.e., cooperative) or negative (i.e., hostile, see below). In addition to the facial expression, NPCs had an action disposition towards hostility to or cooperation with the player character, providing the second part of the congruent or incongruent stimulus. The action disposition was made unambiguous by presenting an on-screen marker (i.e., a password of the resistance movement in the game's fictional story frame). Thus, there were two main event types of interest, one where the facial expression was first viewed and the other one where the action disposition was made clear. Regardless of the expression, the participants were supposed (but not forced) to kill the hostile NPC and escort the friendly NPC to the safe place (the game level layout and player decision script, i.e., the anticipated game mechanic, is shown in Fig. 1). The research interest was on the responses elicited in the players by congruent and incongruent expressions and action tendencies of the NPCs.

4.2. Requirements analysis

The physiological responses (EDA, ECG, facial EMG, and EEG) were recorded during the entire experiment, but to get additional insights into participants' subjective motivations and gameplay experience, self-report data was required in the specific context of the relevant events. However, there are currently no methods to pinpoint a specific event in a series of game tasks for self-reporting without relying on interrupting gameplay and administering a questionnaire [7] or interviewing about the event retrospectively. An interruption would defeat the point of a more ecologically valid situation for the experiment and retrospective interviews have no visual aids to help player recall the game experience at the event, which makes them less reliable from a psychological viewpoint. Therefore, the technical requirements for the analysis software were to:

1. Provide a game environment for presenting the stimuli within an intrinsically motivated gaming activity.
2. Present the in-game stimuli (i.e., congruent and incongruent facial expressions and actions of natural human characters).
3. Provide a method for administering self-report measures without interrupting the activity.
4. Provide the ability for the game researcher to compare the self-report measures with psychophysiological responses at the event point (i.e., basic triangulation).

For the first two requirements we used an existing game and development Kit, but requirements 3 and 4 needed a new methodology. We finally settled with stimulated audiovisual retrospective self-reports. Retrospectively showing the participant selected video clips of the relevant events immediately after the game could serve as an audiovisual reminder of the actual experience. The self-report measures could then be administered after each clip to ask about that particular event (similarly to stimulated retrospective think-aloud method employed in usability studies; see e.g., [23]). By using an active reminder, the participants should be able to recall the events more clearly, recall their original experiences more accurately than without the audiovisual reminder. It was not clear, however, whether the video reviews of the game events would actually provide a sufficient reminder, whether the participants would actually imagine the gameplay experience and not use the video itself as a stimulus, or whether the imagined experience would be close enough to the actual experience. By additionally recording physiological responses during the review phase we could then compare the two physiological signals to each other, and to the self-report measures, to see if there were significant differences or if the procedure provided what it was designed to

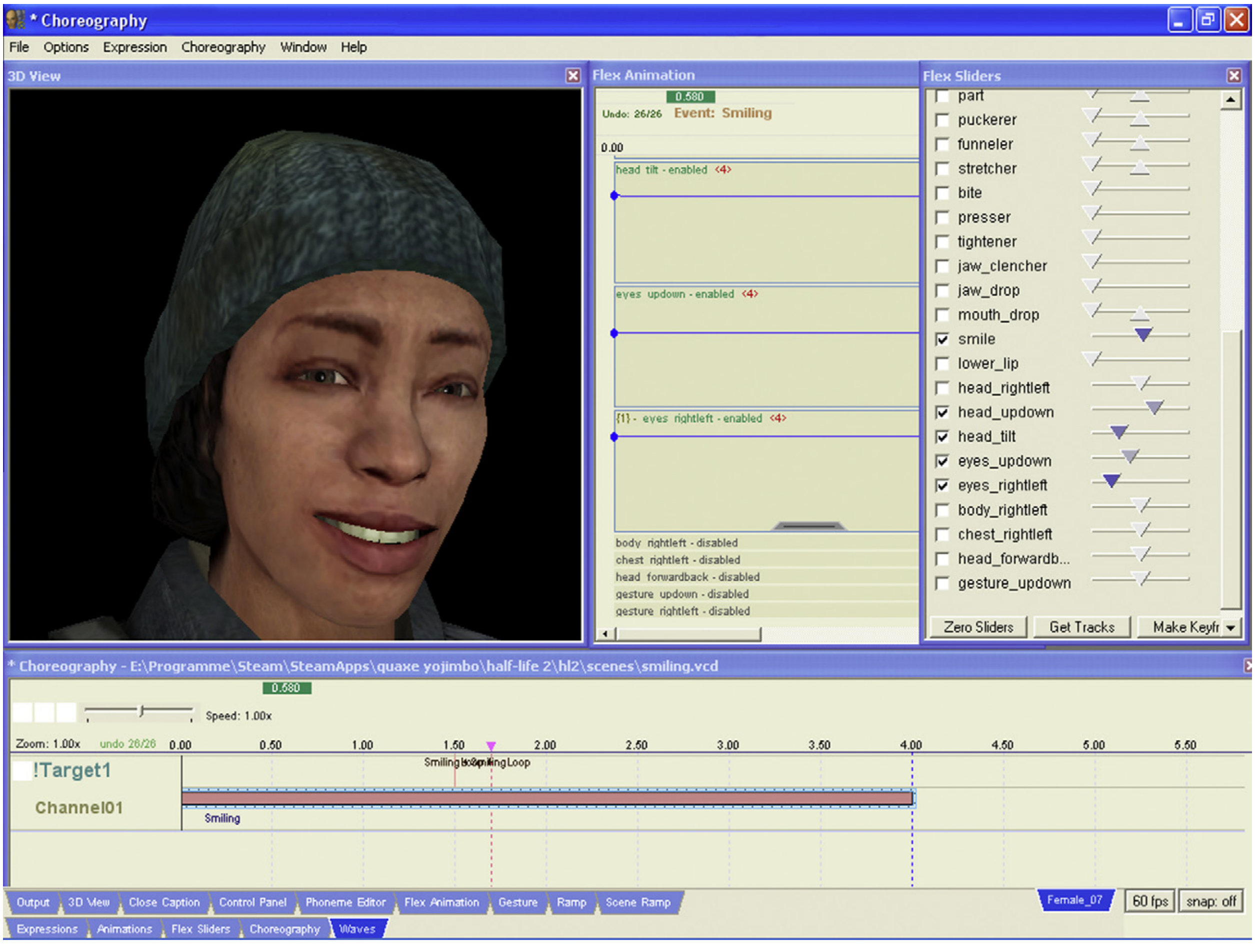

Fig. 1. The game level layout and the decision tree of the experiment game. The friend/enemy status and the facial expression of the Captured NPC (3) was varied in four combinations, and the participant was supposed (but not forced) to follow the decision tree presented in the figure regardless of the NPC's facial expression.

provide. Thus, to fulfill the requirements 3 and 4, additional requirements for the tool were to:

5. Provide markers for time-points of the events.
6. Automatically parse video clips of predefined length from the whole recording based on markers.
7. Present video clips (with an ability to replay) in conjunction with the text directions and show questionnaires immediately after gameplay.
8. Provide markers for time-points of video clip presentations (for later comparisons with physiological data).

4.3. Game stimulus and tool development

To fulfill the requirements 1 and 2 we chose the Source SDK (Software Development Kit of the game Half-Life 2) as a platform for stimulus game creation, since it was available for free (with the $20 purchase of Half-Life 2), shipped with visual level creation tools (i.e., Hammer Level Editor), a library of 3D objects (i.e., game assets), had a big online developer community, and full access to the source code of the game engine for integrating a customized logging system, and most importantly, a tool for creating the facial expressions of virtual characters (called Face Poser). Access to the game engine code itself was essential to be able to satisfy the requirement 5.

All the level and artificial intelligence (AI) scripting was done in the Hammer editor of the Source SDK, and only ready-made 3D objects and models were used due to time constraints. The smiling and frowning expressions for the characters were created with the Source SDK Face Poser, using Ekman and Friesen's [24] happy and angry faces as examples. Although, according to the developers, the Face Poser tool is based on Ekman and Friesen's Facial Action Coding System (FACS), it does not directly adhere to it (Fig. 2). The tool provided some default expressions, but they were not immediately suitable for use on the 12 different NPC models we planned to use. After tests with evaluators ($n = 6$) from our organization we settled with modified expression prototypes that would, on average, look more like the example faces [24] on all of the NPC models. To validate the created expressions, we asked the participants to separately assess the expressions after the experiment; the recognition of explicit expressions of anger and happiness (out of six basic emotions: anger, happiness, disgust, fear, sadness, and surprise) was still not excellent, as the anger was often confused with disgust or surprise (in case of 5 out of 24 pictures), and to lesser extent, fear (3 out of 24). Apparently the tilt of brow characteristic of anger was not sufficiently controlled in all – especially the female – NPC models, and the open mouth present in the example faces led to an unwanted interpretation (see examples in Fig. 3). However, when the expressions were not rated for the basic emotions but only for valence and arousal, they were reliably told apart by their valence (i.e., happy expressions were recognized as positive and angry as negative; $F(911.039) = 2366.095$, $p < .001$). As this was the main requirement for the congruency experiment, we considered the expressions acceptable.

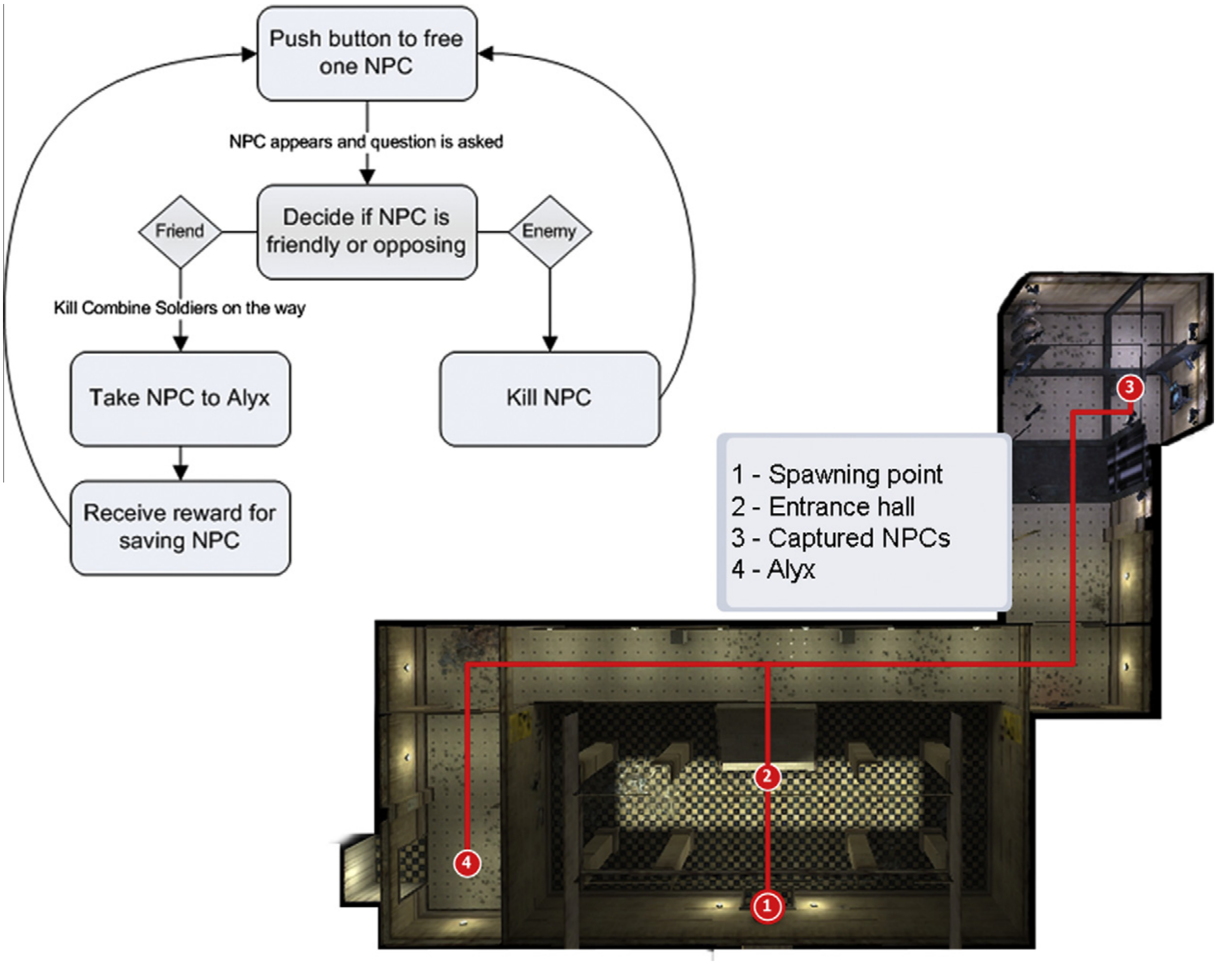

Fig. 2. A screen capture of Face Poser, Source SDK, a tool for creating facial expressions for virtual characters in Source environments. In upper right corner are the sliders controlling the virtual muscles, according to the developers based on the Facial Action Coding System [13], but not following it exactly.

4.4. Logging system for linking game events to physiological responses

We had to extend the Source SDK to provide additional necessary facilities for data logging in our experiment. The modified data logging software would log pre-defined events to the computer hard disk (containing additional information, such as time stamps and game parameter names) and simultaneously to the computer parallel port allowing synchronization of physiological or behavioral data recorders and game events. A physiological data logging principle for games first described by Nacke et al. [20] and Stellmach [23]. Relevant events could be defined in two ways: (1) low-level input and trigger events, such as key presses, could be defined in the code of the Source SDK, (2) high-level events such as looking at a virtual face, could be defined in the Hammer level editor through a level entity that would work as an event listener and sender in the game world.

The event-logging system consisted of two components: the transmission and the event components. The event component

Fig. 3. Examples of angry and happy facial expressions in stimulus game. Numbers 1, 3, 5, 6, 7, and 9 were presented as happy, and numbers 2, 4, 8, 10, 11, and 12 as angry expressions. However, numbers 8 and 11were often (mis)interpreted as surprised, number 4 as disgusted, and number 12 as fearful.

caught events from the game code and reported them to the transmission component, which was then responsible for communicating this signal to the parallel port [20]. Each data line of a parallel port (from a total of 8) can be turned on by a charge of 5 volts registered by the external trigger input of the psychophysiological data recorder, which equals a binary value of one for each line. Thus, unique decimal values from 0 to 255 can be transmitted via the 8 data lines of a parallel port. In our experimental setup, signals representing the events of interest were automatically transmitted to the psychophysiological data acquisition system, a Psylab Stand-Alone Monitor (Contact Precision Instruments, London, UK), via a connection to the parallel port of the game computer. In the game level environment, these 8-bit event code values were then referred to as event codes and each event code was deciphered using an externally saved event code key table with an individual description of each game event. Using this system, a precise logging of game events to the psychophysiological hardware was possible.

4.5. Video management system

To fulfill requirements 6–8, a separate system was developed, combining a commercial frame grabber and a custom video player. This would allow us to generate self-reports to events of interest using retrospective video that would be synchronized with the game event logging system. Fraps frame grabber software was used for video recording (Beepa P/L, Melbourne, Australia, 2007) with the capture rate set to 25 frames per second, and the resolution equalling the game's screen resolution. A custom software written in C++ recognized the key to start Fraps and saved a timestamp to the data log. After the recording finished (i.e., after each playing session), our software parsed the video file along with the game logs, and predefined game events were extracted by calculating the time of all desired video clips from the timestamps in the log in relation to the start time of the frame grabber. This also meant that the events were shown in the same order they occurred during gameplay, to provide more clues for recalling the original event. The timeframe of events was set to 2 s before the event and 4 after it, the shortest possible time for participants to recognize the event and all the physiological signals to operate within. Video clips were created while the participant answered the self-report questionnaires about the general experience (Game Experience Questionnaire [25]) and read the directions for the next phase of the experiment, so there was no waiting time for participant. The participant was directed to watch the video as a reminder of the original experience, and after it answer a short questionnaire on the emotions elicited by it (Self-Assessment Manikins [26] and a shortened PANAS scale [27], adapted specifically for the relevant event type by the software). Each review video of a game event was practically identical to the corresponding game event in audio and video modalities to provide the best possible reminder of the original game experience.

5. Discussion

The system described in this paper enabled the participants to self-report experiences of game events by reviewing them from automatically created video clips and using questionnaires about the events. This was expected to greatly increase the accuracy of self-reports for a given event compared to questionnaires administered after the experimental session without any reminder of the event. Preliminary results suggest – despite technical problems originating from separate developers and some workarounds – the (in)congruency effect (between facial expressions and action dispositions) could be found in both physiological and self-report data using our stimuli. In principle, the system satisfied the requirements we had for the experiment. In addition, experimental results suggest that the virtual character during an intrinsically motivated task was viewed by the participants in similar way that we know people normally view real humans, and speaks for using a game environment for studying questions of experimental psychology.

The logging and video management system ensured that we could administer questionnaires on individual events of interest, without the need to disturb the participant during the game. This system is a promising way to arrange experiments where the activity cannot be disturbed, but the self-report measures have to be directed at specific events and not the whole experience. This is potentially useful for experiments in digital game research and other media psychology.

Using an event-based paradigm for psychophysiological game research has a few inherent limitations. First, the parallel port interface allows only for 256 different events to be encoded using the 8-bit event codes. A general technical advice for game experiments is to log everything possible in the system under investigation, so that all research questions can be answered without rerunning the experiment even if further data is required for a more extensive analysis. So, while the number of events might be limited using this system, it is questionable whether a large amount of event codes can be analyzed effectively in psychophysiological data. This in turn shows a second limitation of event-based studies: the time between events needs to be sufficient to provide meaningful data for analysis. Repetitive events, such as keypresses might follow too quickly on one another, which could result in a complicated analysis, given the slow responsiveness of some physiological measures such as skin conductance. Although, event based studies have these limitations, they can provide a fine level of psychophysiological analysis not provided by other game evaluation techniques.

There are some previous examples of using digital games for experimental psychology, but mainly they have used simple games (e.g., [28,29]), which limits the space of possible research questions. Another issue are experimental game designs that are too simplistic to be considered games since they do not provide the playability and intrinsic motivation that would convince people that this is not just an experiment (e.g., [30,31]). Of course there is always a tradeoff between natural gameplay and strict control of the experiment, but the limitation can be mitigated by a design that provides gameplay in addition to the experimental setup.

Although modern game creation Kits such as the Source SDK and the Unreal Development Kit (UDK) provide tools for quite realistic environments and human characters and they allow creating plausible games instead of simply a virtual environment, they still require programming skills and development resources not often available to all researchers. Another possibility is for researchers to find a game that already uses stimuli that could be used in their study, thus not having to create their own game. This in turn requires specialized previous knowledge of available games, and still potentially means scouring through dozens of games in hopes that one of them had the features needed, or that the research question is tailored to suit the features of the game and not the other way around. Despite this dilemma, it seems that at least according to the (in)congruency phenomenon under investigation in our experiment, game characters can be used instead of real persons to study human behavior and that our approach of study was time and resource efficient.

By recording physiological responses during the original gameplay and while reviewing the events, we are able to compare the results of the self-reports to both recordings and verify whether retrospective stimulation actually can serve as an effective audiovisual reminder for the original experience, although these analyses are not yet ready. If the method of stimulated retrospective self-reports is found valid and reliable, it will provide an important tool for studying gameplay experience. Until now, tapping into individual game events has been impossible without disturbing gameplay and therefore potentially contaminating the experience with outside influence. The methodology presented in this paper could potentially be used also in game evaluation, which is a vital part of game development. Retrospective think-aloud methods have sometimes been used, but our method provides a more focused and less actively demanding way with higher data-precision, if evaluation for individual events is needed.

An additional way to implement our solution would be without the psychophysiological equipment. As it was a requirement only for our specific research questions, the absolutely necessary software consists of a video management system that – when given the video file, event times and types, and predefined settings based on different event types – can present the video clips of the original events immediately after gaming, and combine questionnaires with them. We solved the problem of getting the event times by extracting and logging them directly from the game. This saves the researcher time compared to marking them approximately while observing the game from another computer (via a clone screen). This could be a useful methodology for many human interaction experiments in social psychology, where the interaction between people could be recorded on video, and the exact starting time of the event of interest is not paramount.

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