



Non-conscious neural regulation against mortality concerns



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HIGHLIGHTS

- Neuroimaging studies suggested that the rVLPFC activity plays a key role in regulation of threats.
- We examined whether rVLPFC activity serves a function to down-regulate the unconscious death concerns.
- We found greater rVLPFC activities relative to the prior baseline in the non-conscious death (but not pain) prime condition.
- These activities negatively predicted the defensive reactions after death priming.
- Our findings contribute to understanding of the neural regulation against mortality concerns.

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ABSTRACT

Social psychological studies have shown that an experience of threat such as an encounter with death-related stimuli and social exclusion results in tuning toward positive emotional information. Neuroimaging studies have also begun to uncover the neural basis of threat coping, and in this literature, the activity of the right ventrolateral prefrontal cortex (rVLPFC) has been suggested to play a key role in detection and regulation of threats. Using near-infrared spectroscopy (NIRS), we examined the activity of rVLPFC while participants were subliminally primed with the concept of “death” or the control concept “pain”. We found greater rVLPFC activities relative to the prior baseline in the death prime condition, and furthermore, these activities negatively correlated with the evaluation of the positive (but not negative) essay. These data provide initial evidence to suggest that lesser neuronal regulation of threat, when it is first encountered, may lead to subsequent regulation by affect tuning.

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1. Introduction

Recent research has begun uncovering the neurological underpinnings of psychological reactions to threat. In particular, studies have highlighted the activity of the right ventrolateral prefrontal cortex (rVLPFC) as playing a fundamental role in the individual's self-regulatory responses to threats such as ostracism [13]. For example, research has demonstrated that rVLPFC activities can inhibit the feeling of psychological pain that results from social exclusion [14,21,35]. Moreover, recent studies have

confirmed that stimulating the rVLPFC using transcranial direct current stimulation (tDCS; compared to bogus stimulation) reduces the unpleasantness and hurt feelings experienced by victims of social exclusion [31]. Thus, it seems likely that neural activities in the rVLPFC can modulate threat responses through implicit affect regulation, even in the absence of the person's intention to self-regulate. In the present research, we examined if this functional role of rVLPFC can be generalized to the psychological threat posed by reminders of personal mortality, often referred to as mortality salience threat (e.g., [28]).

A large body of social psychological work has shown that thoughts of death, induced explicitly or implicitly, trigger a range of cognitive and behavioral reactions, including expressions of shared values and attitudes, self-enhancing or in-group favoring behaviors, and the use of stereotypes and other cognitive heuristics (e.g., [19]; for a meta-analysis see [6]). Moreover, one previous study has

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shown that thinking about death prompts an automatic cognitive tuning toward positive emotional information [11]. According to terror management theory, these various reactions to thoughts of death are psychological defenses that inhibit the notion of mortality from rising to consciousness and paralyzing people [16,28]. Nevertheless, relatively little is known to date about neural mechanisms that serve such a function.

One study examined neural activities while German men read sentences concerning death (e.g., “I am afraid of a painful death”) as opposed to dental pain (e.g., “I am getting panicked, when I am sitting in the dentist’s waiting room”) and responded either “Yes” or “No” by tapping a key. The study found higher levels of activity in the right amygdala, left rostral anterior cingulate cortex, and right caudate nucleus [30]. In another study, Chinese women who read death-related words in contrast to negative or neutral words were found to have higher levels of activity in the lateral prefrontal cortex and in the precuneus/posterior cingulate [17]. These findings resonate with the claim, supported by substantial data, that threats activate the “neural alarm system” [10,13,18,22,27]. Nonetheless, neuroscience research has also shown that the alarm system, once activated, is modulated through the cognitive control processes served by the lateral prefrontal cortices including the rVLPFC [22,23,26,34]. It is yet to be investigated whether or not the vigilant responses triggered by the thought of death are also modulated by the functions of cortices including the rVLPFC.

Some indirect evidence in support of this prediction is nevertheless available. As already mentioned, thinking about one’s own death causes an automatic coping response involving tuning into positive emotional information, or “affect tuning” [11]. The same response has also been found to follow an experience of social exclusion [12]. For example, ostracized subjects showed increased accessibility of positive emotional information, or chose positive emotion words more often than semantic associates as a partner of target words. Given that responses to ostracism (social pain) are regulated by the rVLPFC, and as the rVLPFC has also been found to play a role in affect regulation ([8], for a review), the rVLPFC may also be implicated in affect tuning after threat.

Clarifying the potential roles played by rVLPFC activity when reminded of death therefore seemed essential for understanding more fully how individuals deal with a mortality salience threat. In this study we tested a hypothesis that a subtle reminder of death activates the rVLPFC.

Although recent neuroscience studies presented subjects with death-related stimuli *explicitly* (supraliminally) to examine their reactions (e.g., [17,30]), our study presented the word ‘death’ *implicitly* (subliminally) for the following reasons. First, a conscious encounter with death reminders can trigger defensive reactions involving denial of death and vulnerability, and these cognitive reactions may conceal or interfere with implicit affect regulation, whereas non-conscious death priming enables us to steer clear of such problems [28]. Moreover, prior research has implied that rVLPFC activity might modulate threat reactions when the threat is encountered non-consciously. Indeed, the rVLPFC has been highlighted in recent reviews [5,8] as the most commonly activated region for conscious and non-conscious self-regulation. For example, rVLPFC activity can regulate emotion or inhibit amygdala activity without intention [5,8,24], even when emotional responses are evoked non-consciously by subliminal stimuli [25].

To test our prediction that a subliminal death-prime activates the rVLPFC, we compared the level of rVLPFC activity before and after the priming task. Those who are primed with the word “death” should increase rVLPFC activity more than their counterparts who are primed with the control word “pain”. This is because the concept of death is a much stronger threat than pain, as demonstrated in previous research [6,17].

We further considered that increased rVLPFC activities may be implicated in automatic regulation of the amygdala and affective responses to the death prime, and consequently, they may eliminate the further need for engaging in affect tuning, which would otherwise follow death priming. This prediction was tentative however, as to the best of our knowledge there is no prior evidence that subliminal death primes are followed (or not-followed) by affect tuning. To test our assumption, we asked our participants to read and evaluate positive and negative essays. The previous affect tuning studies have found stronger orientation toward positive (but not negative) information after death priming [11]; therefore, death priming might engender a more positive evaluation of the positive essay. Nevertheless, this tendency should be observed among individuals who activate the rVLPFC relatively less. Thus, there should be a negative correlation between rVLPFC activity and positivity in the rating of the positive essay. As death reminders do not enhance orientation toward negative information [11], subliminal death priming was less likely to affect the rating of the negative essay. This implies that the evaluation of the negative essay would be relatively independent of the prior rVLPFC activity level.

We utilized near-infrared spectroscopy (NIRS) to measure bilateral VLPFC activity during the presentation of stimuli (e.g., [35]). The two-channel NIRS system implemented in the present protocol provided temporally precise measurements of oxy-hemoglobin (oxy-Hb) within those brain circuits restricted to the VLPFC. Previous studies point to the activation of the right, but not the left, VLPFC as being necessary for self-control [4,7]. Thus, we predicted that non-conscious priming of death would enhance the level of oxy-Hb in the rVLPFC relative to the prior baseline level.

2. Methods

2.1. Participants

Thirty undergraduates (17 females; mean age = 20.07 ± 1.72 years) at Hijiya University in Japan participated in the experiment. They were paid 500 yen (≈6 USD) for compensation. Participants were randomly assigned to either the death prime condition or the pain prime condition. The Ethics and Safety Committee of Hiroshima University approved the study protocol. Details of the procedure are in Supplementary Online Materials.

2.2. Procedure and materials

The participants were told that the study concerned perceptions of word relationships and evaluations of two essay writers. Instructions were provided both verbally and on a 19-inch color monitor before each task. Participants first completed a word relationship task modeled on a previous study [3], which was presented using the software platform Inquisit 3.0.1.0 (Millisecond Software, 2008). The first few frames informed participants that they would be shown a pair of words consecutively on the screen and that they were to indicate whether the words were related or unrelated by pressing one of two keys. All words were drawn from plant and animal categories. If two words were both instances of plants (or animals), they were to press the right shift key. Otherwise, they were to press the left shift key. These words were displayed for 360 ms each. As was done in previous English language studies, the critical subliminal primes were presented for 27 ms (e.g., [3]): i.e., the word “death (死)” in the death condition and the word “pain (苦)” in the pain condition. All word stimuli used in both conditions were single characters and were matched in orthographic complexity (based on stroke counts), $t(18) = 0.75$, $p = .94$, as well as character frequency [1], $t(18) = -1.65$, $p = .12$. All word stimuli were presented in MS Mincho 100-point font at the center of the

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