

Tolerating dissimilar other when primed with death: neural evidence of self-control engaged by interdependent people in Japan

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Abstract

Mortality salience (MS) has been shown to lead to derogation of others with dissimilar worldviews, yet recent research has shown that Asian-Americans who presumably adopt an interdependent self-construal (SC) tend to reveal greater tolerance after MS induction. In the present study, we demonstrated that Japanese individuals who are high on interdependent SC indeed show greater tolerance toward worldview-threatening other in the MS (*vs* control) condition, thus replicating the prior research. Extending this research, we also found that interdependent people's tolerance toward worldview-threatening other was mediated by increased activity in the right ventrolateral prefrontal cortex in the MS condition. These data suggested that when exposed to death-related stimuli, highly interdependent individuals may spontaneously activate their neural self-control system which may serve to increase tolerance toward others.

Key words: interdependent self-construal; mortality salience; rVLPFC activity; self-control

Introduction

Fear of death is universal to most societies, and according to terror management theory (TMT; Greenberg *et al.*, 1997) it is managed by two distinct defensive systems; one that deals with conscious thoughts of death and the other that defend people from unconscious thoughts of death (Pyszczynski *et al.*, 1999). When the notion of mortality is brought to the focus of attention, people quickly suppress the thought of death or deny its

immediate relevance to the self and push the issue of death to distant future (i.e. the proximal defenses; see Arndt *et al.*, 2003; Routledge *et al.*, 2004). Yet, as the issue of death is essentially non-addressable, unconscious concerns for death may continue, making the thoughts of death highly accessible—the state known as high mortality salience (i.e. MS hereafter). The unconscious concern for death is in turn addressed in more indirect and symbolic manners, by embedding oneself in meaningful cultural constructions (i.e. the distal defenses); for example, by

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emphatically defending one's cultural worldviews (Greenberg et al., 1994). In doing so, people may at times go so far as derogating or harming others who pose threats to their cultural worldviews (Pyszczynski et al., 2004; Burke et al., 2010, for meta-analysis).

Despite accumulating evidence, however, not all studies conducted across cultures have consistently shown that MS leads people to derogate worldview-threatening others. Indeed, TMT posits that people's reaction to worldview-threatening others would depend on the cultural mandate inscribed in a particular worldview (Greenberg et al., 1994). Consistent with this notion, Jonas et al. (2008) have demonstrated that MS can generate some contrasted behavioral reactions, depending on the situational norm: for example, either pro-social (pro-peace or benevolent) behaviors or pro-self (pro-violence, conservative) behaviors could follow a MS induction. Similarly, Ma-Kellams and Blascovich (2011) have shown that in contrast to European-Americans who evaluate the worldview-threatening others (prostitutes in Study 1 and victim of a car accident in Study 2) more negatively in the MS condition, Asian-Americans evaluate the same targets more positively. These divergent reactions of the Asian- and European-Americans to MS have been attributed to their contrasted self-construals (SC)-interdependent SC that promotes social harmony, and independent SC that promotes self-affirmation, respectively (Markus and Kitayama, 1991). As MS increases the psychological need for cultural worldviews, Asian-Americans, who have an interdependent SC, would harmonize with dissimilar others to protect their interdependent worldviews. As ethnic difference in SC was only assumed by Ma-Kellams and Blascovich (2011), we aimed to replicate their results by directly measuring SC in our research.

As outlined, research has shown that MS can bring about culturally distinct behavioral reactions to death reminders. Nevertheless, specific mechanisms that mediate such culturally-unique reactions to MS remain poorly understood. Presently, we offer a new model that can be used to understand why and how individuals who have an interdependent SC may react with greater tolerance toward worldview-threatening others when primed with thoughts of death. We propose that interdependent SC enhances *self-control* when death reminders are encountered. Our rationale is as follows.

First, the worldviews based on interdependent SC prescribe that individuals adjust themselves to others' expectations to maintain social harmony (Kitayama et al., 1997). To live in accord with their cultural worldviews that emphasize social harmony, highly interdependent individuals exert self-control regularly so that their attitudes and behaviors are consistent with the norms and expectations of others in the ongoing social contexts. Consistent with this notion, evidence indicates that relative to less interdependent people, those who are highly interdependent tend to attend to relational cues more (Masuda and Nisbett, 2001; Ishii et al., 2010) and take others' perspectives more (e.g. van Baaren et al., 2003; Wu and Keysar, 2007), as well as making behavioral decisions based on perceived attitude of others rather than their own attitude (e.g. Hashimoto and Yamagishi, 2015). As MS increases the importance of cultural worldviews, highly interdependent people, relative to less interdependent people, may engage in greater self-control and behave in a more socially acceptable, tolerant manner after they are exposed to death reminders.

Second, existing evidence also implies that highly interdependent people may promptly and spontaneously respond to death-reminding stimuli by activating their self-control system, and do so in greater degrees than low interdependent people

tend to do. For instance, research by Vohs and Heatherton (2001, 2004) has shown that negative feedback (i.e. ego-threat of which effects are often similar to MS threat, see Schmeichel and Martens, 2005) leads highly interdependent individuals to self-control spontaneously, allowing them to behave in a socially acceptable and likable manner toward their interaction partner, in contrary to low interdependent (and/or highly independent) individuals who behave impulsively and antagonistically in response to negative feedback. Behaving in socially desirable manners while experiencing a threat likely requires multiple operations of self-control, such as down-regulating negative affect, inhibiting impulsive behaviors, taking other's perspective and making the own behavior appropriate. Though pursuing multiple operations at once would be resource intensive, high-interdependent people may be able to do so more efficiently and effectively than their low-interdependent peers would be able to do if they regularly engage in self-control in daily life and thus have a robust system of self-control (Baumeister et al., 1998). When the notion of mortality is brought to the focus of attention as well, highly (vs low) interdependent individuals' braking system may turn on more promptly (i.e. the stage of proximal defenses). Then, multiple operations of self-control may continue to serve the individuals; if they subsequently face additional challenges such as encountering a worldview-derogating other (i.e. the stage of distal defenses), they would be able to calibrate their reactions to be culturally and socially more acceptable.

We submit that the neural processes that underlie this braking system involves the right ventrolateral prefrontal cortex (rVLPFC, also called the *right inferior frontal gyrus*) as its hub (Lieberman, 2013). Accumulated neural and behavioral evidence suggests that the rVLPFC plays an important role in a range of self-control processes: suppressing and inhibiting a specific affect, thought, or motor action, and sometimes replacing them with an alternative affect, thought or action (Lieberman et al., 2007; Berkman and Lieberman, 2009; Cohen et al., 2013). The function of the right, rather than the left, VLPFC has been highlighted as necessary for self-control (Aron et al., 2004; Cohen et al., 2013). Corroborating that threat activates the braking system of rVLPFC, Eisenberger et al. (2003) have shown that social exclusion (vs inclusion) enhances the rVLPFC activity and that the level of its activity is associated with reduction in self-reported distress. Moreover, reinforcing the notion of individual differences in the relative efficiency of the neural braking system, research has shown that the rVLPFC activity during a motor self-control task such as Go/No-Go task can predict real-world self-control (e.g. Hooker et al., 2010; Berkman et al. 2011; Lopez et al., 2014). Thus, to test a hypothesis that highly interdependent people self-control to react more tolerantly toward dissimilar other when primed with death, it seemed possible to use a similar proxy measure of self-control targeting the rVLPFC.

We predicted that rVLPFC activity while performing a quick word-categorization task, which presents with death-related words (vs non-death-related control words) as part of stimuli, would predict the degree to which participants later evaluate the worldview-threatening target with greater tolerance. The higher the level of rVLPFC activity the more tolerant the target evaluation would be. As more interdependent people would activate the rVLPFC more in response to death-related stimuli, we expected rVLPFC activity to be a moderated mediator. In short, we tested a conditional indirect effect of interdependent SC on target evaluation through rVLPFC activity. Interdependent SC was predictor, target evaluation was criterion, experimental

condition was moderator, and rVLPFC was mediator. Activity of VLPFC was measured by scanning the brain with near-infrared spectroscopy (NIRS), a relatively economical and non-invasive method that can provide with temporally precise measurements of oxy-hemoglobin (oxy-Hb) within target brain circuits (Ruocco et al., 2010; Yanagisawa et al., 2011). Based on the previous neuroscience research associated with TMT, the target brain area was restricted to the rVLPFC (Klackl et al., 2014; Yanagisawa et al., 2016).

Finally, Ma-Kellams and Blascovich (2011) reported that Asian-Americans were less tolerant of dissimilar other than were European-Americans in the absence of MS threat. We also anticipated that highly interdependent people in Japan would show less tolerance than low interdependent people in the absence of death-related stimuli.

Methods

Participants

We recruited 30 undergraduate students (17 females; mean age = 19.85 ± 1.26 years) from a university in Hiroshima, Japan. We predicted a large effect size for interaction effect based on previous study (Ma-Kellams and Blascovich, 2011; study 1, $f = .52$, study 2, $f = .40$). The optimal total sample size to detect an expected large effect size of $f^2 = 0.35$ (a large effect size) with a power = 0.8 and $\alpha = 0.05$ was calculated a priori with the statistical software G-Power (Faul et al., 2009). Participants were randomly assigned to the MS ($n = 15$) or the control ($n = 15$) conditions. We stopped our data collection when our target was reached. Three participants (two females) were excluded from analysis due to equipment failure, with resultant 13 and 14 participants in the respective condition. These cases were not replaced.

Procedure and materials

One week prior to the NIRS experiment, all participants completed the independent-interdependent SC scale (Takata, 2000; see also Okazaki, 1997; Taras et al., 2014) involving 10 interdependence items (e.g. 'It is important for me to be in good harmony with the in-group', 'When my opinion is in conflict with that of another person's, I often accept the other opinion', $\alpha = 0.75$) and 10 independence items (e.g. 'I often make decisions by myself', 'I always try to have my own opinions', $\alpha = 0.82$). Each item was rated on a seven-point scale (1 'strongly disagree', 7 'strongly agree'). As expected, the mean level of interdependent SC was higher ($M = 5.30$, $SD = 0.69$) than that of independent SC ($M = 4.27$, $SD = 0.81$). Unexpectedly, the two scales were correlated positively, though not significant ($r = 0.28$, $P = 0.157$). For this reason, independent SC and condition by interdependent SC interaction were controlled in subsequent analyses.

The NIRS experiment was introduced to participants as concerning word semantics. All stimuli as well as instructions were presented on a 19-inch color monitor by using the software platform Inquisit 3.0.1.0 (Millisecond Software, 2008). Experimenter assisted participants to attach the NIRS probe to their left and right sides of the forehead. Then they received instructions for the word relationship task, which presented them with a pair of words consecutively and required them to indicate, as quickly and accurately as possible, whether the words belonged to a same category or different categories by pressing either the right shift key (for a same category) or the left shift key (for

different categories). The proportion of same category pairs was 50%.

All words were presented in a single kanji character and concerned either death or plants (e.g. 'tree' and 'flower') in the MS condition, and either negatively valenced (e.g. 'damage' and 'grief') or concerned plants in the control condition. A total of 30 words were used; 10 each of death-related, plant-related, and non-death-related negative words. The three sets of words were matched in orthographic complexity (based on stroke counts), $F(2, 27) = 1.12$, $P = 0.341$, as well as letter frequency (Amano and Kondo, 2000), $F(2, 27) = 1.65$, $P = 0.211$. To validate the stimuli, an independent group of 40 participants rated the semantic death-relevance of the death-related, negative, and plant-related words on a 7-point scale (e.g. 'To what degree do you think this word is related to death?', 1 = not related at all, 7 = very strongly related) and the degree of emotional valence evoked by each word, also on a 7-point scale ('How does this word make you feel?', 1 = extremely negative, 4 = neutral, 7 = extremely positive). Death relevance was higher for death-related words ($M = 6.59$, $SD = 0.36$) than for both negative words ($M = 5.07$, $SD = 1.11$, $P < 0.001$) and plant-related words ($M = 1.64$, $SD = 0.66$, $P < 0.001$), $F(2, 78) = 426.77$, $P < 0.001$. Valence was lower for both death-related words ($M = 2.01$, $SD = 0.46$, $P < 0.001$) and negative words ($M = 2.17$, $SD = 0.53$, $P < 0.001$) than for plant-related words ($M = 4.46$, $SD = 0.39$), $F(2, 78) = 347.21$, $P < 0.001$.

The stimulus words were displayed in MS Mincho 100-point font at the center of the computer screen, for 360 ms per word, followed by a blank screen which remained until a button press (see Figure 1). Ten practice trials were followed by three blocks of 30 trials (in roughly 60 s per block), with a 30 s inter-block rest period. Thus, there were a total of 100 trials (100 word pairs). In the MS condition, a death word pair was presented in 25 trials, a plant word pair was presented in 25 trials, and a death-plant pair in 50 trials, resulting in each of 10 death words (and each of 10 plant words) used 10 times during the experiment. Likewise, in the control condition, a negative word pair was presented in 25 trials, a plant word pair in 25 trials, and a negative-plant pair in 50 trials, resulting in each of 10 negative words (and each of 10 plant words) used 10 times during the experiment.

When the word relationship task was complete, the NIRS probe was removed. The procedure took about four minutes on average. Next, participants were asked to read and evaluate two essays adopted from Heine et al. (2002). The first essay, written ostensibly by a foreign student, was highly critical of the Japanese culture. The second essay by a different student author concerned his favorite pastime and was mildly positive. Participants evaluated each author on four items ('How much do you like this person?', 'How intelligent do you think this person is?', 'How knowledgeable do you think this person is?' and 'How much do you agree with this person's opinion?') as well as five positive traits (flexible, rational, patient, warm and practical) and five negative traits (rigid, arrogant, insensitive, obnoxious, and self-centered) using a seven-point scale (1 'not at all' to 7 'extremely'; $\alpha = 0.71$ for negative essay, 0.84 for positive essay). Fourteen ratings on the same author were averaged after reversing negative items, and thus a score of 7 indicated the most favorable, 1 indicated the most unfavorable, and 4, neutral.

NIRS recording and processing

NIRS measurements were performed throughout the word relationship task using a two-channel NIRS system (NIRO 200, Hamamatsu Photonics, Japan). The NIRS apparatus measures

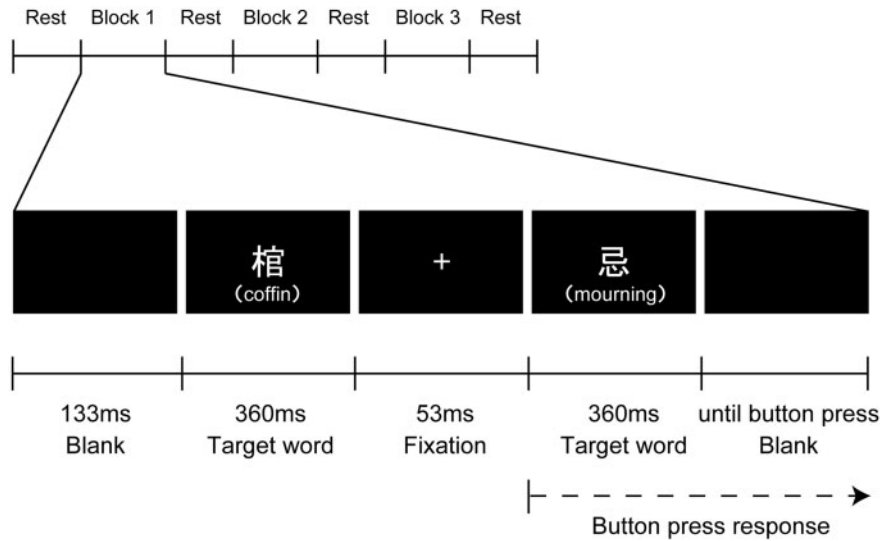


Fig. 1. Presentation of stimuli during the word relationship task.

changes in oxy-hemoglobin (oxy-Hb), deoxy-hemoglobin (deoxy-Hb) and total hemoglobin (total-Hb) levels in the cortical regions of the brain using a reflectance mode with three different wavelengths (775, 810, 850 nm) of near-infrared light, based on the modified Beer-Lambert law (Cope and Delpy, 1988). The distance between the emitter and the detector was set at 4 or 5 cm, depending on the specific light attenuation. Recordings were acquired at a sampling rate of 1 Hz. All hemoglobin concentration values were expressed in $\mu\text{mol/l}$. The time resolution of the NIRS measurements was every 1 s. Change in oxy-Hb is the most sensitive indicator of regional cerebral blood flow (rCBF) changes (Strangman et al., 2002) and we therefore evaluated changes in oxy-Hb signals. Two probe holders were placed on the left and right sides of the forehead using double-sided adhesive tape. These positions in the ventral area of the prefrontal cortex were localized between Fp1 and F7 (left) and between Fp2 and F8 (right), according to the international 10–20 system. Okamoto et al. have shown that the locations of 10–20 cortical projection points in the standard MNI or Talairach space can be estimated with an average standard deviation of 8 mm (Okamoto et al., 2004). Average oxy-Hb levels were calculated for the pre-task baseline, which was defined as the last 10 s of the pre-task period. The average level difference between activation condition and baseline was defined as the size of activation ($\Delta\text{oxy-Hb}$).

Data analysis

All analyses were conducted by using the SPSS macro PROCESS (Hayes, 2013) with 5000 bootstrapped samples. Model 1 was used to predict negative author rating as a function of manipulated condition (1 = MS, -1 = control), interdependent SC (mean-centered) and their two-way interaction. Model 1 was used also to predict VLPFC activities from the same predictors. Finally, Model 7 was used to test the conditional indirect effect of interdependent SC on author rating through rVLPFC activity. Condition \times interdependence interaction effects on both rVLPFC (mediator) and negative author rating were predicted. Independent SC (mean-centered) and interaction between Independent SC and condition were included as covariate in all analyses.

Table 1. Means, standard deviations and t-test comparisons for age and self-construal scores

	MS (n = 13)	Control (n = 14)	t-value
Age	19.85 (1.35)	19.86 (1.62)	0.02 (P = 0.98)
Interdependence SC	5.23 (0.76)	5.36 (0.65)	0.49 (P = 0.63)
Independence SC	4.16 (0.69)	4.36 (0.91)	0.65 (P = 0.52)

Results

Preliminary analysis

The MS group and the control group were similar in age, gender balance (MS group: male = 6, female = 7, control group: male = 6, female = 8, $\chi^2 = 0.03$, $P = 0.86$), interdependent SC and independent SC (see Table 1). Prior to main analysis we confirmed that individual differences in SC and MS induction had no impact on error rate ($M = 7.49\%$, $SD = 5.55\%$) or reaction time to word stimuli ($M = 793.58$ ms, $SD = 159.25$ ms), $ps > 0.05$. The negative essay author was rated more negatively ($M = 3.52$, $SD = 0.61$) than the mildly positive essay author ($M = 4.51$, $SD = 0.74$) overall.

Interdependent SC and negative author rating

The regression model for negative author rating was significant overall [$R^2 = 0.47$, $F(5, 21) = 3.71$, $P = 0.01$]. Interdependent SC main effect ($B = -0.40$, $t(21) = -2.66$, $P = 0.01$, 95% CI = [-0.71, -0.09]) and condition \times interdependent SC interaction ($B = 0.36$, $t(21) = 2.42$, $P = 0.02$, 95% CI = [0.05, 0.67]) were significant, and the condition main effect was non-significant ($B = 0.15$, $t(21) = 1.55$, $P = 0.14$, 95% CI = [-0.05, 0.35]). As anticipated, highly interdependent participants (1 SD above the mean) evaluated the negative author more negatively in the control condition than in the MS condition, and the simple effect of condition for highly interdependent participants was significant, $B = 0.40$, $t(21) = 2.83$, $P = 0.01$, 95% CI = [0.10, 0.69]. In contrast, low interdependent participants (1 SD below the mean) rated this author similarly in the MS and control conditions, and simple test was non-significant, $B = -0.10$, $t(21) = -0.71$, $P = 0.49$, 95% CI = [-0.39, 0.19]. See Figure 2. When positive author rating was included as a covariate in the analysis, the Condition \times Interdependent SC

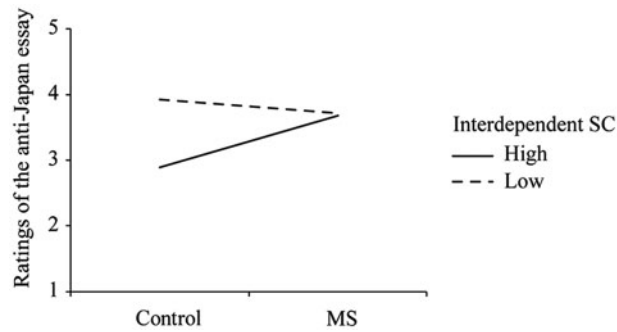


Fig. 2. Negative author rating as a function of condition and interdependent SC.

interaction effect was still significant ($B = 0.35$, $t(20) = 2.45$, $P = 0.02$, 95% CI = [0.05, 0.65]).

For positive author rating, the regression model was non-significant ($R^2 = 0.18$, $F(5, 21) = 0.94$, $P = 0.47$); no significant main effect or interaction effect was found ($ps > 0.05$).

Interdependent SC and VLPFC activity

The oxy-Hb changes in the bilateral VLPFC (Δ oxy-Hb: right VLPFC, $M = 0.19$, $SD = 0.43$; left VLPFC, $M = 0.12$, $SD = 0.33$) were each analyzed. The regression model for the rVLPFC activity was marginally significant, $R^2 = 0.37$, $F(5, 21) = 2.51$, $P = 0.06$. The expected Condition \times Interdependence interaction was significant ($B = 0.24$, $t(21) = 2.13$, $P < 0.05$, 95% CI = [0.01, 0.48]) and qualified the main effect of condition, $B = 0.17$, $t(21) = 2.13$, $P = 0.04$, 95% CI = [0.01, 0.32]. Analyses of conditional effects revealed that as anticipated, highly interdependent participants (1 SD above the mean) activated the rVLPFC more in the MS than control condition ($B = 0.33$, $t(21) = 3.09$, $P < 0.01$, 95% CI = [0.11, 0.56]) whereas low interdependent participants (1 SD below the mean) showed no difference, $B = -0.004$, $t(21) = -0.03$, $P = 0.97$, 95% CI = [-0.23, 0.22] (see Figure 3). For lVLPFC activity, the same analysis was conducted, but no main effect or interaction effect ($ps > 0.05$) was found.

Conditional indirect effect of interdependent SC through rVLPFC Activity

We analyzed negative author rating and rVLPFC activity together to test the predicted conditional indirect effect of interdependent SC on author rating mediated by rVLPFC. As expected, a Condition \times Interdependent SC interaction effect on rVLPFC was significant ($B = 0.22$, $t(23) = 2.14$, $P = 0.04$, 95% CI = [0.01, 0.44]), suggesting that the first stage of the mediation model ($X \rightarrow$ Mediator) was moderated by manipulated condition. Controlling for interdependent SC, rVLPFC activity had a marginally significant effect on author rating (Mediator \rightarrow Y), $B = 0.51$, $t(22) = 2.07$, $P = 0.05$, 90% CI = [0.09, 0.94]. Controlling for rVLPFC activity, the direct effect of interdependent SC on negative author rating also remained significant, $B = -0.43$, $t(22) = -2.67$, $P = 0.01$, 95% CI = [-0.76, -0.09]. Further consistent with the anticipated role of rVLPFC in prediction of negative author rating, the index of moderated mediation was 0.22, boot 95% CI = [0.01, 0.55]. As hypothesized, the indirect effect of interdependent SC through rVLPFC activity was positive and significant in the MS condition ($B = 0.20$, boot 95% CI = [0.01, 0.39]) and non-significant in the control condition ($B = -0.03$, boot 95% CI = [-0.27, 0.11]). The overall model was significant, $R^2 = 0.38$, $F(4, 22) = 3.38$, $P = 0.03$ (see Figure 4). We also added positive author rating as a control in supplementary analysis. The support

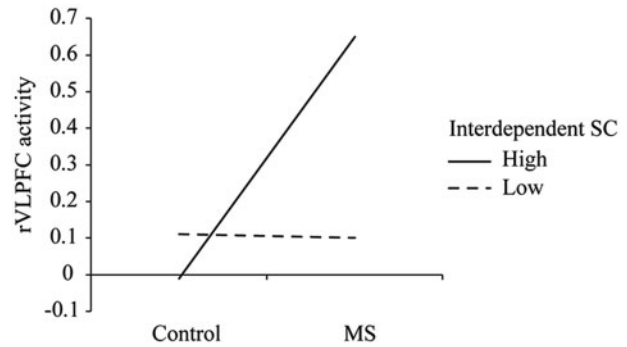


Fig. 3. The activity of rVLPFC as a function of condition and interdependent SC.

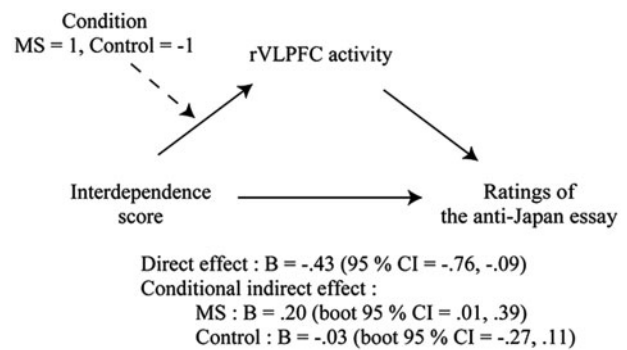


Fig. 4. The moderated effect of interdependent SC on the rating of negative essay author, mediated by rVLPFC activity.

for the moderated mediation model was maintained: the index of moderated mediation was 0.19, boot 95% CI = [0.01, 0.58].

Discussion

Highly interdependent individuals in Japan, compared to their low interdependent counterpart, evaluated the anti-Japan author more negatively in the absence of exposure to death-related words. Due to their higher relational tendency, the out-group critic may seem more offensive to highly interdependent people, and therefore their evaluation may be harsher compared to low interdependent people. Nevertheless, after an exposure to death words, the same negative author was evaluated less negatively and thus more tolerantly by the highly interdependent individuals. The result replicated the previous Asian-American data (Ma-Kellams and Blascovich, 2011).

By extending the previous research, the present study further tested a new model that interdependent SC enhances self-control when the concern for mortality is heightened, which provides a potential explanation for the highly interdependent people's tolerance toward worldview-threatening other. Results were highly promising. When exposed to the death-related (vs non-death-related negative) stimuli, the higher the interdependent SC the higher was the level of activity in the rVLPFC, the hub of the neural braking system. Also, the higher the level of activity in the rVLPFC, the more tolerant was the rating of the essay authors, controlling for the levels of interdependent SC. Furthermore, the predicted indirect effect of interdependence through rVLPFC activity was supported, suggesting that rVLPFC activity mediated the effect of interdependent SC on more tolerant rating of the targets in the MS condition. Taken together, the evidence supported our contention that highly

interdependent people may activate the neural braking system more promptly when presented with a death reminder, which may then facilitate their engagement in self-control such as calibrating their reactions toward others to be more acceptable, socially and culturally.

Previous research has rarely studied both the individuals' immediate reactions to the death-reminders (the proximal defenses) and their subsequent, unconscious distal defenses. For this reason, how these two processes are causally linked is still not understood well. According to the dual-process model of TMT, suppressing thoughts of death and denial of death are not likely to resolve the issue of death, and after a delay and distraction, symbolic defenses will follow (Pyszczynski et al., 1999). In our study, the activity of rVLPFC may have captured the neural process that underlies the potential proximal defenses, and because the activity of rVLPFC was further associated with later target evaluations, it may be possible to interpret the results as first evidence for the link between the proximal and distal defense systems. As brain activity during author evaluation was not measured, further research should investigate the relationship between the dual defense systems further.

There are several limitations in the current study. Our sample size was relatively small, and neural activities were assessed with NIRS, which offers poor spatial resolution compared to other blood oxygenation-sensitive measures such as functional magnetic resonance imaging (fMRI). Although previous fMRI studies have also found that the activity of rVLPFC increases when death-related stimuli are encountered (Klackl et al., 2014; Yanagisawa et al., 2016), we cannot reject a possibility that brain areas adjacent to the rVLPFC could have exerted some influences and biased our results, including the null results for the left VLPFC. As the right and left PFCs are known to serve distinct self-control functioning (e.g. Kuhl et al., 2015) it is important to clarify the contributions of the left PFC as well in further research. Accumulated evidence also suggests the right-hemisphere of the brain more broadly, rather than the rVLPFC more specifically, to be concerned with the functioning that facilitates holistic perception, pro-social attitudes and behaviors, and positive social interactions (Quirin et al., 2013; Hecht, 2014). As our brain scan focused on bilateral VLPFC, it is important to probe in future research other right-hemisphere brain activities that may explain the greater interpersonal tolerance shown by interdependent people in the MS condition. The use of an additional, verbal measure of self-control is also recommended in future research.

We theorize that mortality reminders promote self-control in interdependent people, serviced by the rVLPFC activities, to downregulate negative emotions roused by death-related words and to suppress the urge to derogate a worldview critic. Nevertheless, from a view to see self-control as a limited resource (Muraven and Baumeister, 2000), using it to regulate negative emotions aroused by death-related words may result in reduced rather than increased ability to control one's urge to derogate a worldview critic. As ability to self-control depends on long-term effects of practice as well as the short-term effects of demands, both these effects need consideration in future research. Further, the key findings from the current study rely on reverse inference (e.g. exposures to the concept of death elicits rVLPFC activities; self-control elicits activation in the rVLPFC; thus, exposure to the concept of death elicits self-regulation). Explanations other than self-control should also be considered carefully. The Anxiety-to-approach model of threat and defense by Jonas et al. (2014) proposes that mortality salience disrupts approach-related, goal-directed action planning, which people

subsequently try to restore by pursuing alternative goals derived from cultural worldviews. Changes in frontal asymmetry in favor of the right hemisphere are typically taken to indicate reduced motivation for goal pursuit. As we have found activities in the right VLPFC to be associated with more lenient rating of the author in the current study, interdependent individuals might have pursued their goal of achieving interpersonal harmony to restore approach motivation.

Finally, current research should be replicated in future studies in both Asian and European cultural contexts. As different cultural contexts might afford the development of distinct neurological as well as behavioral processes (e.g. Han et al., 2013), our current results could be due to the cultural context of our research participants. The propensity to activate the rVLPFC in response to death-related stimuli is likely enhanced by a regular engagement in self-control in accord with the interdependent worldviews. In Japan, these worldviews are culturally salient, opportunities for self-control are abundant, and doing so is likely rewarded. In cultures where alternative worldviews drive self-control, for instance some religious worldviews, a different model of moderated mediation may be relevant. Future research will examine different nexus of culture, brain, and threat reaction.

Authors' contributions

All authors contributed to the study design. K.Y. collected the data and performed the data analysis. K.Y. and E.K. wrote the initial draft of the manuscript, and all authors provided critical comments. All authors approved the final version of the manuscript.

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