Title

Risk Taking and Impulsivity in Boredom: an EEG investigation

Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 42(0)

Authors

Yakobi, Ofir
Danckert, James

Publication Date

2020

Risk Taking and Impulsivity in Boredom: an EEG investigation

Ofir Yakobi (ofiryakobi@gmail.com)
James Danckert (jdancker@uwaterloo.ca)
Department of Psychology, University of Waterloo, Waterloo, ON, Canada

Abstract

Previous research on boredom suggest it function as an important self-regulatory signal, indicating that the current state of the environment carries opportunity-costs and therefore driving the need to explore alternative activities. Trait boredom proneness is associated with negative consequences including increased risk-taking and impulsivity. These findings often rely on self-reports and not much is known about the role of state and trait boredom in controlled laboratory tasks, or their neural correlates. Sixty-two participants completed the Balloon Analogue Risk Task and a go/no-go task while electrical brain activity was recorded using EEG. Results showed that state boredom leads to impulsivity and poor performance monitoring, as evident by behavioral, subjective and ERP metrics. Trait boredom was associated with increased risk-taking, and modulated the correlation between errors and state boredom: high boredom proneness increased the sensitivity of trait boredom to errors. Overall, these findings emphasize the involvement of executive functions in the interaction between state and trait boredom.

Keywords: Boredom; Risk-taking; Impulsivity; P3; FRN; ERN; BART; Go/no-go;

Introduction

Boredom is an unpleasant feeling of being mentally unoccupied, despite wanting to be engaged (Danckert, 2019; Eastwood, Frischen, Fenske, & Smilek, 2012). When adaptively responded to, boredom can be thought of as an important signal that translates goals into actions (Danckert, 2019). Recent research supports this notion of boredom as a self-regulatory signal indicative of rising opportunity costs. Kurzban et al. (2013) suggest that the experience of boredom and its associated performance decrements result from a computational process indicating that mental resources are not efficiently utilized. This opportunity cost signal, in turn, can lead to disengagement from the task and exploration of alternate options for mental engagement.

High levels of boredom (mainly trait) are associated with various negative consequences, including poor attentional control, increased impulsivity and risk-taking (e.g., gambling, substance use; Blaszczynski, McConaghy, & Frankova, 1990; Danckert, Mugon, Struk, & Eastwood, 2018; Vodanovich, 2005). Studies show that high boredom prone individuals tend to have higher rates of addiction, problem gambling, binge drinking, and are prone to making risky financial decisions (Biolcati, Mancini, & Trombini, 2018; Igou, 2019; Miao, Li, & Xie, 2019).

It is not yet clear what mechanism(s) drives risk-taking in boredom, and what unique contributions are made by state and trait boredom in these behaviors. One possibility involves reward sensitivity. Risk-takers are often characterized by high reward sensitivity and impulsivity (Van Leijenhorst et al., 2010). Support for this hypothesis stems from the notion that high boredom prone individuals are more sensitive to the utility and costs in their environment, as formulated by the opportunity cost model (Kurzban et al., 2013; Struk et al., under consideration). However, most findings relating boredom to risk-taking and impulsivity rely on self-reports (e.g., scales or self-reported behaviors) with far less known about their neural signature or expression in laboratory tasks.

Preliminary neuropsychological support for the increased reward sensitivity hypothesis was observed with the feedback-related negativity (FRN), an event-related potential (ERP) elicited in response to feedback stimuli. There is ample evidence that the FRN represents computation of reward value, involving the midbrain dopaminergic system and the anterior cingulate cortex (Holroyd & Coles, 2002). In a recent paper, Milyavskaya et al. (2019) manipulated state boredom, effort, and reward type, and found that the FRN was strongest in the boredom condition. This is the first neuropsychological finding to show boredom affects reward sensitivity.

In summary, previous findings imply that the prevalence of risky behaviors in high boredom prone individuals represents a tendency for maladaptive responding to the state boredom signal. Here we explored the behavioral and neuropsychological associations between both trait and state boredom and performance on tasks intended to measure response inhibition (i.e., using a go/no-go task; Pfefferbaum, Ford, Weller, & Kopell, 1985) and risk taking (i.e., in the Balloon Analogue Risk Task, BART; Lejuez et al., 2002).

Method

Participants

Sixty-two undergraduate students (47 females) aged 18 to 23 (M=19.98) participated in the study. After completing questionnaires as part of an online survey administered to a larger sample of undergraduates at the University of Waterloo, participants took part in the study for course credit and a monetary reward. All participants gave written informed consent prior to participating and the protocol received approval from the University of Waterloo's Office of Research Ethics.

Procedure

The experiment took place in the mornings and lasted approximately 80 minutes. Resting state EEG was recorded with eyes closed and eyes open for a period of 2 minutes each, followed by the two tasks performed in a random order. Each task started with a state boredom probe, written and video instructions, and a few practice trials with feedback (four in the BART and ten in the go/no-go task). After each task was completed, a subjective workload scale and another state boredom probe were administered. After completion of the experiment participants received monetary reward based on their performance in the BART.

Balloon Analogue Risk Task (BART). In the classic BART participants are presented with a sequence of balloons, with each one preset to explode at a random point (drawn from a 1-128 uniform distribution). They are required to ‘pump’ air into each balloon manually until it either explodes or they decide to move to the next one. In instances in which the balloon explodes they receive no points. However, if they decide to move to the next balloon before it explodes, their points in this trial correspond to the number of pumps made (Lejuez et al., 2002). Hence, the goal is it to pump each balloon as many times as possible without popping it. There are two limitations for this design in our context. First, there are significantly more pumps that lead to positive feedback (no explosion) than negative (explosion), which can be problematic for calculating event-related potentials. Second, risk-taking is confounded with the duration of the task: given that more pumps represents increased risk-taking, then risk-taking in this context is time costly and may confound the association between risk-taking and willingness to invest more time in the task. We address these two issues by basing our task on another variation of the BART (Pleskac, Wallsten, Wang, & Lejuez, 2008). In this version, participants determine the number of pumps (1-128) for each of the 100 balloons by choosing a value on a slider and then pressing “Pump”. Feedback appears after 1000ms for a fixed duration, unrelated to the number of pumps. If the balloon popped, the popping point appears as feedback (Fig. 1).

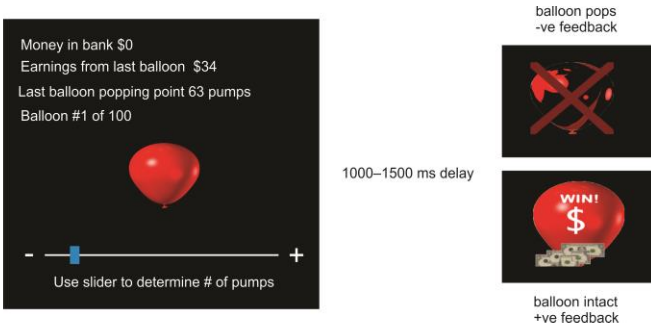

Figure 1: A trial in the BART (left) and possible feedback screens (right).

Go/no-go task. We used a go/no-go task to measure response inhibition and sustained attention. In this task, based on similar tasks (Garavan, Ross, Murphy, Roche, & Stein, 2002; Garavan, Ross, & Stein, 1999), participants were presented with a sequence of randomly drawn digits and letters. They were instructed to press the space bar for every stimulus presented on the screen, with the exception of a repeated stimulus. The sequence included 600 stimuli separated into ten blocks, with each block ending with feedback indicating how many points they gained in the current block and in total (Fig. 2). Stimuli were generated randomly with two constraints: (1) No-go stimuli rate of 30% and (2) No more than one no-go stimulus in a row. Due to our interest in error-related ERPs, we aimed to keep the rate of false-alarms around 30% by adjusting the stimulus onset asynchrony (SOA) automatically throughout the task. Participants started with an SOA of 1100ms. If false-alarm rates dropped below 33%, the SOA decreased by 50ms to a minimum of 800ms. If false alarm rates rose above 66%, the SOA was increased by 50ms to a maximum of 1400ms.

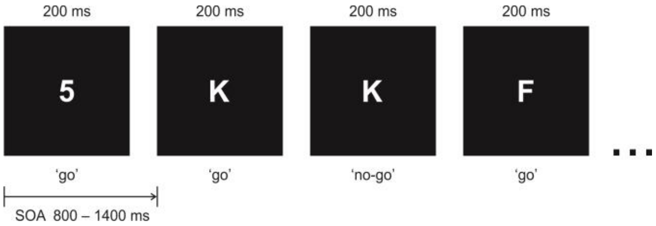

Figure 2: Trial types in the go/no-go task.

Short Boredom Proneness Scale. Trait boredom was measured using an 8-item scale (Struk, Carriere, Cheyne, & Danckert, 2017), rated on a 1 (strongly disagree) to 7 (strongly agree) Likert scale, averaged to form a composite trait boredom proneness score.

Boredom Probes (state boredom). Participants were asked to rate “How bored are you feeling right now?” on a 1 (not at all) to 9 (highly) scale, using a slider. There were three boredom probes –before the tasks started, and after each task.

Task-demands. After each task, participants were asked to rate “How demanding was the task you just completed?” on a 1 (not at all) to 100 (highly) scale, using a slider.

EEG recording. Electrophysiological data were recorded using Biosemi Active-Two amplifier with active Ag/AgCl electrodes in 32 scalp sites (10-20 system). Additional electrodes were placed over the left and right mastoids as linked reference, next to each outer canthus for horizontal ocular movements, and one below the right eye for detecting vertical ocular movements. Data were sampled in a 2048 Khz rate and down-sampled offline to 256 Hz.

Event-Related Potentials (ERP). Based on visual inspection and previous research, we defined the no-go P3 as the most positive peak in a 300-600ms window after the onset of a go or no-go signal. The event-related negativity (ERN) was defined as the most negative peak in a 0-100ms window.

In the BART, the FRN was the most negative peak occurring 220-320ms after feedback onset.

Results

For pre-processing analysis of the EEG signal we used MATLAB, EEGLAB (Delorme & Makeig, 2004) and ERPLAB (Lopez-Calderon & Luck, 2014). The automatic pre-processing pipeline used ICA to detect and correct artifacts. Bad channels were removed and interpolated, and residual artifacts were handled by rejecting contaminated trials. We used the R based JAMOVI package to analyze the ERP and behavioral data.

BART. In order to assess the effect of boredom on risk-taking, we entered trait and state boredom into a Poisson regression model predicting the number of pumps. Trait boredom, but not state boredom, predicted the number of pumps (B=0.068, Chi-Square=15.43, p<.001; B=-0.012 Chi-Square=1.80, p=.179, respectively). We regressed the thinking-time in the BART (time from trial start to pressing "pump") over boredom proneness and post-task state boredom, yielding a negative significant estimate for state (B=-0.038, p=.032), but not trait boredom (B=0.006, p=.858; Fig. 3). These findings suggest that higher state boredom is associated with more impulsivity, and boredom proneness with increased risk-taking. This increased risk-taking led to higher monetary payoffs, as shown by the correlation between boredom proneness and payoff (r=.306, p=.014).

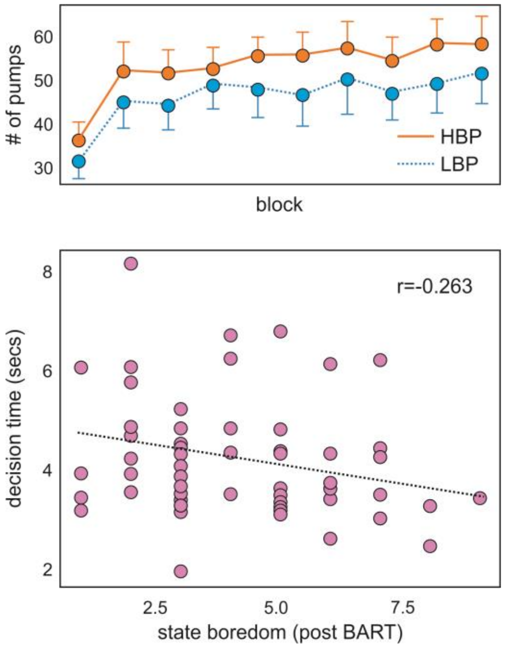

Figure 3: Upper panel: Risk-taking in the BART by BP[1] over ten blocks (error bars represent 95% CI). Lower panel: scatter plot of thinking time and state boredom after the BART.

Go/No-go. We used a general linear model (GLM) with both boredom measures as predictors for accuracy in the go/no-go task. The model was significant with R^2=0.25, suggesting an interaction between state and trait boredom (F(1,59)=8.28, p=.006). Simple slopes analysis showed that in low boredom prone participants, state boredom did not affect accuracy (t(59)=0.376, p=.708). High BP individuals, however, were sensitive to state boredom: the more bored they reported being at the end of the task, the less accurate they were during the task (t(59)=3.6, p<.001; Fig. 3).

Event Related Potentials. In each task, we correlated the relevant ERPs with state boredom as measured post-task. There were no significant correlations between state or trait boredom and the amplitude of the FRN in the BART, as measured at the Fz electrode.

In the go/no-go task, parietal no-goP3 amplitude showed a significant negative correlation with post-task state boredom, indicating diminishing no-goP3 amplitudes with higher state boredom (r=-.432, p<.001). The ERN's amplitude in Cz was positively correlated with state boredom, suggesting that a weaker ERN was associated with higher reports of state boredom (r=.3, p=.018; Figure 4).

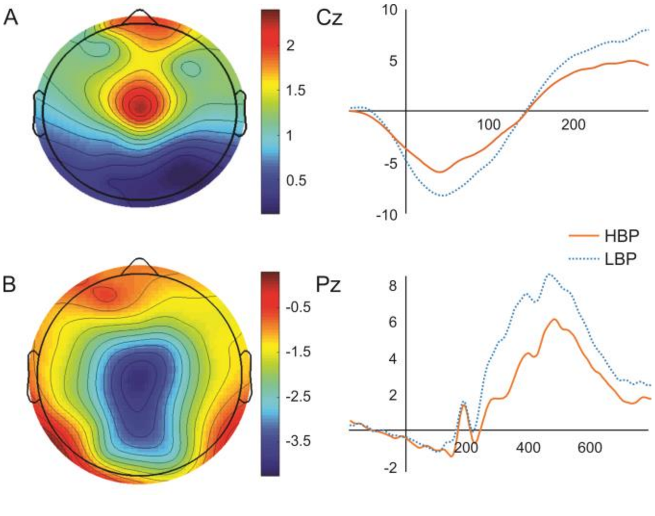

Figure 4: ERP in the go/no-go task by boredom proneness. (A) Response locked (left: topography of the difference in ERN – 40ms latency, right: ERP in Cz) and (B) Stimulus locked (left: topography of the difference in P3 – 450ms latency, right: ERP in Pz)

Task demands. The correlation between task demands and corresponding state boredom ratings were not significant

---

[1] For graphing purposes, we used a median-split to create a low- and high-boredom prone groups.

(R_{BART}=.031, p=.8; R_{GNG}=-.072, p=.574). However, the state boredom probes *before* each task predicted the experience of workload in the task (R_{BART}=.251, p=.045; R_{GNG}=.314, p=.012).

Discussion

The present study investigated the neuropsychology of two related phenomena associated with boredom: impulsivity and risk-taking. On the behavioral level, we found a double dissociation between state and trait boredom in the BART. Trait boredom was associated with risk-taking but not thinking-time, and state boredom with thinking-time but not risk-taking. It is important to note that in the BART, participants are not explicitly presented with the distribution of the popping points. In order to explore this distribution, they have to take risks (i.e., to determine what the popping point is for any given balloon). Thus, it could be that the risk-taking associated with boredom proneness we observed, reflects a more general drive to explore, while state boredom pushes us to simply "get on with it". Moreover, the average number of pumps was lower than optimal (i.e., the optimal strategy in this task is to make, on average, 64 pumps per trial). In the current context – boredom proneness was not maladaptive: it essentially pushed participants towards the optimal strategy, leading to higher monetary payoffs. Therefore, boredom proneness is not necessarily all "bad", but rather, in some contexts may drive a more optimal set of behaviors. Future studies should take this into account and investigate under which situations boredom (both state and trait) can be adaptive.

In the go/no-go task, the relationship between accuracy and state boredom was modulated by boredom proneness: higher boredom prone individuals exhibited higher sensitivity to state boredom. These findings support our idea that the negative consequences of boredom proneness may reflect a maladaptive response to the boredom signal.

Contrary to our prediction, the feedback-related negativity did not correlate significantly with boredom proneness or state boredom. Thus, we did not replicate[2] Milyavskaya et al.'s (2019) results of a stronger FRN associated with higher state boredom. Analysis of the ERPs in the go/no-go task showed decreased nogo-P3 amplitude with higher levels of state boredom, and weaker (less negative) event-related negativity. The nogo-P3 is hypothesized to reflect an inhibitory process in various inhibition tasks (Jackson, Jackson, & Roberts, 1999), implying state boredom may be associated with some difficulty in inhibitory control.

At the phenomenological level, we found that state boredom pre-, but not post-task, predicted the subjective experience of workload in both tasks. Simply put, engaging in cognitive tasks when one is already experiencing boredom, is mentally demanding. There is evidence that traumatic brain injury (TBI), especially in frontal regions, is linked with higher boredom proneness (Goldberg & Danckert, 2013). The frontal lobes are crucial for executive functioning, emotional regulation and cognitive control. It may be the case then, that highly boredom prone individuals experience difficulty in tasks dependent on frontal functioning.

Our present work demonstrates that the increased risk-taking associated with boredom proneness can be observed in common cognitive tasks. We also provided evidence that state boredom more so than trait boredom proneness, is associated with impulsivity, and modulates event-related potentials involved in inhibitory control and performance monitoring. One limitation of this study is its correlational nature; future studies should explore these relationships with a more direct boredom manipulation. A second consideration in subsequent studies should be the "adaptiveness" of risk-taking: risk-taking is not ubiquitously negative. In many circumstances, taking risks reflects an adaptive, exploratory response to the task constraints or goals of the organism.

References

Biolcati, R., Mancini, G., & Trombini, E. (2018). Proneness to Boredom and Risk Behaviors During Adolescents' Free Time. *Psychological Reports*, *121*(2), 303–323. https://doi.org/10.1177/0033294117724447

Blaszczynski, A., McConaghy, N., & Frankova, A. (1990). Boredom proneness in pathological gambling. *Psychological Reports*, *67*(1), 35–42. https://doi.org/10.2466/pr0.1990.67.1.35

Danckert, J. (2019). Boredom: Managing the Delicate Balance Between Exploration and Exploitation. In *Boredom Is in Your Mind*. https://doi.org/10.1007/978-3-030-26395-9_3

Danckert, J., Mugon, J., Struk, A.A., & Eastwood, J. (2018). Boredom: What Is It Good For? In Heather C. Lench (Ed.), *The Function of Emotions*. Springer, Cham. https://doi.org/10.1007/978-3-319-77619-4

Delorme, A., & Makeig, S. (2004). EEGLAB: an open sorce toolbox for analysis of single-trail EEG dynamics including independent component anlaysis. *Journal of Neuroscience Methods*, *134*, 9–21. https://doi.org/10.1016/j.jneumeth.2003.10.009

Eastwood, J. D., Frischen, A., Fenske, M. J., & Smilek, D. (2012). The Unengaged Mind: Defining Boredom in Terms of Attention. *Perspectives on Psychological Science*, *7*(5), 482–495. https://doi.org/10.1177/1745691612456044

Garavan, H., Ross, T. J., Murphy, K., Roche, R. A. P., & Stein, E. A. (2002). Dissociable executive functions in the dynamic control of behavior: Inhibition, error detection, and correction. *NeuroImage*, *17*(4), 1820–1829.

---

[2] Note that our design and tasks were not intended for a direct replication: out design differed significantly, as well as the task eliciting the FRN.

https://doi.org/10.1006/nimg.2002.1326

Garavan, H., Ross, T. J., & Stein, E. A. (1999). Right hemispheric dominance of inhibitory control: An event-related functional MRI study. *Proceedings of the National Academy of Sciences*, *96*(14), 8301–8306. https://doi.org/10.1073/pnas.96.14.8301

Goldberg, Y., & Danckert, J. (2013). Traumatic Brain Injury, Boredom and Depression. *Behavioral Sciences*, *3*(4), 434–444. https://doi.org/10.3390/bs3030434

Holroyd, C. B., & Coles, M. G. H. (2002). The neural basis of human error processing: Reinforcement learning, dopamine, and the error-related negativity. *Psychological Review*, *109*(4), 679–709. https://doi.org/10.1037//0033-295X.109.4.679

Kılıç, A, van Tilburg, WAP, Igou, ER. Risk-taking increases under boredom. J Behav Dec Making. 2019; 1– 13. https://doi.org/10.1002/bdm.2160

Jackson, S. R., Jackson, G. M., & Roberts, M. (1999). The selection and suppression of action: ERP correlates of executive control in humans. *NeuroReport*, *10*(4), 861–865. https://doi.org/10.1097/00001756-199903170-00035

Kurzban, R., Duckworth, A., Kable, J. W., & Myers, J. (2013). An opportunity cost model of subjective effort and task performance. *Behavioral and Brain Sciences*, *36*(06), 661–679. https://doi.org/10.1017/s0140525x12003196

Lejuez, C. W., Richards, J. B., Read, J. P., Kahler, C. W., Ramsey, S. E., Stuart, G. L., … Brown, R. A. (2002). Evaluation of a behavioral measure of risk taking: The balloon analogue risk task (BART). *Journal of Experimental Psychology: Applied*, *8*(2), 75–84. https://doi.org/10.1037/1076-898X.8.2.75

Lopez-Calderon, J., & Luck, S. J. (2014). ERPLAB: an open-source toolbox for the analysis of event-related potentials. *Frontiers in Human Neuroscience*, *8*(April), 1–14. https://doi.org/10.3389/fnhum.2014.00213

Miao, P., Li, X., & Xie, X. (2019). Hard to Bear: State Boredom Increases Financial Risk Taking. *Social Psychology*. https://doi.org/10.1027/1864-9335/a000408

Milyavskaya, M., Inzlicht, M., Johnson, T., & Larson, M. J. (2019). Reward sensitivity following boredom and cognitive effort: A high-powered neurophysiological investigation. *Neuropsychologia*, 123, 159-168.

Pfefferbaum, A., Ford, J. M., Weller, B. J., & Kopell, B. S. (1985). ERPs to response production and inhibition. *Electroencephalography and Clinical Neurophysiology*. https://doi.org/10.1016/0013-4694(85)91017-X

Pleskac, T. J., Wallsten, T. S., Wang, P., & Lejuez, C. W. (2008). Development of an Automatic Response Mode to Improve the Clinical Utility of Sequential Risk-Taking Tasks. *Experimental and Clinical Psychopharmacology*, *16*(6), 555–564. https://doi.org/10.1037/a0014245

Struk, A. A., Carriere, J. S. A., Cheyne, J. A., & Danckert, J. (2017). A Short Boredom Proneness Scale: Development and Psychometric Properties. *Assessment*, *24*(3), 346–359. https://doi.org/10.1177/1073191115609996

Struk, A., Scholer, A.A., Danckert, J., & Seli, P. (under consideration). Rich environments, dull experiences: How environment can exacerbate the effect of constraint on the experience of boredom. *Cognition and Emotion.*

Van Leijenhorst, L., Moor, B. G., Op de Macks, Z. A., Rombouts, S. A. R. B., Westenberg, P. M., & Crone, E. A. (2010). Adolescent risky decision-making: Neurocognitive development of reward and control regions. *NeuroImage*. https://doi.org/10.1016/j.neuroimage.2010.02.038

Vodanovich, S. J. (2005). Boredom Proneness: Its Relationship To Positive and Negative Affect. *Psychological Reports*, *69*(8), 1139. https://doi.org/10.2466/pr0.69.8.1139-1146