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EEG FINDINGS DURING FLOW STATE

AKIŞ DURUMUNDA EEG BULGULARI

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Abstract

Flow state emerges when a person engages in autotelic activities, which are both enjoyable and challenging. While studies generally focused on qualitative data of flow state, a few were conducted on psychophysiological basis of it. Present study aimed to investigate EEG correlates of flow. Twenty participants preliminarily filled out Flow Short Scale Turkish Version and completed a ping-pong game at two levels (slow boring and fast-flow) during EEG recording. The results revealed that theta power was significantly greater for all regions during flow condition compared to non-flow condition and delta power was significantly greater during flow on central and parietal regions. There is no difference between flow/non-flow conditions for coherence. A positive correlation was found between delta and theta powers and subscales scores of Flow Short Scale. The increases in these theta and delta frequency bands could be important indicators of flow state. The coherence results revealed that interhemispheric synchronization was not modified by flow. If confirmed with multiple tasks and in clinical groups, EEG correlates of flow state could be useful increase performance and well-being.

Keywords: flow state, EEG, theta, delta, coherence

Özet

Akış, kişilerin zorlayıcıyken aynı zamanda eğlenceli olan ototelik aktiviteleri gerçekleştirmesi sırasında ortaya çıkar. Akış ile ilgili çalışmalar genellikle kalitatif yöntemlere yoğunlaşırken, akışın psikofizyolojik temelleri üzerine çok az çalışma yapılmıştır. Bu çalışma akışın nöral temellerini araştırmayı amaçlamaktadır. Çalışma kapsamında 20 katılımcı Akış Kısa Ölçeği Türkçe Versiyonu tamamladıktan sonra, EEG kaydı süresince yavaş (sıkıcı) ve hızlı (akış) olmak üzere iki farklı seviyede ping-pong oyunu oynamışlardır. Sonuçlarına göre akış koşulunda akış olmayan koşula göre, teta gücü tüm bölgelerde daha yüksek ve delta gücü ise santral ve parietal bölgelerde daha yüksektir. Koherans için koşullar arasında anlamlı bir farkında bulunamamıştır. Teta ve delta bantları ile Akış Kısa Ölçeği alt ölçekleri arasında pozitif korelasyon saptanmıştır. Teta ve delta bandındaki artış akış durumunun önemli göstergeleri olabilir. Sonuçlar farklı paradigmalar ve hasta gruplarında tekrarlandığı durumda, akış durumunun elektrofizyolojik temelleri performansı ve iyi oluş halini arttırmak için kullanılabilir.

Anahtar Kelimeler: *akış durumu, EEG, teta, delta, coherence*

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1. Introduction

Csikszentmihalyi (1975) has brought forward a question: "why do people continue doing activities that are time-consuming and dangerous?", and he started to do research about the concept of flow state. Flow state and autotelic activity are interchangeable concepts meaning that a person does an activity for the sake of doing an activity. In other words, doing an autotelic activity is worth doing. A person drives because he/she likes driving, or a person teaches a language because he/she likes teaching etc. Autotelic activity includes difficulty to a certain extent, and the person is obliged to challenge with difficulty. Thus, a person who does an autotelic activity is fully engaged with the activity, and he/she has to use full capacity to achieve it. Meanwhile, the person gets positive feedback with regard to doing the activity, and he/she is able to estimate the results of the autotelic task in a realistic way (Csikszentmihalyi, 1975). The person who does the autotelic activity is more pleased with the way of doing the related task than what specific task she/he is doing (Csikzentmihalyi, 1999). Several studies have associated doing leisure activities, hobbies, and adventurous activities with flow-state ranging from employees to late-adults (Csikszentmihalyi & LeFevre, 1989, Myllykangas et. al, 2002, Elkington 2011, Chilton 2013, Boniface, 2000). Flow is a mental state that emerges when a person does enjoyable and challenging activities. However, there is different body of research suggesting that flow state is not related to hobby activities and positive well-being. These studies showed that positive well-being and flow-state are negatively correlated, and hobby activities do not have meaningful effect on the flow state (Heo et. al, 2010). Alternatively, the meaning of occupation has a significant effect on the probability of experiencing flow state, and in this respect, it promotes psychological well-being (Wright et. al., 2007).

The occupation and doing a task are different concepts within the framework of the flow-state. Occupation is something that a person is fully engaged with and is doing in a passionate way (Seligman, 2007). Thus, it can be said that a person prefers occupation instead of a task when he/she experiences a flow state. Csikszentmihalyi (2005) asserts that a person who is pleased with doing occupation can experience the flow state. It is required to get positive feedback via doing open-targeted, hard, purposeful occupation in order to get pleased. Csikszentmihalyi named this situation as "tidy conscious" in which a person focuses on purposeful occupation in a self-controlling way, thus it contributes to self-consolidation (Csikszentmihalyi et. al., 2005). Csikszentmihalyi (1990) defines the nine characteristics of flow state as follows:

- Concentration on the task in hand: Being concentrated via focusing attention on "occupation" and "moment",
- Challenge-skill balance: Being adjusted to the occupation,
- Action awareness merging: Awareness of occupation,
- Loss of self-consciousness: Loss of self-reflective consciousness,
- A sense of control: Feeling of control, ability to predict the next stage of occupation, and necessary problem-solving principles,
- Transformation of time: Perversion of temporary activity (ex. Feeling of faster time elapse than normal),
- Autotelic Experience: Experiencing rewarding activity, reaching the goal of activity with the enjoyment.
- Clear Goals: this corresponds to the balance between perceived ability and task requirement as described by Csikszentmihalyi's (1975) in his original model of the flow state.
- Unambiguous Feedback: Clear and immediate feedback about ongoing occupation.

Ongoing researches have shown that, flow state helps a person to define real self, to develop problem-solving skills and insight (Warren, 2007, Lee, 2013). Another research from South Korea proposes that there is a high probability of experiencing flow state for students who have high level of procrastination. However, results propound that the academic success can be predicted via flow state instead of procrastination. Although procrastination and flow state have positive correlation, procrastination is not the predictor of academic success (Lee, 2005). On the other hand, flow state is effective in developing positive attitude toward game advertisements, and it provides an opportunity to self-actualization (Hernandez, 2011 and Nesbit, 2006).

Interestingly, there are a few studies on the psychophysiological base of flow state. Mansfield et. al. (2012) reported that there was no correlation between flow state and heart rate. In another study, Kramer (2007) examined the relationship between electrical activation patterns in the cortex and flow-based performance on a motor response task. Left temporal alpha activity was found to be a predictor of performance. In addition, the theta power (4-8Hz) and the mid-beta power (16-20Hz) were also related to performance. Similar research using a visuo-motor task showed that, during flow state, there was increased low-beta (12-15 Hz) power in the sensorimotor cortex together with beta band synchronization between the prefrontal and sensori-motor cortex and de-synchronization between the other areas (Kock, 2014). Another functional near infrared spectroscopy study explored brain metabolism during flow state and found that flow state is associated with increased prefrontal oxygenated hemoglobin (Yoshida et al., 2014).

Although these studies give important knowledge on EEG features associated with flow state, inconsistency of the findings prompts further studies. In this study, we aimed to induce flow state using different speed levels of the classical Ping-Pong game. This method is used because studies showed that people are more likely to experience flow state if the game or event is adjusted with the level of skill (Procci et al., 2012).

2. Method

2.1. Participants

Twenty (13 females, 7 males), right-handed (mean age: 24±4.83 years, age range: 20-35) participants were recruited with no history of any neurological and

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psychiatric disease. Participants' daily PC playing time are changing between 1 and 3 hours (mean: 1.55±0.6 hour). The study protocol was approved by the local Ethics Committee and was performed in accordance with the Declaration of Helsinki. All the participants were informed about the study procedures and provided written informed consent.

2.2. Psychological Assessments

All participants filled out self-report questionnaires, including Turkish version of Flow Short Scale. The Flow Short Scale was developed by Rheinberg, Vollmeyer and Engeser (2003) in Germany and adapted for Turkish by Isigüzel and Çam (2014) and consists of eighteen items rated on a seven-point Likert-type self-assessment scale.

2.3. Procedure

Participants completed a ping-pong game at two speed levels. The speed was determined based on a pilot study. Slow condition was rated as boring during most participants during the pilot study, whereas the fast condition was rated as enjoyable. The order of conditions were counterbalanced across participants. Each condition took approximately 2 minutes.

2.4. EEG data collection and preprocessing

Dimly lit room was provided to participants during data collection. EEG data and subjects were observed by EEG technician to minimize drowsiness and excessive head motion during recording. EEG data collection was accomplished using BrainVision actiCHamp amplifier (Brain Products Inc. Munich, Germany) which was connected to a 32-channel actiCAP (Brain Products Inc. Munich, Germany) sampled at 1000Hz.

The data were processed using BrainVision Analyzer software (Brain Products GmbH., Gilching, Germany). The data were down sampled to 250 Hz to ease computations. Down sampled and filtered data was re-referenced to average of the two mastoid electrodes. Resulting signals were filtered with a 0.5 Hz high-pass filter and a 30 Hz low-pass filter with 24 dB/octave roll-off to minimize high and low frequency artifacts. Artifact detection was used visually to exclude artifacts caused by muscle, eye and head motion. In order to correct ocular artifacts, independent component analysis (ICA) was performed. Non-overlapping segmentation with 2.0 s epochs was performed to the acquired data. The second artifact rejection and then fast-fourier transforms were used.

2.4.1. Power

Each participant's data were averaged across the acquired epochs for each electrode, and the mean absolute power was calculated for each frequency bands: Delta (0.5 – 4 Hz), Theta (4 – 8 Hz.), Alpha1 (8 – 10 Hz.), Alpha2 (10 – 12 Hz.), Beta1 (12 – 20 Hz.), Beta2 (20 – 30 Hz.). A natural log transform was computed for all EEG power variables. Electrodes were grouped to create 4 region of interest: frontal (F7, F3, Fz, F4, F8), central (C3, Cz, C4), parietal (P7, P3, Pz, P4, P8), and temporal (T7, T8).

2.4.2. Coherence

Inter-hemispheric coherence was calculated for previously defined all bands. Inter- hemispheric coherence was assessed between the pairs F3-F4, C3-C4, P3-P4, and T7-T8.

2.5. Statistical Analysis

All statistical analyses were conducted using statistical package for the social sciences version 22 (SPSS, SPSS Inc. Chicago, USA). Grand average within each group was compared with general linear model (GLM). When normality assumption was violated non-parametric test was used (Delta, Beta1, Beta2), and when assumption of sphericity or homogeneity were violated the Greenhouse-Geisser was performed. Significant main effect were followed up with post-hoc comparisons.

We examined difference in power between conditions via repeated-measure ANOVA for each frequency bands. Each omnibus ANOVA included two within subject factor (condition: flow and non-flow), and (region: frontal, temporal, parietal, central). Group difference in inter-hemispheric coherence was examined via repeated-measure ANOVAs for each frequency band. Omnibus ANOVAs was performed included two within factors (condition: flow, non-flow), and (region: F3-F4, C3-C4, P3-P4, T7-T8). In addition, the correlations between the mean powers of the frequency bands and flow scales were also calculated. In the correlation analyses, Spearman non-parametric correlation coefficient was used, because the scores of the flow scale and powers in some frequency bands did not distributed normally.

3. Results

3.1. Power

There was a significant main effect of condition at only theta band ($F(1, 19) = 13.91$, $p < 0.05$; see figure 1). Mean EEG power was significantly higher at flow condition ($M = 12.405$, $SE = 1.09$) than non-flow condition ($M = 11.303$, $SE = 1$). In addition, at theta, we observed a significant interaction effect between condition and region ($F(3, 57) = 5.01$, $p < 0.05$) and a significant main effect of region ($F(3, 57) = 61.41$, $p < 0.001$). Follow-up analyses indicated that mean EEG power was statistically different at all regions of interest (frontal = $t(19) = 2.48$, $p < 0.05$, temporal = $t(19) = 2.28$, $p < 0.05$, central = $t(19) = 4.57$, $p < 0.01$, parietal = $t(19) = 4.31$, $p < 0.01$). Delta, Beta1, and Beta2 bands were analyzed using Wilcoxon-signed rank test because of violation of normality assumption. Wilcoxon test revealed that, there was significant difference between conditions at frontal ($z=-2.69$, $p<0.01$), central region ($z = -3.73$, $p < 0.01$), and parietal region ($z = -3.17$, $p < 0.01$) at delta frequency band with greater delta power during flow state. On the other hand, temporal delta power was not significantly different between conditions ($p=0.9$).

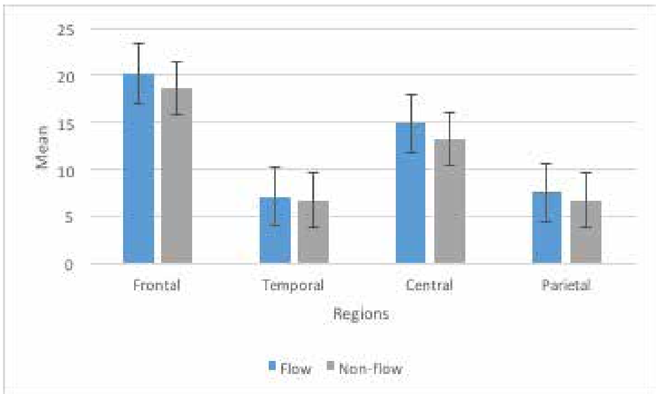

Figure 1: The mean EEG powers at flow and non-flow conditions in theta band.

3.2. Coherence

Two-way repeated ANOVA and Wilcoxon signed-rank test revealed that neither main effect of condition no interaction effect between conditions and regions of interests were not significant at any band frequency, after bonferroni correction for multiple comparisons.

3.3. Correlations

The correlations were performed only between theta and delta frequency bands and flow scale, because the effect of the flow condition is only significant in these frequency bands. The correlation results showed that there was a positive correlation between frequency bands and subscales scores of Flow Short Scale, namely absorption, enjoyment and intrinsic motivation subscales (see table 1).

Table 1: Results of Correlational analysis

		Absorption	Enjoyment	Intrinsic Motivation
Delta frontal	C.C.	0,36	0,40	0,37
	Sig	0,11	0,08	0,11
Delta temporal	C.C.	0,47*	0,40	0,24
	Sig	0,04	0,08	0,30
Delta central	C.C.	0,61**	0,63**	0,42
	Sig	0,00	0,00	0,07
Delta parietal	C.C.	0,45*	0,46*	0,21
	Sig	0,05	0,04	0,37
Theta frontal	C.C.	0,22	0,33	0,38
	Sig	0,35	0,16	0,10
Theta temporal	C.C.	0,42	0,39	0,35
	Sig	0,07	0,09	0,13
Theta central	C.C.	0,32	0,45*	0,50*
	Sig	0,16	0,04	0,02
Theta parietal	C.C.	0,34	0,49*	0,43
	Sig	0,15	0,03	0,06

C.C.=correlation coefficient

4. Discussion

This study shows that the main effect of condition is only found on theta and delta band frequencies, which is significantly higher on flow than non-flow condition. For theta band, condition effect was significant for all regions. On delta band, a significant difference was found between conditions and only central and parietal regions where during flow delta activity is greater than non-flow. However, there is no significant difference between conditions for coherence, which means that interhemispheric synchronization was not modified by flow.

Increased theta activity during flow can be explained from a number of perspectives. First, theta activity indicates encoding process of data into short-term (Vertes, 2005) and long-term memory (Klimesch, 1999). High theta activity in frontal midline (Fz) may also be a predictor of concentration, sustained attention and at the same time relaxation (Kubota et. al., 2001). Laukka et al.(1995) proposed that theta increases, as a function of learning process, which may be related to decreased effort allocation. Kock (2014) proposed that performing a task require two phases. First phase is learning stage in which resources, like attention, are fully used to make associations. Second stage is automaticity in which motor responses elicit unconsciously and with little mental effort (i.e, flow). During flow, brain uses minimum resources to reach maximum performance and this state may be associated with slow theta activity. In our study, therefore, high theta activity may indicate concentration and relaxation. Interestingly, it has been shown that theta power decreases after errors (Laukka et. al.1995). After every error, a new adjustment is made to reach competence and competence in turn will be associated with increased theta activity.

Second explanation may be related to satisfaction. Theta activity may reflect pleasure and an innate tendency to reach highest joy and one's peak capability because of satisfaction (Horan, 2009). One of the flow dimensions is having an autotelic experience, which means someone does a task accompanied by an intrinsic reward, namely enjoyment (Jakson & Marsch, 1996). Therefore, increased theta power on our subjects showed that they had autotelic experiences. It can be also suggested that theta activity are related to dopamine signals that play a role in synchronization between frontal cortex and hippocampus (Benchenane et al., 2010).

The results also showed a greater delta powers in frontal, central and parietal regions during flow state compared to non-flow. The delta activity is generally considered as an inhibitory type oscillation. For instance, it has been claimed that frontal delta activity increases during several tasks such as Sternberg and Go/no-go; and they may correspond to inhibition of sensory afferents (Harmony et al., 2013). Inhibition of sensory inputs can play a role for better performance by increasing concentration (Harmony et al., 2006). In our task, we assumed that the participants have used a similar strategy: the sensory inputs were ignored, while the level of concentration increased.

It should be noted that there are not many reliable reports on EEG during flow state. In addition to that, there is substantial inconsistency among existing EEG studies during flow state. For instance, Kock (2014) mainly reported low-beta power during flow state. Kramer (2207) reported that left temporal alpha power could be used as a predictor of performance. Despite this, there is considerable methodological heterogeneity among studies. For instance, Kramer used a single flow condition and aimed to find predictors of higher performance. In addition, only two temporal electrodes were used for EEG recording. In addition, Kock also used performance data to separate flow from non-flow conditions. However, in our study we assumed that task speed is a determinant of slow state. Similar speed manipulations were also used previously in other experiments (Yoshida et al., 2014). In this way, different flow states can be induced and each states require different cognitive resources.

Our research has a number of limitations. First, we only tested young students who enjoy video games. The EEG representation of flow can be different in other populations, such as older people or people who do not like video games. Otherwise, only one type of task was used. In the present study, we only investigated the effect of speed level on flow states. Limited number of EEG-flow studies indicates that EEG findings during flow may be task dependent. Third, we did not use performance monitoring to determine the most effective flow conditions. A different analysis method could be done by including only the EEG during very high level of performance. To overcome these difficulties, future studies should test different samples with multiple tasks and may analyze EEG by considering the performance.

Finally, flow state is a condition that boosts the performance and well-being. Flow is a desirable state for people whose works are based on their performance, for instance athletes, musicians, artists etc. Behind an obligatory work, experiencing flow comes with enjoyment and intrinsic motivation. In Maslow's hierarchy, self-actualization is last step to reach. Therefore, feeling good as doing one's best could be a purpose of life. Otherwise, flow measures are limited to qualitative scales or questionnaires with some methodological problems: Interrupting flow process in order to take instant information from participants and interviewing with participants after a while from flow moment (Rettie, 2001). Given the limited number of studies on EEG during flow, it is difficult to reach a general conclusion. However, our results indicate that theta and delta bands could be important predictors of flow state. We definitely need more EEG studies to better understanding EEG correlates of flow studies, while other studies should focus on using EEG knowledge to increase performance and well-being via methods such as neurofeedback.

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