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The relation of flow-experience and physiological arousal under stress — Can u shape it?☆

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HIGHLIGHTS

- We investigated psychophysiological processes of flow-experience under stress.
- Flow showed an inverted u-shaped relation with HPA-axis activation.
- Flow showed an inverted u-shaped relation with indices of sympathetic arousal.
- Parasympathetic activation was linearly and positively related to flow.
- Possibly a co-activation of both branches of the ANS facilitates task-related flow.

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ABSTRACT

In this study, we investigate the relationship between stress and flow-experience with the help of psychophysiological arousal indicators. Whereas recent studies suggest a positive relation between flow and physiological arousal, so far nothing is known on the relation between flow and high arousal in response to a salient stressor. We here suggest that the relation of flow with sympathetic arousal and hypothalamic–pituitary–adrenal (HPA) axis activation follows an inverted u-curve rather than a linear function: moderate physiological arousal should facilitate flow-experience, whereas excessive physiological arousal should hinder flow. In order to experimentally stimulate high physiological arousal, we exposed 22 healthy male participants to a modified version of the Trier Social Stress Test. Then, participants had to perform a complex computer task for 60 minutes and to rate their flow-experience on the Flow Short-Scale directly after task completion. During the experiment, cortisol samples were taken every 15 minutes, and heart rate variability measures were assessed by continuous electrocardiography. We found an inverted u-shaped relationship of flow-experience with indices of sympathetic arousal and cortisol, whereas parasympathetic indices of heart rate control during stress were linearly and positively correlated with flow-experience. Our results suggest that moderate sympathetic arousal and HPA-axis activation and possibly a co-activation of both branches of the autonomic nervous system characterize task-related flow-experience.

Introduction

Flow-experience is a pleasant state of absorption of a person during an optimally challenging activity. During flow, the acting person shows undivided attention to a limited stimulus field, while time experience is typically distorted and self-referential thoughts are faded out of the mind (Csikszentmihalyi, 1975). This experiential state occurs when skills of a person and demands of the activity are in balance, and both above average (Csikszentmihalyi & LeFevre, 1989; Rheinberg, 2008).

The first studies on the physiology of flow were published in the last few years, e.g., from Kivikangas (2006), Nacke and Lindley (2009), De Manzano and colleagues (De Manzano, Theorell, Harmat, & Ullén, 2010) and Keller and colleagues (2011), who – apart from Kivikangas –

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found flow-experience to be associated with increased physiological activation on our bodies' two stress-systems: the fast reacting sympathetic nervous system (De Manzano et al., 2010; Nacke & Lindley, 2009) and the slow reacting hypothalamic–pituitary–adrenal (HPA) axis (Keller et al., 2011). Can we conclude that flow is from a physiological view point a state of stress (Keller, Bless, Blomann and Kleinbohl, 2011)?

Flow-experience has been described in the context of stress before: Csikszentmihalyi (e.g., Csikszentmihalyi, 1975) often refers to rock climbing – a high-risk sport – when investigating flow, and Rheinberg and colleagues (Rheinberg, Vollmeyer, & Engeser, 2003) found the highest flow values (compared to their earlier studies) in a study on graffiti spraying (Rheinberg & Manig, 2003) — an activity that is often performed illegally with a risk of being caught by authorities. Weimar (2005) explicitly investigated flow in relation to stress: In his cross-sectional study with teachers, he found support that flow can be experienced in situations that are stress-relevant according to the transactional stress model (e.g., Lazarus & Folkman, 1984). The transactional stress model states that an individual will experience stress, if – as a result of a subjective appraisal – a situation or task is rated as personally relevant and if the demands of a situation or task exceed the skills and coping resources of the individual. A stress-relevant situation can be appraised as a threat, a loss or a challenge. In contrast to threat and loss, challenge is followed by pleasurable emotions (Lazarus & Folkman, 1984). Csikszentmihalyi (1990) drew a link between flow and challenge, stating that stress could be transformed into flow when it is interpreted as challenge (see also: Ohse, 1997; Peifer, 2012; Weimar, 2005). Correspondingly, Lazarus and colleagues (Lazarus, Kanner, & Folkman, 1980) described flow as a very functional experience during challenging activities that helps to sustain coping when required.

Taken together, there is empirical and theoretical evidence that a certain amount of stress (more precisely: challenge) and the requirement to cope are linked to flow-experiences. Accordingly, studies found heightened physiological arousal on the two stress systems during flow. Does that imply a positive and linear relationship between physiological arousal and flow-experience?

When we compare the transactional stress-model with the flow-model, both models make use of a comparison between demands of the situation and skills of the person. If demands exceed skills, Lazarus calls this state stress, while Csikszentmihalyi calls it anxiety (compare Fig. 1A). Beyond stress, the flow-model describes other experiential states depending on different demand-skill-ratios: boredom and relaxation occur if skills exceed demands; and flow occurs when skills and demands are in balance (Csikszentmihalyi, 1975; Csikszentmihalyi & LeFevre, 1989). From a physiological point of view, anxiety and stress are characterized by high physiological arousal, as indicated by increased sympathetic nervous system and HPA-axis activation; boredom and relaxation are characterized by low physiological arousal, respectively. As flow-experience in the flow-model is located between

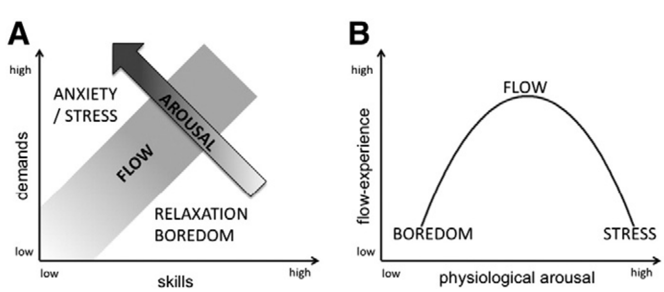

Fig. 1. Physiological arousal during flow-experience between stress and relaxation. A. The flow-channel model adapted from Csikszentmihalyi (1975) and Rheinberg (2008): physiological arousal increases continuously from a low arousal state of boredom or relaxation to a high arousal state of anxiety/stress leading to the suggestion that flow-experience comes along with moderate physiological arousal. B. The relationship of flow-experience and physiological arousal as described in Panel A. can be drawn as an inverted u-curve.

boredom and anxiety, we expect – from a physiological perspective – flow-experience to occur between high arousal (characteristic for anxiety) and low arousal (characteristic for boredom), at a state of moderate activation of the sympathetic nervous system and the HPA-axis (Fig. 1A). This means that the highest flow-values should be measured during moderate sympathetic nervous system or HPA-axis activation, whereas low flow-values will occur in both in a state of low (boredom) as well as in a state of high (stress) physiological arousal. As illustrated in Fig. 1B, we conclude that the relation of flow-experience with arousal on the two stress systems describes an inverted u-function. In detail, we expect an inverted u-shaped relationship between flow-experience and sympathetic activation (Hypothesis 1) and between flow-experience and HPA-axis-activation (Hypothesis 2).

Also De Manzano et al. (2010) suggested that an inverted u-shaped relationship between arousal and flow is intuitively plausible, despite finding a linear relationship between arousal and flow in their study, when participants played their favorite piano piece. They speculated that flow-experience might be related to arousal in a similar way as performance and point to the Yerkes-Dodson Law (Yerkes & Dodson, 1908), which states the relationship between arousal and performance follows an inverted u-curve.

In spite of strong theoretical arguments for the postulated inverted u-shaped relationship of flow-experience with physiological arousal, this relationship has not been tested until now. The research existing so far on the psychophysiology of flow found support for a positive relation between flow and arousal. However, these findings do not contradict the proposed inverted u-shaped relationship: none of these studies tested (and did not intend to test) physiological arousal on a stress level and were, consequently, only able to test the left side of the proposed u-curve, representing a positive relationship between flow and arousal. All past studies on physiological aspects of flow have taken place in a safe laboratory context, either playing a computer game (Keller et al., 2011; Kivikangas, 2006; Nacke & Lindley, 2009) or playing a favorite piece of music on the piano (De Manzano et al., 2010). Both – even when computer games are played at a high demand level – will most likely not be appraised as so personally relevant to perceive threat or loss and will not lead to high arousal and stress in a physiological and psychological sense. Furthermore, none of these previous studies tested quadratic relationships. The major aim of this study is, thus, to assess the relation between flow and physiological arousal *under stressful conditions*, in order to test the predicted inverted u-shaped relationship. In contrast to previous studies on the physiology of flow, we apply a special design feature to make sure our participants experience a significant amount of stress: we manipulate the participants' stress-level with a well-established stress protocol before the start of the actual experiment and use the transfer of arousal to test our predictions (compare Schachter, 1964, 1970; Schwarz & Clore, 1983; Schwarz, 2011; Zillmann, 1971; cf. the Methods section for a more detailed explication of this approach).

While we expect an inverted u-shaped relation between flow and sympathetic activation, the expected relation between flow and parasympathetic activation (= vagal tone) is less clear: The parasympathetic nervous system is the counter player of the sympathetic nervous system and down regulates physiological arousal (Porges, 1995). Both players can be active at the same time and influence arousal measures independently (Berntson, Cacioppo, & Quigley, 1991). The interaction pattern of sympathetic and parasympathetic activation can be reciprocal, positively related (coactivation or coinhibition) or uncoupled (Berntson et al., 1991). The different possibilities of sympathetic and parasympathetic interaction provide a higher flexibility and precision of the autonomic response in order to meet anticipated or realized environmental challenges (Berntson et al., 1991; Thayer & Lane, 2000). De Manzano et al. (2010) found indication that flow-experience might be associated with increased parasympathetic modulation of sympathetic activity. This speaks for a coactivation of the autonomic branches during flow and, in terms of parasympathetic activation, for a positive relation to