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The Psycho/Bio/Neurological Bases of Subjective Time Flow

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Abstract

Time is one of the things that people face for a long time throughout their lives. Time has continued to mark itself from the time the concept was first created until today. Subjective time that flow while living daily life has a different speed, and it affects other psychological functions. However, to best of our knowledge, it is little known about psycho/bio/neurological bases that contributed to of one's subjective time. Considering the psycho/bio/neurological mechanisms of subjective time flow, we hypothesize that the interaction of fantasy and metacognition, and these bio/neurological components. Fantasy makes time flow faster, and metacognition makes time flow slower are suggested. Looking at the hypothesis of biological and neurological mechanism of these processes, the relationship between opioid, oxytocin, hypothalamic-pituitary-adrenal axis (HPA axis), and cortisol are important. This biological and neurological mechanism causes differences in flow of subjective time. Then, I explain the psychological, biological and neurological variability in individual with Alzheimer's dementia who has abnormality in subjective time flow. As suggests, when abused child grows up, he/her may immerse himself/herself in a fantasic world to avoid recalling aversive memories. They may speed up subjective time in order to forget (avoidance) aversive memories. Neverthless, there are limits to the accompanying biological and neurological changes. When that limit is exceeded, their subjective time becomes very slow, and eventually time will stop.

Keywords: Subjective time flow, fantasy, metacognition, opioid, oxytocin, HPA axis, cortisol.

Introduction

Time is one of the things that people face for a long time throughout their lives. Time has continued to mark itself from the time the concept was first created until today. Time is the length of time between two points. There are times when the flow of time is as precise as the second hand of a clock, others times when the speed of the flow changes each time. For example, when individual have to touching dry ice with bare hands, that time will feel very long, as if time has stopped. On the other hand, the fleeting time people spend with his/her lover feels like a blink of an eye. Even if it was yesterday, it is difficult to remember all the information in detail as if from a video film. Sometimes, everyone can come up with innovative ideas by combining knowledge, information, and concepts that are far apart. These contradict each other if the amount of information changes over time. Therefore, subjective time that flow while living daily life has a different speed, and it affects other psychological functions. There was reported that individual with psychiatric disorder has abnormality in speed of their subjective time. However, to best of my knowledge, it is little known about psycho/bio/neurological bases that contributed to of one's subjective time. In this article, we focus on and discuss about fantasy, metacognition, and its bio/neurological bases that composes subjective time flow. Then, we also explain the both abnormality of them that caused by developing a psychiatric disorder, and adequate regulation method of subjective time flow.

Psycho/bio/neurological mechanisms of subjective time flow

Time—whether objective ("clock") time or the subjective experience of time—is essential for understanding how individuals, teams, and organizations evolve, grow, learn, and change (Shipp & Jansen, 2021). Subjective time passes for everyone, and sometimes everyone notices the flow of time at random moments. Then, the flow of subjective time differs each time, just as the time taken to do things that are fun or require concentration is felt to be fast, and the time taken to do things that are not interesting feel slow. As central and peripheral nervous system of the subjective time, previous studies indicated that dorsolateral prefrontal cortex (dlPFC), insula and, autonomic nervous system are related to it (Critchley et al., 2004; Krivonogova et al., 2021). As biological associates, endogenous opioid that contain enkephalin oxytocin, and cortisol are contributed to it (Chen et al., 2020; Colonnello et al., 2016; Hennessy et al., 2022). Considering the psycho/bio/neurological mechanisms of subjective time flow, I hypothesize that the interaction of fantasy and metacognition, and these bio/neurological components are contributed to it (Figure 1). First, when discussing at the relationship between one's fantasy and metacognition (see review Shiota, 2024), fantasy is defined as the mental experiences associated with a tendency to identify and transpose (immerse) with characters in movies, novels, plays, and other fictional situations (Davis, 1980; Davis, 1983; Shiota & Nomura, 2022). As neurological

correlates of fantasy, previous studies reported that dlPFC and sympathetic nervous system are related to it (Banissy et al., 2012; Gemignani et al., 2000). In biological bases, previous studies report that an endogenous opioid that contain enkephalin enhances fantasy (Bershad et al., 2015), while oxytocin reduces fantasy (Montag et al., 2020). Metacognition is defined as the cognitive function of objectively monitoring one's inner experiences and emotional events, which vary from moment to moment (Kabat-Zinn, 2023). As neural correlates of metacognition, insula are related to this (Critchley et al., 2004). As biological correlates, previous studies indicate that the endogenous opioid that contain enkephalin reduces metacognition (Sadeghi et al., 2017), while oxytocin enhances metacognition (Aydın et al., 2018), respectively. Previous psycho/neurological studies revealed that fantasy and its neural bases contribute to metacognition and its neural networks (Gilpin et al., 2015; He et al., 2017; Shiota & Nomura, 2022). According to previous biological study (Hirose et al., 1997), oxytocin is produced in the hypothalamus posterior pituitary, and this process is induced by enkephalin.

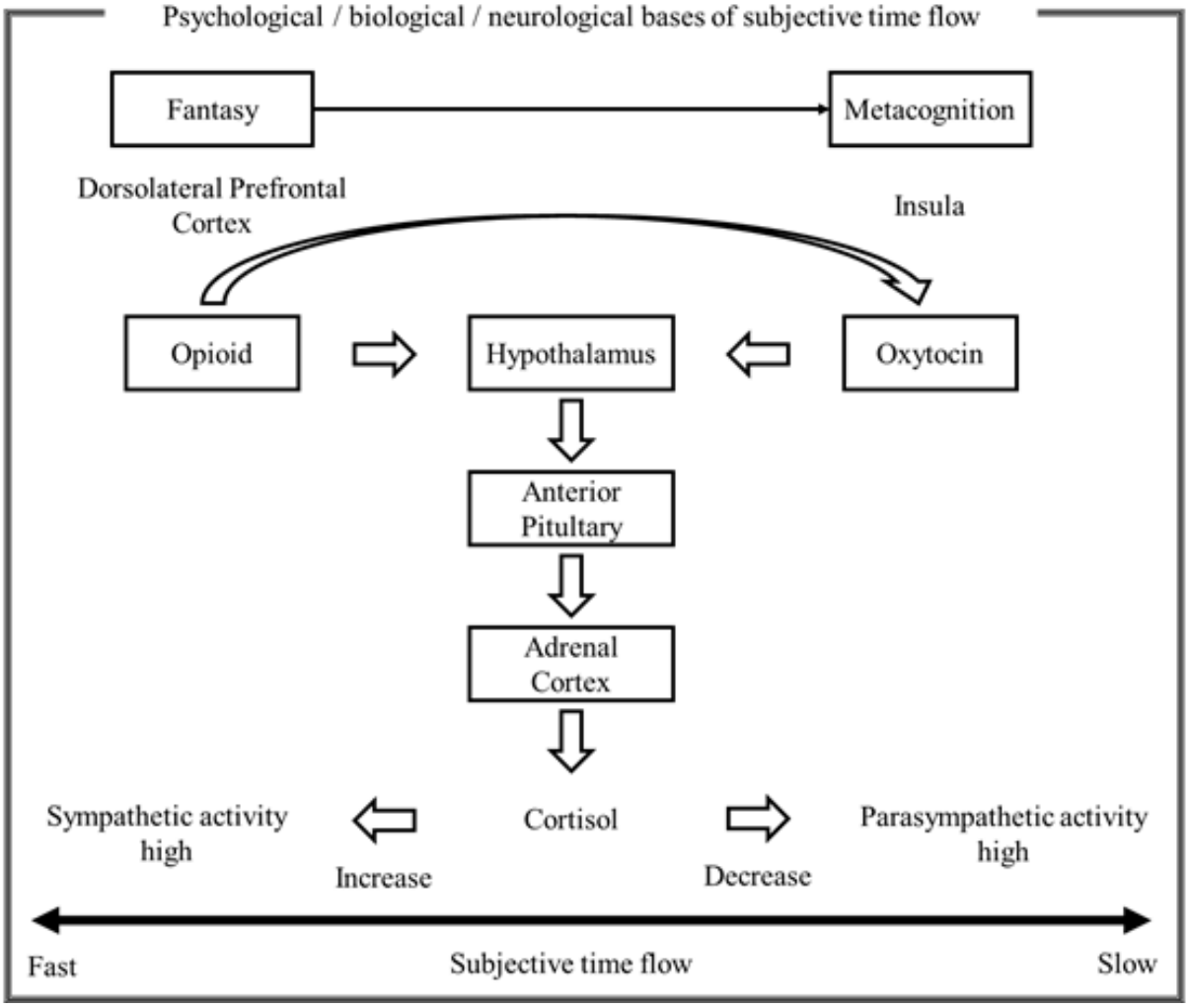
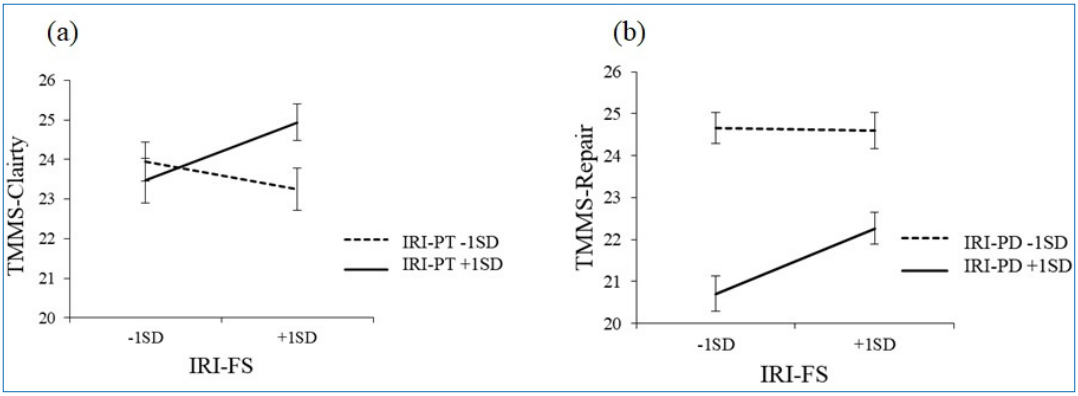


Figure 1: Psycho/bio/neurological mechanism of subjective time flow



According to previous study, there is suggested that fantasy makes subjective time faster. For example, Tobin and Grondin (2009) had examined the effects of fantasic video game for one's subjective time flow. As results, participants have felt faster their subjective time flow during play fantasy video game compared to control condition. Likewise, Wood et al. (2007) have indicated that video game makes feel faster on participant's subjective time. Rutrecht et al. (2021) have examined that which video game allows time to pass faster, one uses virtual reality or another one that uses normal screen. They have reported that participants who had playing video game with virtual reality felt faster their subjective time compared to participants who had playing video game with normal screen. There is also suggested that metacognition makes subjective time slower. For example, Witowska et al. (2020) have revealed that there was negative correlation between inter individual differences of meta-awareness for temporal situation and inter individual differences of speed of subjective time flow. Wittmann and Schmidt (2013) reported that mindfulness meditators who enhances sensory experiences, aware of feelings, and of body states has felt slowing down of time interval. Therefore, fantasy makes time flow faster, and metacognition makes time flow slower are suggested. Looking at the hypothesis of biological and neurological mechanism of these processes, the relationship between opioid, oxytocin, hypothalamic-pituitary-adrenal axis (HPA axis), and cortisol are important. HPA axis is the key components of the stress system (see review Guilliams & Edwards, 2010). When the hypothalamus is triggered by a stressor, corticotropin-releasing hormone and arginine vasopressin are secreted, eliciting both the production of adrenocorticotropin hormone from the posterior pituitary and the activation of the noradrenergic neurons of the locus caeruleas/norepinepherine system in the brain. The locus caeruleas/norepinepherine system is primarily responsible for the immediate "fight or flight" response driven by epinephrine and norepinephrine, while adrenocorticotropin hormone drives the production of cortisol from the adrenal cortex. Blood cortisol levels affect the function of the autonomic nervous system. Under normal conditions, the production of corticotropin-releasing hormone and adrenocorticotropin hormone fluctuate in a predictable circadian cycle and are inhibited by high levels of blood cortisol via a well-described negative feedback loop. By adding opioid that related to fantasy and oxytocin that associated to metacognition, this stress system model applied to a model of subjective time flow. According to previous studies (Kemper et al., 1990; McCaul et al., 2001; Wand et al., 2002), opioid modulates one's HPA axis, and it leads to increases cortisol levels. Increase in cortisol levels speeds up the flow of one's subjective time (Hennessy et al., 2022). Oxytocin also modulates one's HPA axis, it leads to decreases cortisol levels (Ditzen et al., 2009; Yeùen, 2010). Therefore, it is suggested that both opioid that related fantasy and oxytocin that associated to metacognition effects cortisol via HPA axis. And there is also suggested that this biological and neurological mechanism causes differences in flow of subjective time. In the next section we will discuss psychological, biological and neurological variability in individual with psychiatric disorder who has abnormality in subjective time flow. we will discuss where variability occurs in the basis of flow of the subjective time.

Psychological, biological, and neurological abnormality in subjective time flow in individual with Alzheimer's dementia

Dementia including Alzheimer's dementia is the loss of cognitive functioning - thinking, remembering, and reasoning - to such an extent that it interferes with a person's daily life and activities (National Institute on Aging, 2022). Gustavsson et al. (2022) reported that approximately 22% of the population suffers from Alzheimer's dementia. When individual became Alzheimer's dementia, several biological and neurological changes occur, and it leads to impairment of their episodic memory. For example, Guo et al. (2009) reported that individual with Alzheimer's dementia has significantly reduction gray matter volume in temporal pole, dlPFC, hippocampus, para-hippocampus, insula, caudate, thalamus, and cingulate cortex. Especially, previous study (Wong et al., 2014) showed that reduction gray matter volume in dlPFC predicts impairment episodic memory performance in people with Alzheimer's dementia. As biological changes when individual became Alzheimer's dementia, previous studies (e.g., Tanguturi & Streicher, 2023) reported that abnormality of β-site amyloid precursor protein. On this, Tanguturi and Streicher (2023) also suggested that the opioid receptor family is a promising candidate for targeted drug development to treat Alzheimer's dementia. β-site amyloid precursor protein, cleaving enzyme 1, and γ-secretase enzymes promote the amyloidogenic pathway and produce toxic Aβ peptides that are predisposed to aggregate in the brain. Hence, the targeted inhibition of cleaving enzyme 1/γ-secretase expression and function is a promising approach for Alzheimer's dementia therapy. Changes in the signaling pathways of opioid receptors increased the expression of cleaving enzyme 1 and γ-secretase, and is strongly related to abnormal production of Aβ and pathogenesis of Alzheimer's dementia. Ouanes and Popp (2019) reported that individual with Alzheimer's dementia has higher cortisol level compared to healthy. Then, they also reported that high cortisol level exert neurotoxic effects on the hippocampus, and amyloid β peptide toxicity. Applying these findings to my model, there is suggested that opioid-induced excessive secretion of cortisol via the HPA axis causes subjective time to pass too fast. When subjective time passes too fast, it actually too slows down. Then, eventually time will stop. There is suggested that abnormality of fantasy in individual with Alzheimer's dementia. For example, El Haj et al. (2019) demonstrated that individual with Alzheimer's dementia more frequently immerse their fantasy world than in controls. El Haj et al. (2020) also indicated that people with Alzheimer's dementia frequently immerse their fantasy world than control, and contents of it is negative, oriented toward the past, less vivid and specific. Radford et al. (2017) showed that childhood adversity is significantly predicted Alzheimer's dementia. Fantasy is much like a canvas in one's mind, on which one can draw characters such as themselves or others (Shiota & Nomura, 2022). This canvas immerses people in a comprehensive image of an event (Shiota & Nomura, 2022). In

case of child abuse, children immerse themselves fantastic world in order to escape from the tragic experiences that are repeated on a daily living by the caregiver (Shiota, 2024). Or, when abused child grows up, he/her may immerse himself/herself in a fantasic world to avoid recalling aversive memories. They may speed up subjective time in order to forget (avoidance) aversive memories. However, there are limits to the accompanying biological and neurological changes. When that limit is exceeded, their subjective time becomes very slow, and eventually time will stop. There is thought that it becomes difficult to know the front, back, left, and right directions or the passage of time (Figure 2).

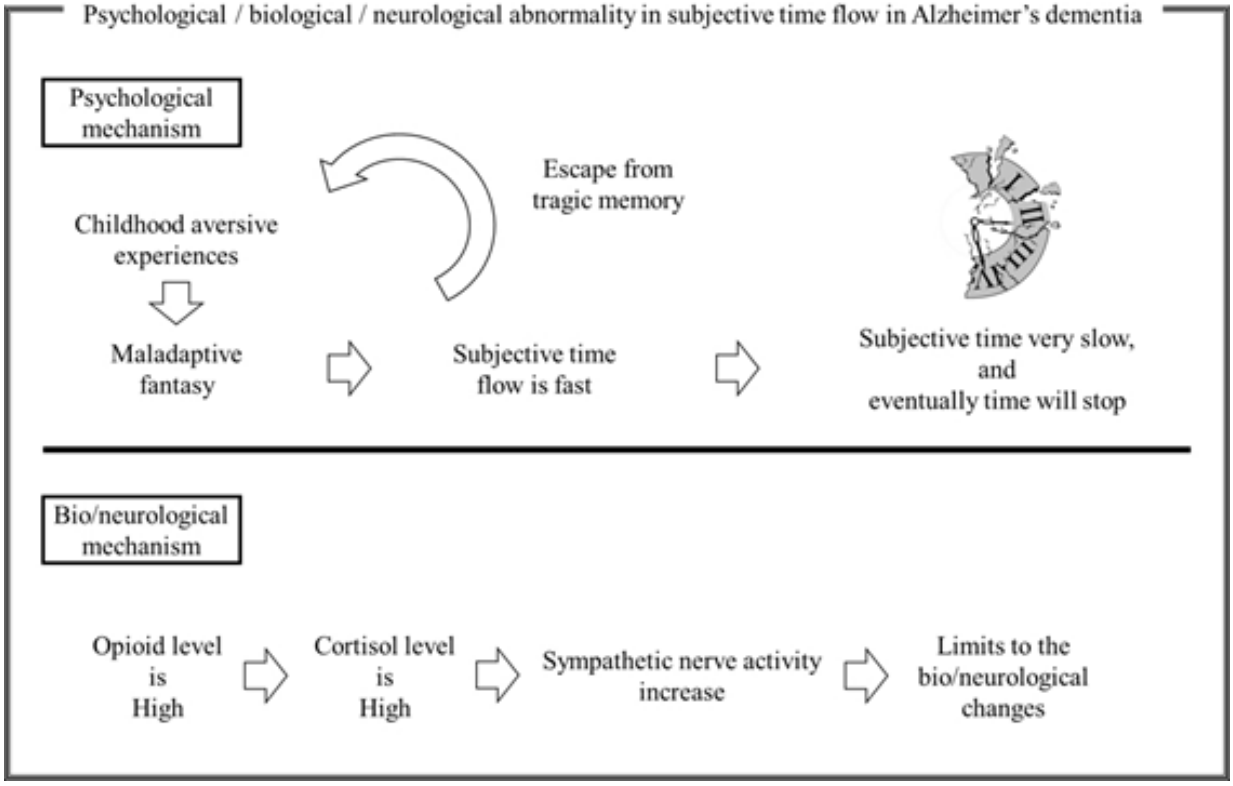


Figure 2: Pathology of Alzheimer's dementia

Conclusion

In this article, we discussed about the psychological, neurological and biological bases of subjective time flow. we hypothesized the interaction of fantasy and metacognition, and these bio/neurological components such as opioid, oxytocin, sympathetic nervous system, and para sympathetic nervous system are contributed to it via HPA axis. Then, we explained the psychological, biological and neurological variability in individual with Alzheimer's dementia who has abnormality in subjective time flow. As suggests, when abused child grows up, he/her may immerse himself/herself in a fantasic world to avoid recalling aversive memories. They may speed up subjective time in order to forget (avoidance) aversive memories. Neverthless, there are limits to the accompanying biological and neurological changes. When that limit is exceeded, their subjective time becomes very slow, and eventually time will stop. This is my hypothesis of pathologic mechanism of Alzheimer's dementia. However, there are several limitations in my article. First, the effects of opioids on one's cortisol via HPA axis are inconsistent. This is thought to be related to the difference in the prescribed amount of naltrexone. It is necessary to the further studies which examine the effects of low dose naltrexone on one's cortisol via HPA axis. Second, considering time axis, it is slightly difficult to explain the relationships between child abuse and Alzheimer's dementia. It has to clarify the mediating factors of them. Third, there is no concrete intervention method has been established for one's subjective time. There is needed to new intervention that stimulate the central nervous system from the body surface via peripheral nerves.

Running Title

subjective time flow, fantasy, and metacognition.

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Conflict of Interest

The authors declare no conflict of interest.

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