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# Measuring Flow: Perceived Emotions & Arousal-Valence

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## ABSTRACT

Deep focus states, like Immersion and Flow are important parameters when it comes to an enjoyable experience during learning activities. To measure these mental states usually self-assessment questionnaires, answered by the subject after the experience, are used. Because of the shortcomings of this method, the ultimate goal is to establish an alternative measuring method through correlations of physiological sensor data. Exploring the Physiology of deep focus, in the course of prior studies, physiological data of participants was recorded during activities and inspected for correlations with Flow and Immersion. By broadening the experimental scope, this paper explores the effect of participant's emotions on reaching states of deep focus.

**Keywords:** Flow, Arousal, Valence, Emotion, Measurement

## INTRODUCTION

One of the central questions in games research and psychology and of particular interest for the development of serious games is how video games are perceived as enjoyable, more so how this fun can be transferred into learning or working contexts, as enjoyment is proven to be linked to an effective learning process (Deci and Ryan, 1985; Krapp, 2009).

Mihály Csíkszentmihályi defined "the optimal experience of an action" as Flow, which is achieved when the individual is so engrossed in the activity that nothing else seems relevant anymore. It is a deep sense of enjoyment, that occurs when a "person's body or mind is stretched to its limits in a voluntary effort to accomplish something difficult and worthwhile" (Csikzentmihaly, 1990). A similar experience in the video game domain is commonly called Immersion, describing the transfer of consciousness into a virtual world. Cairns et al. define game Immersion by dividing it into three levels: Engagement, Engrossment, and Total Immersion. These levels are used to describe the degree of involvement with the game (Brown and Cairns, 2004; Cairns et al., 2006).

Both Flow and Immersion are linked to an intrinsic motivation in the task or game, which means deriving enjoyment from the action itself rather than from external gains like money or a fear of punishment for not completing a task. Due to the similarities of definitions and conditions for Immersion and

Flow, authors suggest on unifying and not separating both terms for further research, especially in the video game domain (Michailidis et al., 2018).

## RELATED WORK

A model combining Immersion and Flow, based on the definitions by Csíkszentmihályi and Cairns, was proposed (Kannegieser et al., 2018) and later extended by additional emotional dimensions in 2021 (Kannegieser et al., 2021). Traditionally, questionnaires have been used to measure Flow and Immersion, but this method has limitations such as potential inaccuracies due to delayed elicitation and subjective answers. An alternative approach to measure deep focus states could be to record subjects' physiological data during an activity and analyze correlations between the physiological data and states of Flow and Immersion. This could establish a more robust and objective measurement method, potentially making questionnaires obsolete. One particular area of interest is the measurement of brain activity using electroencephalography (EEG), which non-invasively records electrical brain activity from the scalp. EEG is easy to use in medicine and research and provides valuable information on the mental states of subjects (Kannegieser et al., 2021).

## STUDY

In order to assess and understand perceived flow, an experiment has been designed using video games to induce a flow state and questionnaires to assess perceived emotions. During the experiment, the subjects' physiological data from various sources (e.g., heart rate, skin conductance and electroencephalography) are also recorded.

## PROCEDURE

A study was conducted with 23 self-selected participants, who all had at least some experience with video games in the past. Game selection was free, i.e., participants were allowed to 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 levels, at the cost of game-specific analysis options.

Participants played their chosen game for 30 minutes, during which physiological data was recorded. Among other data sources, heart rate and skin conductance were measured using the Mionix Naos QG mouse. After playing, participants watch a re-cording of their game session as well as web cam footage of themselves. While watching this footage, they answer questionnaires about their mental states during the time frames they just watched. This way, more accurate and time correlated data is gathered without interrupting the flow during the game session, as shown in a similar study by Rajava and Kivikangas (Rajava and Kivikangas, 2008).

## ANALYSIS

Perceived flow was measured every two minutes using the flow short-scale questionnaire by Rheinberg (Rheinberg et al., 2003). It was originally designed for being used multiple times in a row, making it perfect for this iterative approach.

The study was originally designed to understand the relationship between flow and immersion in addition to physiological data. As such, arousal and valence were not directly part of the questionnaires. However, perceived valence could be inferred from a question within the used immersion questionnaire by Cheng (Cheng et al., 2015), which specifically asks players how much they liked to play the game in the given time frame.

Arousal on the other hand could not be inferred in a similar way, which is why physiological data was used to measure arousal. Arousal is proven to be linked to a higher heart rate (Azarbarzin et al., 2014) as well as higher spontaneous skin conductance (Wang et al., 2018). Therefore, heart rate and skin conductance data captured by the Mionix mouse was used as an indicator of arousal. Measured data was normalized and averaged over every two-minute portion of the recording to fit to the flow and valence assessments.

## RESULTS

First, only flow and valence data are correlated leaving out arousal data. Figure 1 shows the combination of both variables in a scatterplot. Pearson correlation coefficient between valence and flow was calculated as 0.587, indicating a strong positive correlation. However, flow combined with arousal values (i.e., heart rate and skin conductance) only, resulted in no linear relation (Pearson corr. < ±0.1).

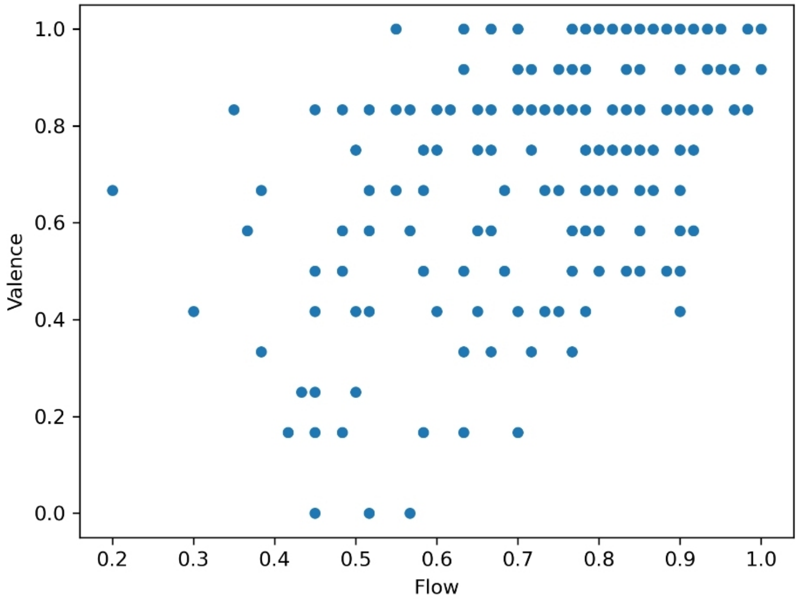


**Figure 1:** Scatterplot of the assessed flow and valence values.

In order to calculate the relation between combined arousal-valence and flow, multiple correlation (Abdi, 2007) was used. The multiple correlation coefficient $R$ of two predictor variables ($v$=valence, $a$=arousal), one target variable ($f$=flow), and their Pearson correlation coefficient $r$ is calculated as:

$$R = \sqrt{\frac{r_{vf}^2 + r_{af}^2 - 2r_{vf}r_{af}r_{va}}{1 - r_{va}^2}}$$

Depending on using heartrate or skin conductance as indicator for arousal the multiple correlation coefficient results in $R_{hr} = 0.612$ and $R_{sc} = 0.590$, both indicating strong correlations between perceived arousal-valence and flow. This can also be shown by multiplying arousal and valence values and combining the resulting value with flow (Figure 2).

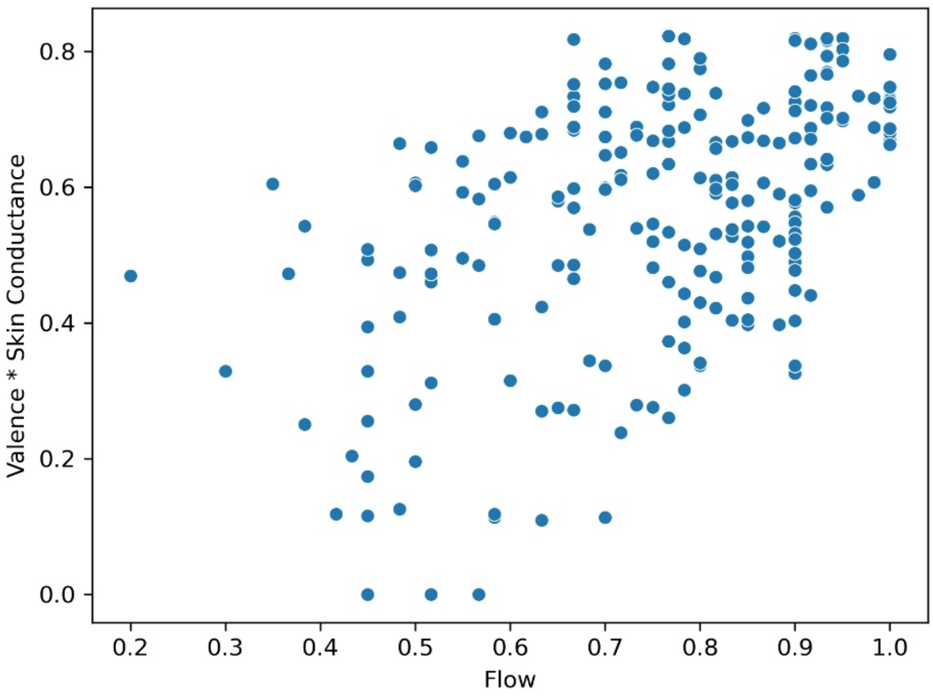


**Figure 2:** Scatterplot of combined arousal-valence (skin conductance for arousal) and flow.

## DISCUSSION

Results show a correlation between perceived valence and flow and moreover a correlation between combined arousal-valence and flow. While the connection between valence and flow is rather apparent as flow is proven to be connected to an intrinsic enjoyment in the task, it is interesting to see the connection between flow and the arousal-valence emotion model. Figure 2 shows that especially very high flow values (>0.9) are related to a high combination of both valence and arousal. However, when it comes to comparing lower flow values to combined arousal-valence, there's less of a relation. This corresponds to the proposed model of arousal-valence and flow in section 2, as flow is only perceived when combined arousal-valence is high.

Though, the results are not yet generalizable and need to be proven by further studies and investigations. Due to the study not being initially intended for assessing arousal-valence workarounds needed to be made in order to get the data. Valence was only measured by one question, and arousal was directly concluded from heart rate and skin conductance data. This heavily reduces the result significance.

Still, the found correlations suggest further research possibilities and offer a potential advancement of the arousal-valence model. Future studies should focus on assessing the variables of interest correctly and in a generalizable way. Arousal-Valence could be measured by another questionnaire e.g., the self-assessment manikin (SAM) (Bradley and Lang, 1994) and physiological data could be measured to further strengthen result significance.

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