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Experimental Study of Flow Experience: State-Related and Performance Factors Affected by Personality Antecedents

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Abstract

There is a lack of experiments about Csikszentmihalyi's flow, so to support the cause-and-effect relationships between the conditions and the subjective experience we performed an experimental study. We measured the state-related aspects of flow and antiflow conditions and the personality antecedents of the people.

28 healthy adults took part in the laboratory study. They played the game Tetris under flow, boredom, and anxiety conditions, then completed self-reported questionnaires related to each condition. Participants also underwent a psychological evaluation.

Our results replicated previous results about the positive mood-inducing effect of flow and the optimal challenge level of the activity. Flow proneness can help people to have higher flow under more severe conditions (anxiety). Moderate level of difficulty can enhance flow the most, a U-shaped curve was revealed where boredom and anxiety conditions shows lower levels of optimal experience.

The study supports earlier results and makes flow research more open to both the development of intervention programs and future laboratory and physiological investigations.

Keywords*:* flow, experiment, performance, personality, U-shape.

Introduction

The natural scientific aspect of Csikszentmihalyi's flow experience has become an important focus of recent positive psychological studies (Moller et al., 2010; Mózes et al., 2012; Rich, 2013; Ulrich et al., 2014). To induce flow and still keep experimental control, experimental research is conducted in a laboratory setting (Schwartz & Waterman, 2006).

Flow is a state in which people are so involved in a task that nothing else matters: the experience itself is so motivating that the person is participating in it for its own sake (Csikszentmihalyi, 1990). The definitions of optimal experience are complicated by the constructs along which flow state is defined, as it is rather a set of different components: Csikszentmihalyi identified 9 factors to determine flow: (1) challenge-skill balance; (2) merging of activity and attention; (3) clear goals; (4) continuous feedback; (5) concentration on the activity; (6) sense of control; (7) loss of self-awareness; (8) change in time perception; (9) autotelic experience. The 9-factor theory has become the defining framework for many studies (Kawabata et al., 2008; Kawabata & Mallett, 2011), but later Csikszentmihalyi modified his 9-factor concept and divided it into two parts, discussing the factors that describe the conditions and the dynamics of flow (Csikszentmihalyi et al., 2005; Nakamura & Csikszentmihalyi, 2002).

The other nomenclature refers to the proximal conditions necessary for the flow experience to occur (high perceived challenge-skill balance, clear goal, immediate, continuous feedback) and the accompanying factors that characterize the dynamics of the experience itself (attention, loss of self-awareness, merging of activity and consciousness, sense of control, altered perception of time, autotelic nature) (Nakamura & Csikszentmihalyi, 2002). After getting out of the flow zone we can also talk about affective effects of the experience as a possible consequence of experiencing flow (Keller & Landhäußer, 2012).

Researchers use a variety of techniques to induce flow which can be practiced in a laboratory setting: solving mathematical problems (Morrison, 2017), playing computer games (Soltész, Mózes, et al., 2014), playing music (de Manzano et al., 2010), and playing Tetris (Scheepers & Keller, 2022). The goal during these activities was to create the relative balance between challenges and skills as the basic condition of flow experience (Moller et al., 2010; Soltész, Magyaródi, et al., 2014). By manipulating the level of the difficulty of the task (Delle Fave et al., 2011), flow and antiflow states can be compared by their physiological indicators also (Kivikangas et al., 2010; Ulrich et al., 2014), then these different states can be validated by using self-reporting measures which indicate the psychological aspect of optimal experience.

The history of flow research mainly consists of correlational studies, and there is limited data from controlled experiments about flow experience (Šimleša et al., 2018). In the experimental design we can manipulate our independent variables so the cause-and-effect relationship (Howitt & Cramer, 2011) can be studied. The causal hypothesis like the compatibility between the person's skills and the demands of the situation on the emergence of flow can be supported with this methodological tradition (Keller & Bless, 2008a). Peifer and her colleagues emphasize executing more experimental studies about flow in the future (Peifer et al., 2022).

Studying flow from a physiological perspective is a relatively new research area – this new aspect has facilitated the experimental design of flow research. Dietrich's study (Dietrich, 2004) was pioneering as he assumed frontal lobes may be less active during flow experience and behavior regulation is rather automatic (van der Linden et al., 2021). This hypothesis has contributed to the development of the concept of effortless attention (Ullén et al., 2010a), but physiological flow studies are still in their infancy (Peifer et al., 2022).

Several physiological flow parameters have been already tested in a well-controlled laboratory setting (Schwartz & Waterman, 2006) including brain function, heart rate, respiration, electrodermal response, facial muscle activity, blood glucose, and cortisol level. Some relevant results about these studies worth highlighting:

- Electroencephalogram (EEG) and some brain imaging techniques like functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) (de Manzano et al., 2013) can provide valuable knowledge for psychological studies to understand the functioning of complex higher order brain structures to fully understand a psychological phenomenon (Moran & Zaki, 2013; Nagy et al., 2010).

- Cardiac and respiratory activity, and changes of skin conductance (SC), are proved predictors of optimal experience which can be differentiated from other subjective states like stress and relaxation through the somatic activity (de Manzano et al., 2013; Mauri et al., 2011; Peifer et al., 2014).

- Previous results found reduced heart rate variability in induced flow situations, which may be a sign of increased mental workload, vagal inhibition, and increased sympathetic arousal (de Manzano et al., 2010; Keller & Bless, 2008a).

If the research methodology and the factors to be tested can be clarified, and potential artifacts can be excluded, the physiological results can help to eliminate the subjective and retrospective evaluation of the flow experience.

They can contribute to a more precise operationalization of the flow experience, to the exploration of its dynamics "online", during the situation, without interrupting the participant, as the physiological measurement will not influence the fading of self-conscientiousness as the characteristic of flow experience (de Manzano et al., 2013; Mauri et al., 2011; Peifer et al., 2014). The general methodology of flow measurement has a retrospective nature (interviews, questionnaires), so next to the experimental control, it would be valuable to see the physiological indicators of flow during the experience itself (Tian et al., 2017). If the specific patterns that characterize flow experience are identified, independently from the nature of the task used in the study and the context, we can eliminate the methodological problems arising from the specificity of the phenomenon (fading of self- conscientiousness, focused attention) like only retrospective measures are possible (Moneta, 2012).

The aim of the present work is to execute an experimental study about flow experience by controlling the difficulty level of the conditions (independent variable) and revealing the effect of this manipulation on the subjective experiences of the participants. Next to the subjective reports we administered the physiological parameters of flow during games of Tetris, with optimal, difficult, and easy difficulty levels – this aspect will be a topic of another paper. In the game of Tetris, players needs to adjust the orientation of 2D block pieces of different shapes to complete full lines at the bottom of the playing screen (Scheepers & Keller, 2022). We aim to replicate previous research – see Table 1 – on a Hungarian sample (Chanel et al., 2008; Harmat et al., 2015; Keller et al., 2011; Scheepers & Keller, 2022).

Table 1 Previous physiological flow experiments with Tetris

Study	Sample size	Measure	Results
(Chanel et al., 2008)	20	EDA, BP, Res, T	Increase in EDA & HR with increasing difficulty
(Keller et al., 2011)	61	HRV, Cortisol	Lower HRV & higher cortisol in the flow condition
(Harmat et al., 2015)	77	fNIRS, ECG, Res	Larger RD & lower LF-HRV in the flow condition
(Scheepers & Keller, 2022)	50	ICG, ECG, BP	Weak relationship between self-reported flow and CV indices of relative challenge, relative challenge correlated positively to flow
(Peifer et al., 2014)	22	HRV, ECG, cortisol	Inverted U-shaped relationship of flow with the values of sympathetic arousal and cortisol. Moderate sympathetic arousal and HPA-axis activation can be related to flow during a task-solving.
(Tian et al., 2017)	40	Res, HR, HRV, SC	Flow and faster respiratory rate, deeper Res, moderate HR, moderate HR variability, and moderate SC

Note. EDA = electrodermal activity, BP = blood pressure, T = temperature, HR = heart rate, HRV = heart rate variability, LF-HRW = low-frequency heart-rate variability, RD = respiratory depth, fNIRS = functional near-infrared spectroscopy, ECG = electrocardiography, Res = respiration, ICG = impedance cardiographic signals, SC = skin conductance.

Previous studies with experimental design suggested that playing at different difficulty levels can induce the different subjective states like flow and antiflow (Chanel et al., 2008;

Keller et al., 2011). According to Harmat and his colleagues (2015) the optimal condition (just like the expectancies of flow) can be described with the highest level of self-reported flow, positive affect, and effortless attention. Systematic replication efforts (Guttinger, 2020) have already started in psychology, our study will be a conceptual replication (Bardsley, 2018), as we aim to support the presented assumptions about the functioning of flow.

Hypothesis

1. There are significant differences among the flow and antiflow (anxiety, boredom) situations in case of

a. mood (Harmat et al., 2015),

b. subjective flow experience of the participants (Csikszentmihalyi, 1990).

2. Based on the clustering of the measured dispositions – flow proneness, achievement motivation – we can draw profiles, and we assume people with higher achievement motivation (Baumann & Scheffer, 2011; Mikicin, 2007) and higher level of flow proneness (de Manzano et al., 2013) tend to have more intense flow during Tetris (in the flow condition) than those who have lower levels in these personality characteristics.

3. People in the flow condition perform significantly better in the game than in the antiflow situations (Bakker et al., 2011; Engeser & Rheinberg, 2008; Scheepers & Keller, 2022).

4. Flow and the difficulty of the task will have a relationship like an inverted U-shape (Tian et al., 2017).

Methods

Sample

We recruited healthy adult subjects by convenience sampling method. Participation was anonymous and voluntary; no personal data were recorded. 28 Hungarian participants took part in the study (previous Tetris studies worked with 20-71 people – see Table 1). The mean age was 27.60 (SD = 8.23). The demographic characteristics of the sample are in Table 2.

Table 2 Demographic characteristics (and practice level of Tetris) (N = 28)

Variable	%
Gender	
Male	53.6
Female	46.4
Education	
College student	21.4
College Graduate	67.9
Postgraduate	10.7
Residency	
Capital city (Budapest)	82.1
City	7.1
Town, village	7.1
Abroad	3.6
Relationship status	
Single	42.9
In a relationship	57.1
Practice in Tetris	
Tried 1-2 times	78.6
Regularly	21.4

Measures

This laboratory study focused on the psychological biological aspects of flow. Next to the recording of the physiological markers, participants filled in different questionnaires in each experimental stage. We propose these instruments as this paper focuses on the psychological aspects of the study:

• At the beginning of the experiment, certain basic indicators are examined: demographic characteristics, experience with Tetris, performance motivation, flow proneness (dispositional flow). We examine the current mood indicators as state characteristics – these are the baseline for the comparison with the experimental situations.

- After each experimental situation, the flow and antiflow state characteristics, then different mood indicators will be questioned.

Shortened Positive and Negative Affect Schedule (PANAS)

We use the Hungarian version (Gyollai et al., 2011) questionnaire from Watson and colleagues (Watson et al., 1988) (Positive and Negative Affect Schedule). It measures the dimensions of positive and negative affectivity by 5-5 items, rating via a five-point Likert scale (1: Not at all – 5: Very much). The internal consistency scores of the scales are acceptable (positive affect scale: $\alpha = 0.73$, negative affect scale: $\alpha = 0.62$).

Achievement Motivation Scale Revised (AMS-R)

The Hungarian version (Mayer, 2012, p. 201) of the AMS-R (Lang & Fries, 2006) examines failure orientation as an avoidance tendency and success orientation as an approach tendency through 10 self-reporting items, using a 5-point Likert scale. The Cronbach's alpha of the success orientation factor is 0.71, the alpha of the failure orientation scale is 0.81, so the internal consistency is adequate.

Flow Questionnaire

Flow Questionnaire (Oláh, 2005) examines flow and antiflow experiences during a given day through 22 items. This is a self-reporting scale, rating the items on a 5-point Likert scale. Internal consistency scores of the scales are acceptable.

Flow State Questionnaire of the Positive Psychology Lab (PPL-FSQ)

PPL-FSQ (Magyaródi et al., 2013) measures the dimensions of flow experience through 20 items. Participants rate the statements on a 5-point Likert scale (1: Strongly disagree – 5: Strongly agree). It consists of two subscales: the 11-item balance between challenges and skills scale (referring to the basic conditions for entering the flow zone) and the 9-item absorption in the activity factor (summarizing the accompanying phenomena of flow). The reliability of the scales is acceptable (balance: $\alpha = 0.92$; absorption: $\alpha = 0.91$).

Procedure

The United Ethical Review Committee for Research in Psychology supported the study; the reference number of the ethical permission is 2023-106.

The research was carried out in a closed, laboratory setting. We used repeated measures design with each subject participating in all the three situations. To avoid the sequence effect, we changed the order of the experimental situations randomly, and noted the order next to the code number of the subjects.

Upon arrival at the laboratory, subjects signed the informed consent form, then we presented the instruments and set up the physiological equipment. After installing the equipment, we started recording with a camera to follow the performance of the subjects during the game.

The research started with a questionnaire (measuring demographic and Tetris-practice data, baseline mood, performance motivation and dispositional flow), followed by a 2-minute baseline measurement: 1 minute with eyes open, 1-minute eyes closed. Participants had the opportunity to practice Tetris for 2 minutes.

After the baseline registration, one of the Tetris experimental settings was the next phase, in a random order (flow – optimal; anxiety – too difficult as the speed is high; boredom – too easy, the participant could not regulate the speed, it was very slow). In each situation, participants played Tetris for 10 minutes. After the game, they filled in questionnaires about their experiences at each stage (see Figure 1). Altogether, the duration of an experiment was 45 minutes.

There was no significant difference in the self-reports of people with lower and higher practice in Tetris, and in the case of the order of the conditions either.

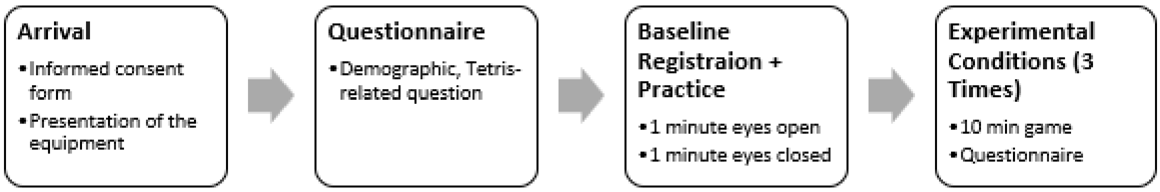

Figure 1. The procedure of the experiment.

Results

Descriptive statistics

As we used dispositional variables and situation-specific measures in the study, we present the descriptive statistics in separate tables – see Table 3 and Table 4.

Table 3 Descriptive statistics of the trait variables in the study (N = 28)

Variables (number of the items)	*M*	*SD*	*α*
Flow – trait (11)	3.64	0.55	0.77
Apathy – trait (3)	1.92	0.43	0.69
Boredom – trait (4)	1.67	0.31	0.74
Anxiety – trait (3)	1.81	0.55	0.65
AMS-R: Approaching success (5)	2.52	0.91	0.84
AMS-R: Avoiding failure (5)	4.12	0.75	0.89

Note. M = mean, SD = standard deviation, α = Cronbach's alpha.

To be able to measure the performance-related aspects of the study, we executed a new variable from all the points a subjects scored in each condition, averaging with the number of the attempts.

Table 4 Descriptive statistics of the situation-specific variables in the study

Variables (number of the items)	*M*	*SD*	*α*
Baseline mood: PANAS positive (5)	3.30	0.62	0.81
Baseline mood: PANAS negative (4)	1.19	0.27	0.60
Boredom mood: PANAS positive (5)	2.34	0.93	0.86
Boredom mood: PANAS negative (5)	1.20	0.47	0.53
Boredom: PPL-FSQ Balance between challenges and skills (11)	3.92	0.90	0.65
Boredom: PPL-FSQ Absorption in the task (9)	2.14	0.71	0.94
Boredom: PPL-FSQ total score (20)	3.03	0.67	0.76
Flow mood: PANAS positive (5)	3.59	0.88	0.91
Flow mood: PANAS negative (5)	1.35	0.36	0.56
Flow: PPL-FSQ Balance between challenges and skills (11) (*N* = 27)	3.82	0.74	0.94
Flow: PPL-FSQ Absorption in the task (9)	3.12	0.55	0.88
Flow: PPL-FSQ total score (20)	3.47	0.47	0.88
Anxiety mood: PANAS positive (5)	3.41	0.96	0.89

Variables (number of the items)	*M*	*SD*	*α*
Anxiety mood: PANAS negative (5)	2.01	0.65	0.65
Anxiety: PPL-FSQ Balance between challenges and skills (11)	2.57	0.71	0.91
Anxiety: PPL-FSQ Absorption in the task (9)	3.07	0.49	0.84
Anxiety: PPL-FSQ total score (20)	2.82	0.51	0.88
Flow performance mean (1)	767.17	414.54	-
Anxiety performance mean (1)	313.53	50.94	-
Boredom performance mean (1)	338.93	40.40	-

Note. M = mean, SD = standard deviation, α = Cronbach's alpha.

The internal consistency coefficients of the variables are acceptable both in the cases of the dispositional and state variables.

Hypothesis Testing

For the hypothesis testing we performed repeated measures ANOVA (as the participants took part in three different conditions during the experiment), K-means cluster analysis with relocation and independent sample t-test. We present the hypothesis testing related to each assumption.

1. There are significant differences among the flow and antiflow (anxiety, boredom) situations in case of

a. mood (Harmat et al., 2015),

We performed a repeated measures ANOVA, to check the positive and negative mood differences among flow, anxiety, and boredom game situations (see the descriptive values in Table 5). Results suggest a significant difference among the situations: Wilk's Lambda = 0.39, $F(2,26) = 20.61$, $p < 0.01$, $\eta2= 0.61$. A Bonferroni post hoc analysis showed there is a significant difference between flow and boredom ($p < 0.01$), but no significant difference between flow and anxiety ($p > 0.05$). The highest positive affect level was found in the flow situation.

Table 5 Means and SD scores of positive and negative affects in the three game situations

	M	*SD*
Boredom: positive affect	2.33	0.94
Flow: positive affect	3.62	0.88
Anxiety: positive affect	3.41	0.96
Boredom: negative affect	1.21	0.47
Flow: negative affect	1.39	0.41
Anxiety: negative affect	2.01	0.66

Note. M = mean, SD = standard deviation.

Another repeated measures ANOVA was performed to find out the negative affect differences: Wilk's Lambda = 0.39, $F(2,26) = 20.70\ 0$, $p < 0.01$, $\eta2= 0.61$ (see the descriptive values in Table 5). A Bonferroni post hoc analysis showed there is a significant difference between flow and anxiety ($p < 0.01$), but no significant difference between flow and boredom ($p > 0.05$). After playing under frustrating conditions, participants felt higher negative affect than in flow and boredom.

b. and subjective flow experience of the participants (Csikszentmihalyi, 1990).

To describe the nature of flow during the experiment we use the summarized total score of PPL FSQ in the three conditions (descriptives in Table 6).

Regarding the flow total score, there is a significant difference (Wilk's Lambda = 0.39, $F(2,26) = 20.17$, $p < 0.01$, $\eta2 = 0.61$), according to the Bonferroni test, between boredom and flow situation ($p < 0.01$), and anxiety and flow also ($p < 0.01$).

Table 6. Mean and SD scores of the flow variables in the three game situations

	M	*SD*
Boredom: total flow score	3.02	0.66
Flow: total flow score	3.49	0.47
Anxiety: total flow score	2.80	0.53

Note. M = mean, SD = standard deviation.

2. Based on the clustering of the measured dispositions – flow proneness, achievement motivation – we can draw profiles, and we assume people with higher achievement motivation (Baumann & Scheffer, 2011; Mikicin, 2007) and higher level of flow proneness (de Manzano et al., 2013) tend to have more intense flow during the Tetris (in the flow condition) than those who have lower levels in these personality characteristics.

We performed K-means cluster analysis with relocation to decide the clusters behind flow proneness and achievement motivation.

In the case of achievement motivation – approaching success, we got a 2 relatively homogenous clusters with an appropriate explained error sum of squares (EESS% = 72.12): 12 people with a low (HC = 0.83, M = 3.52, SD = 0.45) and 16 people with high level of success approaching in their everyday life (HC = 0.4, M = 4.70, SD = 0.31).

Regarding flow proneness a rather homogenous 2-cluster solution can describe the sample appropriately (EESS% = 72.05): people with a higher flow tendency during their everyday life (HC = 0.37, M = 3.96, SD = 0.21), and subjects with a relatively low flow frequency (HC = 0.98, M = 3.12, SD = 0.34).

After having the clusters, we executed an independent sample t-test for all the optimal experience-related variables. In case of the success orientation clusters we could not find any significant differences: $t(25) = -0.14$, $p > 0.05$.

In case of the low and high flow proneness groups there are some significant differences in the in the frustrating condition: in positive affect ($t(26) = 2.26$, $p < 0.05$), the balance between challenges and skills ($t(26) = 3.02$, $p < 0.05$), absorption in the task ($t(26) = 1.71$, $p < 0.05$) and the total score of flow ($t(26) = 2.92$, $p < 0.01$) (the descriptive statistics in Table 7). In every case people with higher level of flow proneness had higher subjective ratings on the affect and flow-related variables.

Table 7 Descriptive statistics of the differences between the low and high flow proneness groups

Variables	Clusters	*N*	*M*	*SD*
Anxiety: positive affect	High flow proneness	18	3.70	0.17
	Low flow proneness	10	2.90	0.37
Anxiety: balance between challenges and skills	High flow proneness	18	2.83	0.15
	Low flow proneness	10	2.07	0.21
Anxiety: absorption in the task	High flow proneness	18	3.15	0.11
	Low flow proneness	10	2.83	0.16
Anxiety: flow total score	High flow proneness	18	2.99	0.10
	Low flow proneness	10	2.45	0.17

Note. M = mean, SD = standard deviation.

3. People in the flow condition perform significantly better in the game than in the antiflow situations (Bakker et al., 2011; Engeser & Rheinberg, 2008; Scheepers & Keller, 2022).

We executed a repeated measures ANOVA, to check the performance differences (see the descriptive values in Table 8). Results suggest a significant difference among the situations: Wilk's Lambda = 0.39, $F(2,26) = 20.38$, $p < 0.01$, $\eta^2 = 0.61$. A Bonferroni post hoc analysis showed there are significant differences among the three conditions regarding the performance in the game. Subjects performed the best during the flow condition (the lowest performance was under frustration), flow performance significantly differs from boredom and anxiety performance ($p < 0.01$).

Table 8 Mean scores during the three different Tetris levels (N = 19)

	M	*SD*
Boredom: mean score	338.93	40.40
Flow: mean score	767.17	414.54
Anxiety: mean score	313.53	50.94

Note. M = mean, SD = standard deviation.

4. Flow and the difficulty of the task will have a relationship like an inverted U-shape (Tian et al., 2017).

In the boredom situation the game speed was very low and the participant could not control it, so this was the easiest condition. In the flow condition the participant played on a normal speed, could regulate the blocks to get into their place immediately if the subject could find its place. During the anxiety (or frustration) condition, the speed was so fast that the participant did not always have enough time to rotate and position the figures, thus it was the most difficult situation. To support the inverted U-shape, we propose Figure 2 about the means of the subjective flow reports of the participants after each condition (Table 6).

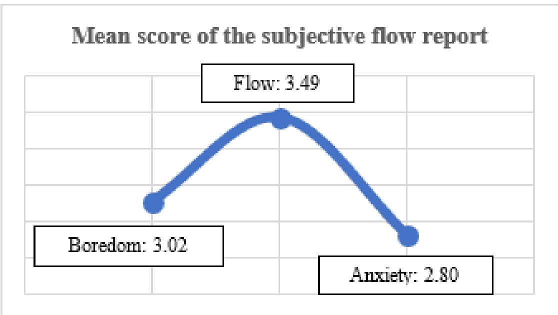

Figure 2. Inverted U-shape between flow and the difficulty of the task.

Next to the inverted U-shape, as the 1b hypothesis testing suggest, there is a significant difference between flow-boredom and flow-anxiety conditions regarding the subjectively reported flow experience of the subjects.

Discussion

There is a need to have more experiments about flow (Peifer et al., 2022), so our study aimed to execute one and conceptually replicate (Bardsley, 2018) the assumptions and results of previous studies to see if we can extrapolate findings into different populations, with different instruments and tools about Csikszentmihalyi's optimal experience (Csikszentmihalyi et al., 2005).

Our first result highlights there is a significant difference regarding positive affect between flow and boredom, and between flow and anxiety regarding negative affect. This result partly supports the previous study of Harmat and his colleagues (Harmat et al., 2015), in which they say flow can be associated with positive affect. It reflects the perceived impact of the flow experience, thus confirming the assumptions of previous research about flow on positive emotions (Gaggioli et al., 2013; Salanova et al., 2014; Sweetser & Wyeth, 2005). Several definitions of optimal experience employ constructs of emotionality (e.g., pleasure, happiness) in their definition (Fritz & Avsec, 2007; Novak & Hoffman, 1997; Tenenbaum et al., 1999). However, if the experience is characterized by a loss of self-consciousness, it cannot be identified as a positive emotion, but it can have consequences of them, like pleasantness, happiness, pleasure (Bringsén et al., 2011; Scherer, 2005).

Regarding flow we distinguish the factors that are necessary for the optimal experience to emerge, those that characterize its dynamics, and those factors that are observed when the flow is over, after the getting back of the self-awareness (Carpentier et al., 2012; Csikszentmihalyi, 1993; Fredrickson, 1998; Keller & Landhäußer, 2012). Flow may include positive emotions (Fredrickson, 1998), which in the long run may even be determinants of subjective well-being related to the experience of competence (Ryan & Deci, 2001), self-efficacy, and increased performance (Diener et al., 2011).

Previous studies indicated that by playing at different difficulty levels participants can experience different subjective experiences (Harmat et al., 2015; Keller & Bless, 2008b). Our study could prove these results, as the reported flow score was the highest during the optimal difficulty situation. We treated it as a possible flow-inducing condition through the challenging but not frustrating game environment. We get a conclusion that by changing the environmental factors of the task, flow experience can be induced (Šimleša et al., 2018).

This experiment was executed in the laboratory, though we wanted to see how the possible antecedents and predictors (like performance motivation and flow proneness) predict optimal experience. Our results did not support the hypothesis that having different dispositions and motivations would affect flow intensity during the Tetris. However previous studies suggests motivating factors are important precursors of daily flow (Digutsch & Diestel, 2021), and for achievement-oriented people high skill and challenge was associated with greater positive affect, task interest, and performance (Eisenberger et al., 2005), we could not prove this difference. The reason was perhaps the lower size of the sample, the homogeneity index of the low success approaching group was a higher, or the nature of the task-setting as it was a short, 10-minute task in every condition, so in future studies we need to replicate this hypothesis test.

Regarding flow proneness we could find significant differences between flow and anxiety (frustration conditions): it suggests performance under frustration can be supported by flow as a trait, people with higher level of flow proneness can have a significantly better flow experience under severe conditions. People with an autotelic personality (Csikszentmihalyi, 1975) can experience more and more intense flow than other people, and dispositional flow can help the person to cope with the difficulties and challenges much better. Autotelic personalities have the ability to transform boring or stressful situations into possibilities to get into the flow zone (Elnes & Sigmundsson, 2023). These people can find challenging situations less stressful than people with lower flow proneness, they can experience flow even when the challenge is higher (Tse et al., 2018).

We could prove that people perform the best under the conditions of flow – the optimal balance between challenges and skills (Bakker et al., 2011; Engeser & Rheinberg, 2008). Flow is a highly functional state and it would facilitate learning through its motivation aspect (Engeser & Rheinberg, 2008). Our research provides evidence that flow is not simply correlated with better performance, but can foster it, as in the three different conditions the same person performed differently. During flow we produce effortless attention, which can lead to a better performance – future physiological studies are needed to further support this hypothesis (Moller et al., 2010; Ullén et al., 2010b).

Related to the physiological studies, it was revealed that an inverted U-curve can be observed in the relationship between sympathetic arousal and flow, so moderate sympathetic arousal seems to be optimal for flow. Increased inhalation depth is also observed with decreased HRV - this may indicate joint activation of the sympathetic and parasympathetic nervous systems (Peifer et al., 2014). Between the subjectively perceived challenge and the person's intrinsic motivation we can find this inverted U-shaped curve also and it was supported by another physiological study (Ma et al., 2017). In our research, the reported subjective flow levels can be differentiated under the three conditions, and we could replicate the U-shaped curve based on our data.

We achieved valuable results, but we must highlight the limitations of the study also. Difficulties caused by laboratory conditions (e.g., achieving the exclusion of self-consciousness while the subject is observed using different equipment) put a challenge for contemporary research (Moller et al., 2010; Rich, 2013): the use of low sample size, as well as the complexity of the flow experience reduce the validity of the results obtained so far. So, it is an important aim to widen the sample size and have a better experimental control even by clustering the people based on their previously measured personality factors or skill levels affected on the actual task. In our future work we would like to expand our study on a physiological level to support the subjective report with biological correlations and to widen the circle of physiological flow studies.

As flow experience is an important subjective state which can facilitate better performance, produce a more positive mood through the broaden-and-build mechanism (Fredrickson, 2013) it can support more creative problem solving, it is worth to use the different intervention techniques to help people learn how to flow (Bartholomeyczik et al., 2023). There have been some flow-fostering interventions related to goal setting (Weintraub et al., 2021), or balancing challenges and skills (Wesson & Boniwell, 2007). In the future it would be useful to have longitudinal research and intervention program about teaching people to get into the flow zone more frequently. For this aim we can use the results of the experimental studies for flow-induction or (bio)feedback, then we can measure the performance (Bakker et al., 2011) and mental health-related (Riva et al., 2016) effects of having more optimal experience.

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