Conducting an Experiment for Validating the Combined Model of Immersion and Flow

Ehm Kannegieser[1], Daniel Atorf[1] and Josua Meier[2]
[1]Fraunhofer Institute of Optronics, System Technologies and Image Exploitation, Fraunhoferstraße 1, 76131 Karlsruhe, Germany
[2]Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany

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Abstract: Detecting high intrinsic motivation and Flow states is key for successful adaptation processes that may be used to improve learning outcome in Simulations and Serious Games. Until now, the method of choice to measure Flow, is the usage of questionnaires. Because of the shortcomings of this method, the ultimate goal is, to establish an alternative measuring method through correlations of physiological sensor data. Beforehand, the theoretical model of Flow is enhanced with the more fine-grained model of immersion plus the design and implementation of an experiment to validate said model is introduced. In conclusion a perspective towards preliminary test results and upcoming data analysis is given.

1 INTRODUCTION

Education is one of the biggest challenges of the 21st century. What better way to improve it than using the vast amount of technology available to us today. A successful tool aiding in education are "Serious Games" (Girard, Écalle and Magnan, 2013), games which do not put entertainment value in the front, but rather focus on achieving learning experiences in players. One of the biggest questions in the field of Serious Game analysis is: How can this learning effect be improved? Previous studies find that the learning effect of Serious Games is linked to the fun they provide to players (Deci and Ryan, 1985; Krapp, 2009). Thus, the question becomes, how can fun be improved? And based on that, how can fun be measured?

When looking at the raw definition of fun, becoming voluntarily engrossed into an activity, similarities can be found to the definition of Flow given by Csikszentmihalyi (Csikszentmihalyi, 1991), which describes the optimal enjoyment of an activity. As such, Flow becomes an interesting measurement when analysing the fun experienced during gameplay (Beume et al., 2008). In order to better measure the range of the immersive experience, the sub-optimal state of experience, Immersion, is also looked at. Flow and Immersion are described in more detail in sections 2.1 and 2.2 respectively, but for general purposes, they can be thought of as states of high concentration on the game. By measuring these states, Serious Game developers can make judgements about how fun, and respectively, how much learning value is provided by their game.

However, there are still problems when using this approach. As they are subjective experiences, measuring Flow and Immersion is difficult. The current approach to measure them is based on questionnaires (Nordin, Denisova and Cairns, 2014). These questionnaires can either be used during the game – disrupting the player's concentration – or after the game, leading to imprecise results. Additionally, questionnaires can only elicit subjective measurements, further degrading the quality of the data gathered.

For this reason, the development of a system for automatic measurement of Immersion and Flow becomes increasingly interesting. Instead of using questionnaires filled out by participants, this system uses the player's physiological measurements to determine their current Flow/Immersion state. In this paper, a study towards the development of such an automatic measurement system is presented. The study attempts to link the experience of Flow and Immersion in participants with reactions in their physiology. First, a combined model of Flow and Immersion is presented in section 3.1 in order to

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measure the player experience in games in better detail. The experiment structure is presented in section 3.2. Section 4 presents how physiological measurement data is used in evaluating the study, as well as approaches for evaluating the model and the physiological measurement data with Flow. In section 5, the validity of the study is analysed based on internal and external factors. Finally, section 6 presents a conclusion and a future outlook.

2 RELATED WORK

2.1 Flow

The definition of Flow was first brought up by Csikszentmihalyi and is commonly known as the state of optimal experience of an activity and a state of great concentration (Csikszentmihalyi, 1991). In the context of sports, Flow might also be known as being “in the zone”. Temporal and spatial dissociation are the main symptoms of having reached the Flow state. The concept of Flow is based on the intrinsic and extrinsic motivation model of behavioural motivation, which describes that actions can either be motivated based on external factors, such as money or fear of reprimand, or internal factors when performing an action for the joy of the action itself. Based on this intrinsic motivation, Csikszentmihalyi considers the optimal way to experience and enjoy an activity as one that is intrinsically motivated and fulfils a certain set of requirements. He first describes this in a three-channel model, showing that a fine balance between skill of the person and challenge of the task at hand must be achieved in order to reach the Flow state. What makes Flow special is that compared to passive enjoyment of an activity, the Flow state enables people to enjoy even traditionally taxing actions such as demanding work.

All this makes Flow an interesting research topic for video games. Unlike television or regular books, games are meant to be enjoyed through active participations. Furthermore, the Flow state is similar to the effect experienced by many players, including loss of a sense of time and spatial awareness. In order to study the Flow state in games, Sweetser and Wyeth map Flow to games in their Game Flow Questionnaire, mapping the original components of Csikszentmihalyi’s Flow model (Sweetser and Wyeth, 2005). This Game Flow Questionnaire is later adapted into the EGameFlow questionnaire for use with Serious Games (Fu, Su and Yu, 2009).

Other variations of Flow questionnaires exist. Rheinberg et al. design a Flow questionnaire to be used iteratively and multiple times to elicit the Flow state in rapid succession due to its low amount of questions (Rheinberg, Vollmeyer and Engeser, 2003). While it was originally for use with sports, its questions are formulated in a way that it can also be used in general purpose environments.

Flow is generally measured using questionnaires. Attempts to link the Flow state with physiological measurements have been made in the past but have not yet reached a level that they can fully replace questionnaire elicitation. For example, Cheng measured Flow in relation to eye movements and found that a lower amount of rest points may be an indicator towards increased Flow (Cheng, 2014).

2.2 Immersion

When talking about Immersion, it is important to realize that there are two concurrent definitions of Immersion being used in parallel (Zhang, Perkis and Arndth, 2017). The first definition of Immersion is based on the term presence and refers to the feeling of being physically inside a virtual world. The second definition, which will be used throughout the rest of this paper, is engagement-based Immersion and is based on the effects of an activity on a person, similar to Flow. As such, it has been called “the sub-optimal experience of an activity” in reference to Flow as the “optimal experience of an activity”.

Unlike with Flow, which is defined by the definition given by Csikszentmihalyi (Csikszentmihalyi, 1991), there are multiple different approaches to defining and measuring Immersion. Ermi and Mäyrä define Immersion based on three dimensions in the model presented in their paper (Ermi and Mäyrä, 2005). The first dimension, sensory Immersion, refers to the visual and auditory presentation of the game as the player takes it in. The idea is that a game with better visuals and audio will be better at immersing players in a virtual world, whereas poor visual and audio quality will distract from the experience presented. The second dimension, imaginative Immersion, is based on story elements and the world of the game. Finally, the third dimension, challenge-based Immersion, is based on the player’s engagement with the game world. Its definition is synonymous with the definition of Flow given by Csikszentmihalyi in that it refers to a balance of skill and challenge to reach a higher state of focus. However, it does not include the state of apathy, added by Csikszentmihalyi to refer to situations in which both skill and challenge are low. The model described by Ermy and Mäyrä is special in that it defines both a dimension based on player engagement, challenge-based Immersion, and two dimension based on analysing the game, imaginative Immersion and sensory Immersion.

The most exhaustive analysis of engagement-based Immersion is given by Cairns et al. in their series of papers (Cairns et al., 2006; Jennett et al., 2008). They define Immersion as a hierarchal model with three levels, each level representing a higher level of Immersion. The first level, engagement, refers to the basic idea of interacting with a game. The second level, engrossment, is reached when players become emotionally involved with the software presented, either positively or negatively. In this state, controlling the game starts feeling completely natural and input devices such as the mouse or the keyboard are no longer consciously part of the experience. The final level, Total Immersion, is reached when players completely become in sync with their avatars in the game and lose their sense of both time and of their surroundings completely.

The weakness of the model presented by Cairns et al. is that while it presents a way to measure Immersion, it can make no statement about which level of the Immersion hierarchy players are in at a given moment. Cheng et al. improve this model by adding dimensions to each levels of the hierarchy (Cheng et al., 2015). The first level engagement is broken down into the three dimensions attraction, time investment and usability. Attraction refers to the ability of the software to make users use it. Time investment refers to the entry barrier of the first Immersion level, which is spending time with the application. Usability refers to the software being usable, as non-usability would prevent user engagement. The second level, engrossment, consists of emotional attachment and decreased perceptions. Emotional attachments can be either positive or negative. Decreased perceptions refers to the loss of sense of time and loss of spatial awareness. The highest level, Total Immersion, is split into the two dimensions presence and empathy. Presence refers to the concept presented in the beginning of this section, the feeling of being present in a virtual location despite physically being present in the real world. Empathy refers to the level of connection with the player avatar and describes a state in which the player can feel the emotions experienced by the avatar in the game. They also present their findings in form of a questionnaire for measuring Immersion.

2.3 Flow vs Immersion

When looking at the definition of engagement-based Immersion as a hierarchical construct by Cairns et al. and Cheng et al., a large amount of overlap can be seen with the Flow definition presented by Csikszentmihalyi in section 2.1. Both definitions have requirements corresponding to the player feeling in control and being presented with an adequate challenge. Both Flow and the two higher levels of the Cairns et al. Immersion model lead to an experience of real-world disassociation, containing both a loss of a sense of time and spatial awareness. The most curious overlap is presented in the highest level of Immersion, Total Immersion. In that state, players appear to be cut off completely from the outside world. This sounds similar to Flow, which has similar symptoms. In fact, Georgiou and Kyza define the empathy dimension of the extended model presented by Cheng et al. in section 2.2 as Flow, considering it as part of the Total Immersion state (Georgiou and Kyza, 2017). The main difference between Flow and Immersion is that Flow does not consider the player's emotional involvement in the game. A comparison between the components of Flow and Immersion is presented in table 1:

Table 1: Comparison between Flow and Immersion.

Flow	Immersion
Task	The Game
Concentration	Cognitive Involvement
Skill/Challenge Balance	Challenge
Sense of Control	Control
Clear Goals	Emotional Involvement
Immediate Feedback	
Reduced Sense of Self and of Time	Real World Dissociation

3 ONGOING RESEARCH

3.1 Proposed Model

One of the proposed ideas in this paper is a combined model of Flow and Immersion (Kannegieser, Atorf and Meier, 2018). For that purpose, the Flow model as described by Csikszentmihalyi and the engagement-based Immersion model described by Cairns et al. are used. Cairns et al. have three layers in their Immersion model, engagement, engrossment and Total Immersion. The highest Immersion states, engrossment and Total Immersion, share similar phenomena, such as a loss of a sense of time and a loss of spatial awareness. As such, a model is proposed, in which Immersion is a hierarchical structure and Flow is a state at the top of the hierarchy. The proposed model is shown qualitatively in figure 1. This figure shows the relationship between increased Flow and the Immersion levels defined by Cairns et al. However, it must be noted that there is no relationship between the skill/challenge balance and Immersion.

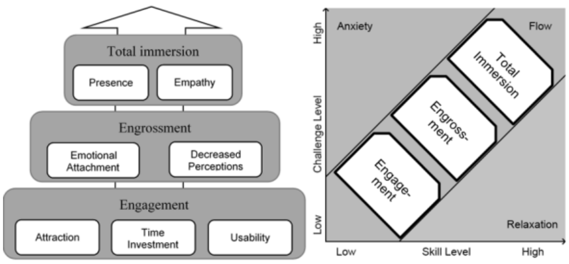

Figure 1: Hierarchical Immersion model presented by Cairns et al. and improved upon by Cheng et al. (left). Proposed combined model of Flow and Immersion. Qualitative view, the skill/challenge balance does not influence Immersion.

3.2 Experiment

The experiment presented in this study has two goals. First, the validation of the combined model of Flow and Immersion. Second, gathering physiological data that can be used to find a correlation between physiological measurements and Flow/Immersion states.

3.2.1 Physiological Measurements

Special care has to be taken when selecting physiological metrics for use in a Flow experiment. Certain types of measurement may hinder the Flow experience and distract participants from becoming immersed in the game. For this reason, metrics were chosen that could be measured with a minimum of intrusion and promised to yield relevant results.

The first physiological measurement type used is Galvanic Skin Response (GSR). GSR measures skin conductivity based on two electrodes placed on the body. This metric was chosen due to being a useful indicator in other psychological states, most notably arousal (Mandryk and Atkins, 2007). Usually, GSR is measured with electrodes placed on the hand, but since hand movements would cause problems when recording data, foot measurement provides an alternate measuring possibility (Gravenhorst et al., 2013). The skin conductance signal consists of two different signals which are overlaid on top of each other. One signal which changes quickly in response to stimuli over seconds, and one signal that changes slowly over minutes. The sensor used to record GSR during the experiment is the Shimmer3 GSR+ unit. It works using Bluetooth, which means participants do not get obstructed by cables placed around their legs. During test runs, participants have noted that they no longer realized they were wearing the sensor, suggesting it does not hinder the Flow experience.

The second measurement type used is an electrocardiogram (ECG). Like GSR, ECG was used successfully in previous studies regarding physiological states, which made it interesting for the study (Mandryk and Atkins, 2007). An ECG is used to measure heart muscle activity from different angles and can be used to extract heart rate and amplitude. It is measured using electrodes place in the chest region. For the experiment, five electrodes were used. The sensor device used in the experiment is the Shimmer3 ECG unit. Like the GSR+ unit described above, it was chosen due to its lack of cables, making the measurement device less noticeable when participants are wearing clothes.

The third measurement type is eye tracking. During gameplay, player’s eye movements on the screen are recorded. Eye movement is divided into saccades, the movement, and fixation points, on which the gaze is focused. Previous work in the research has linked a lower number of fixation points to higher Flow (Cheng, 2014), making this measurement an interesting observation point. As measurement is taken indirectly, it does also not influence Immersion and Flow states. The camera used in the experiment is the Gazepoint GP3 tracker.

The final measurement taken is web cam footage of the player playing the game. Using this footage, emotion recognition can be performed. The weakness of this approach is that only emotions clearly displayed on the face of the participant can be elicited with great confidence. Other options for emotion recognition, questionnaires and a facial EMG are considered too distracting when playing games. Electrodes on the face were found to be harder to ignore than electrodes placed below clothes on the chest. A full-HD camera records the centrally positioned participant.

3.2.2 Experiment Structure

The experiment structure is based on a previous experiment designed for measuring Flow in Serious Games using physiological measurements (Atorf, Hensler and Kannegieser, 2016).

The number of participants chosen for the experiment is 40, as this number is similar to the number of participants used in other experiments in this area (Cairns et al. 2006, Jennett et al., 2008). There were no requirements for participants, as the experiment is aiming for as close to a random selection as possible.

The experiment consists of three phases. During the setup phase, the game is selected, and the sensors are placed on the participant. Game selection is free. Participants can bring their own games or use a distribution platform like Steam to install a game of their choice. Free game selection was chosen to improve the odds of players reaching higher Flow and Immersion states, at the cost of game-specific analysis options.

During the second phase of the experiment, the gaming phase, participants play the game for 30 minutes. The duration was chosen based on test runs, as 30 minutes were found to be enough to reach the Flow / Total Immersion state. While the participant is playing, the physiological measurements presented in 3.2.1 are recorded as well as gameplay footage.

Finally, during the assessment in the third phase, participants watch a recording of their game session as well as web cam footage of themselves. While watching this footage, Flow and Immersion questionnaires are filled out about how immersed the participant was at the time of the recording. By making participants fill out questionnaires while watching a recording, more accurate data can be gathered without interrupting the Flow/Immersion during the game session itself to fill out questionnaires. A similar approach using video footage is used in the study by Rajava and Kivikonga (Ravaja and Kivikonga, 2008). Three questionnaires are used in the experiment, with one of them being split into two parts.

The first questionnaire used is the Immersion questionnaire presented by Cheng et al. based on their improvement upon the hierarchical model presented by Cairns et al. (Cheng et al., 2015; Cairns et al. 2006). The questionnaire was chosen, as it can be used to measure the likeliness to be in each of the individual Immersion levels, making it useful to compare Flow with Total Immersion to test the theorized model presented in 3.1. In order to track the participant's movement within the different Immersion levels, the Immersion questionnaire is asked every three minutes during the recording. However, test runs proved that the Immersion questionnaire was too long at 17 bullet points. Due to this, the quality of the responses given by participants deteriorated. The questionnaire was split into one immersive tendency part with ten questions that is asked at the beginning of the assessment phase, and one iterative part with seven questions that is asked every three minutes. The questions were chosen based on their contribution to determining which state players are in, and the questions with the most contribution for each dimension were put into the iterative questionnaire.

The Flow questionnaire used in the experiment is the Short Flow Scale Questionnaire developed by Rheinberg et al. (Rheinberg et al., 2003) It was chosen due to its low amount of ten questions. While it was originally designed for use with sports, its method of measuring Flow for activities is formulated in a general-purpose sense. During the experiment, social factors of online games are not taken into account, meaning the social component the GameFlow questionnaire adds to the original Flow model can be ignored for this setup. The Flow Short Scale questionnaire is asked every six minutes, along with every second elicitation of the Immersion questionnaire.

Finally, the third questionnaire used in the assessment phase is the Game Experience Questionnaire (IJsselsteijn, de Kort and Poels, 2013). It is used as a support questionnaire alongside the other two questionnaires. It is not focused on Flow or Immersion but asks a wide range of questions about how the participant felt during the game session. By gathering more general info about the player experience and linking it with the Flow/Immersion data measured, new insights can be provided in what experiences facilitate a higher Flow or Immersion state. The questionnaire is asked once after the video playback of the game footage has concluded.

An overview of the different phases is presented in figure 2.

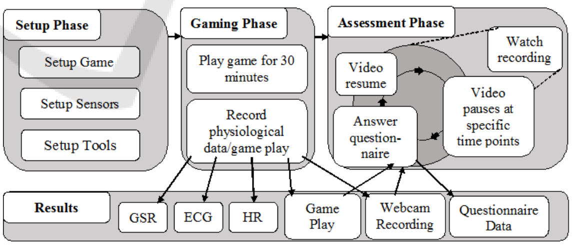

Figure 2: Phases of the experiment.

4 RESULTS

4.1 Preparing the Physiological Data

When working with GSR values from participants, the first step is normalizing the data in a way results from different participants can be compared reliably. Normalization is performed by treating values of the skin conductance measurement as a percentage of the participant's minimum and maximum value (Mandryk, 2008; Lykken and Venables, 1971). The normalization equation follows to:

$$GSR_{norm} = \frac{GSR_i - GSR_{min}}{GSR_{max} - GSR_i} \times 100$$

After this normalization, the calculation becomes a regular correlation analysis.

Evaluations regarding ECG focus on calculating heart rate changes. For this reason, both heart rate changes and heart rate standard deviation are calculated from the signal. Heart rate is calculated using the time between two consecutive maximums in the signal. This can be achieved by comparing sum-differentiated peaks and threshold detection. Based on (Pan and Tompkins, 1985).

Based on previous studies, the most interesting aspect of eye tracking is the number of fixation points. The input data are gaze points of the player, in order to remove noise and get the final amount of fixation points, a spatial threshold is used as outlined in the thesis presented by Olsson (Olsson, 2007).

Emotion recognition data is based on the web cam footage recorded during the gaming session. First, for every second of the video, a cropped image of the participant’s face is generated. This cropped image is scaled to 256x256 and used as input for a pretrained Convolutional Neural Network that recognizes emotions in cropped face images (Levi and Hassner, 2015). As the web cam footage features players frontally, this CNN delivers good results for the data presented. The output of the net are probabilities for the seven states anger, disgust, fear, happiness, neutral, sadness and surprisedness.

4.2 Model Analysis Approach

The original assumption of the Flow/Immersion model presented in this paper is that Flow and Immersion are distinct concepts, and that Flow is considered the final state of the Immersion hierarchy. From this definition, it is assumed that Flow and the Total Immersion state strongly correlate. This result can be proven by correlation analysis between the Flow questionnaire results and the Immersion questionnaire results. For this correlation analysis, Spearman rank correlation is used. When correlating questionnaire results, one problem that comes up during correlation analysis is that, they can only produce discrete results. This makes Pearson analysis impossible if questionnaire results do not follow a normal distribution (Sullivan and Artino, 2013). For this reason, Spearman analysis is chosen for the correlation analysis. For each Flow questionnaire, a normalized Flow value describing the likelihood for the participant to be in Flow is calculated. This Flow value is compared to the values of the three Immersion levels calculated from the corresponding Immersion questionnaire.

4.3 Physiological Analysis Approach

The first test when checking how physiological measurements can be used to determine Flow and Immersion is to look at the direct correlation between the measurements taken and the values calculated by the Immersion and Flow questionnaires. The metrics used in this correlation are the ones described in section 4.1. Based on the raw correlation results, further steps can be taken to measure Immersion and Flow using physiological metrics.

First, these metrics are directly correlated to the Flow and Immersion questionnaire results using the Spearman correlation method explained in section 4.2. These coefficients may still be too low to use them as standalone indicators for measuring Flow, however, their existence may help towards finding future connections.

The first advanced technique used to try and link Flow with physiological measurements is fuzzy logic. Mandryk and Atkins took a similar approach in their measurement of arousal and valence using GSR, ECG and EMG values (Mandryk and Atkins, 2007). Using fuzzy logic rules, new values are created using the measured metrics. For example, excitement is defined as high GSR AND high HR, meaning the minimum of both values. Using this approach, a set of rules is defined and correlated with Immersion and Flow. The main difficulty with this technique is coming up with useful rules based on the raw correlation results. If a correlation between physical measurements and Immersion exists, it may be harder to find than having an expert define a set of rules.

The next idea is to build a classifier via the data that was gathered in the experiment. Using deep learning, a relation can be found between its input features and the two classes called Flow/non-Flow, which are separated by a threshold value based on the questionnaire value. For this purpose, physiological data is generated for every second of the experiment that was measured. Flow and Immersion are extrapolated over the intervals they cover, three minutes and six minutes, respectively. The next step becomes selecting the input features used in the net. For GSR, these features are the mean, the standard deviation, the maximum, the minimum, the maximum ratio, the minimum ratio, the mean of negative values and the ratio of negative values. These values are calculated for the first and second order derivatives as well. For heart rate, the mean and standard deviation are calculated for the signal itself and its first and second order derivatives. Eye tracking is represented with its amount of fixation points, as well as a heat map of fixation points and how often they have been visited. The final set of features analyzed is the cropped face image of the participant's web cam recording.

5 CRITICAL ANALYSIS

5.1 Internal Validity

There are several factors that need to be taken into consideration when regarding the internal validity of the study performed. As the study was short in length, with randomly selected participants, effects that usually occur in studies running over a longer period do not appear. Maturation, the changes in participants over time, Mortality, participants dropping out during the study, and repeated testing, influences when repeating the test multiple times, can be ruled out as threats to internal validity. As the study took place over four months, history might provide a threat to internal validity. External influence that changed over time is the weather, which was hot in summer, but less so in autumn. Measures were taken to reduce the influence outside weather has on the experiment via heat regulation of the room the experiment was performed in. Instrumentation was kept consistent during the experiment. Fixes to the experiment setup were made based on test runs performed before the real study took place.

Participants were not filtered and are self-selected. As such, there might be a bias towards people who enjoy playing video games, and who have time to participate in the study. Selection interaction between participants informing other potential participants of the experiment has happened, but as all participants received the same information before the experiment started, this does not influence the result of the study. As participant selection was not chosen based on the observed variables, Immersion and Flow, Statistical Regression does not become a problem either.

As participants have no way of knowing their own physiological measurements during the experiment, they are unable to fill out questionnaires with a meaningful bias either in favor of the hypothesis or against it. Participants are not informed of the goal of the study to further link Flow and Immersion, so they do not introduce any bias when filling out both Immersion and Flow questionnaires at the same time.

5.2 External Validity

External validity refers to how generalizable the results found in the study are. The experiment presented in this paper puts a strong focus on making its result transferable to a large number of situations. Games are self-selected by participants, erasing the problem of results presented in this paper being valid only for a game or a genre of games. The games chosen by the participants were spread across different game genres. Results also transfer well to the general population, as participants were selected randomly. However, as they are self-selected, they may introduce a bias towards people interested in games.

The effects of the experiment environment were attempted to be kept to a minimum. Of course, the experiment computer differs from the personal computer participants use at home, but having participants bring along their own gaming hardware would have increased the experiment duration and effort unreasonably. External influencing factors, such as noise or irritating lighting were avoided. Participants wear either full size headphones or in-ear headphones, based on their preferences. This helps block out noise, so results in the Immersion experiment may not transfer well to situations in which these quiet, non-disturbing conditions cannot be achieved.

6 CONCLUSIONS

In the previous chapters, a study for linking physiological measurements and Flow/Immersion is presented. Preliminary results suggest that those physiological measurements show no direct correlation to Immersion levels or Flow. A more complex system for evaluating these physiological measurements is needed in order to gather meaningful results. The deep learning approach presented in chapter four promises to deliver useful results based on the input features selected.

In section 3.1, the theory that Flow and Immersion are linked is presented, which states that Flow is observed along with Total Immersion, making it the optimal experience of an activity compared to the sub-optimal experience of an activity provided by the hierarchical Immersion model. Preliminary results support this theory. However, more in-depth correlation analysis is needed to make further statements. Future focus of this research will be put on analysing both the model and the physiological data that was gathered with the help of the deep learning strategy presented in chapter 4.

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