Cogn Affect Behav Neurosci (2017) 17:1210–1220
https://doi.org/10.3758/s13415-017-0543-7

Implicit attitudes and executive control interact to regulate interest in extra-pair relationships

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Published online: 16 October 2017

Abstract Do we actively maintain monogamous relationships by force of will, or does monogamy flow automatically? During functional magnetic resonance imaging (fMRI), male participants in a romantic relationship performed the Implicit Association Test (IAT) to evaluate implicit attitudes toward adultery and a go/no-go task to measure prefrontal activity implicated in explicit executive control. Subsequently, they were engaged in a date-rating task in which they rated how much they wanted to date unfamiliar females. We found that the individuals with higher prefrontal activity during go/no-go task could regulate the interest for dates with unattractive females; moreover, the individuals with both a stronger negative attitude toward adultery and higher prefrontal activity could regulate their interest for dates with attractive females, and such individuals tended to maintain longer romantic relationships with a particular partner. These results indicate that regulation of amorous temptation via monogamous relationship is affected by the combination of automatic and reflective processes.

Keywords Monogamy · fMRI · Dual-process theory · Implicit social cognition · Self-control

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Although extra-pair relationships, such as adultery, are condemned in modern stable social systems (for a review, see Hatfield, Rapson, & Martel, 2010), they still frequently occur (Barta & Kiene, 2005; Thompson, 1983; Wiederman, 1997). This observation leads to the assumptions that adultery is essentially a "default" option that most people will utilize unless they are cognitively persuaded that it is not beneficial. Support for this view is provided by evolutionary observations. Although a long-term monogamous relationship provides limited opportunities for reproduction, an extra-pair relationship is reproductively efficient for both genders (Buss & Schmitt, 1993; Gangestad & Simpson, 2000; Jennions & Petrie, 2000). Serial pair bonding and clandestine adultery are believed to be primary aspects of human romantic love (Fisher, 2006).

If the extra-pair relationship was based on the automatic dispositions of humans, monogamy would be supported by additional cognitive processes. This reflective view on monogamy is supported by previous findings showing that faithfulness is a consequence of controlled processes; that is, individuals with higher control functions can stay faithful by derogating attractive others as potential partners (Ritter, Karremans, & van Schie, 2010), regulating their desire to meet attractive others (Pronk, Karremans, & Wigboldus, 2011), and establishing a constructive relationship with a partner (Finkel & Campbell, 2001). Depleted individuals are more likely to accept a coffee date from and supply private information to an individual of the opposite sex than are nondepleted individuals (Ciarocco, Echevarria, & Lewandowski, 2012). From the cognitive neuroscience perspective, successful derogation of attractive alternatives involves increased activation in the right ventrolateral prefrontal cortex (VLPFC; Meyer, Berkman, Karremans, & Lieberman, 2011), which is part of a network of brain regions associated with deliberate emotion

regulation (for a review, see Ochsner & Gross, 2005). These findings supporting the reflective view imply that romantically involved individuals can only reject the desire for adultery when they have sufficient cognitive resources.

This reflective view of monogamy is challenged by an alternative, automatic view that emphasizes the universality of monogamy in humans (Fisher, 1989). Several studies have demonstrated the existence of automatic processes of relationship maintenance, in which romantically involved individuals are automatically less attentive to attractive alternatives compared with single individuals (Maner, Gailliot, & Miller, 2009; Maner, Rouby, & Gonzaga, 2008). Support for the automatic view also comes from researchers who emphasize the role of control processes in the strategic pursuit of multiple partners. Throughout the evolutionary history of humans, although faithfulness to one partner was the theoretical norm, in some situations, breaking the rules and "mate poaching" were beneficial (Wilson & Daly, 1992). Thus, humans are likely to have evolved cognitive structures to actively manage multiple contingencies (Barkow, Cosmides, & Tooby, 1992; Hrdy, 1981; Wilson & Daly, 1992). According to the automatic view of monogamy, faithfulness results from automatic tendencies, such as a fundamental aversion to adultery, rather than from active self-control.

The present study tested the two competing hypotheses described above and provided a framework for the reconciliation of these hypotheses in terms of temptation strength. Specifically, we examined whether implicit attitudes and executive control could predict the regulation of interest in extra-pair relationships. According to a well-known dual-process model (e.g., Fazio & Olson, 2003; Strack & Deutsch, 2004), decision-making processes are established by the relative strength of automatic implicit attitudes and deliberate executive control. Typically, researchers focus on implicit attitudes as facilitating factors for impulsive behaviors such as eating, drinking, risky sex, and drug-taking (for a review, see Heatherton & Wagner, 2011). However, implicit attitudes also regulate unfavorable behaviors through inhibition, disgust, or twinges of conscience. Fishbach and Shah (2006) proposed the concept of "implicit self-control," in which the automatic avoidance of undesirable targets could lead to successful self-regulation and depends on a given context, such as temptation strength. Consistent with a dual-process model, the recent theoretical model of monogamous relationship maintenance assumes that executive control does not "blindly" enable the maintenance but rather strongly depends on automatic aspects (Pronk & Righetti, 2015). However, to the best of our knowledge, no study has directly investigated the relationships between implicit attitude and executive control in the context of romantic decision-making. Based on these observations, the present study focused on the joint contributions of automatic implicit processes and deliberate explicit processes in the regulation of interest in extra-pair relationships.

Male participants in a romantic relationship with a significant other underwent functional magnetic resonance imaging (fMRI) while completing two independent tasks. Males generally have a stronger desire for a romantic relationship with more individuals than females (e.g., Buss & Schmitt, 1993); thus, males were suitable participants for the present investigation. As an implicit measure, we employed a variant of the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998), which is widely used to measure the implicit attitudes of participants via their reaction times (RTs) while they are performing categorizations. We set the target categories as "monogamy" and "adultery" and the attribute categories as "good" and "bad" through the use of pictures of romantic circumstances as categorization stimuli. If the participant felt that extra-pair relationships were negative, he reacted more slowly in categorizing "adultery" pictures as "good" compared with "bad." Thus, the IAT effect is indexed by increased RTs to incongruent trials, which involve conflict processing and require inhibition toward prepotent responses, compared with congruent trials. As an executive control measure, we employed a widely used go/no-go task (for a review, see Aron, Robbins, & Poldrack, 2004) to record brain activation during response inhibition. Response inhibition is believed to be the core of cognitive control or executive function (Barkley, 1997). Imaging studies have shown that stronger activation of the right VLPFC during response inhibition predicts successful self-regulatory behaviors (Aron et al., 2004; Casey et al., 2011; Lopez, Hofmann, Wagner, Kelley, & Heatherton, 2014; Mischel et al., 2011); thus, this parameter serves as a reliable measure of explicit executive control. Subsequently, outside of the scanner, the participants completed a date-rating task in which they rated how much they would like to date unfamiliar attractive or unattractive females. The participants were also asked to report the mean length of romantic relationships with past/current partners.

We predicted that the VLPFC activity during the go/no-go task and the behavioral IAT effect would predict scores on the date-rating task and the length of past/current romantic relationships. Regarding the neural activity underlying the IAT effect, we predicted that activity in emotion-related regions such as the amygdala or insula would correlate with the individual differences in the IAT effect (Luo et al., 2006), such that the participants with strongly negative attitudes toward extra-pair relationships would show stronger neural responses in emotion-related regions in the incongruent trials relative to congruent ones. We also predicted that female attractiveness in the date-rating task (i.e., the manipulation of temptation strength) would impact the relative contributions of implicit attitudes and executive control in regulating interest in an extra-pair relationship. This prediction was inspired by studies showing that exposure to attractive alternatives could threaten a monogamous relationship (e.g., Gangestad & Thornhill, 1997). More specifically, we predicted that interest in an

extra-pair relationship would be better regulated via executive control at low temptation levels, but would be dependent on implicit attitudes at high temptation levels.

Method

Participants

Twenty-seven right-handed male volunteers with no history of neurological or psychiatric disease (M_{age} = 23.3 years, range: 20–32 years) participated in this study and were remunerated. The sample size was based upon previous fMRI studies on self-regulation (Abe & Greene, 2014; Casey et al., 2011; Lopez et al., 2014). The advertisements requested male volunteers between 20 and 39 years of age who had been in a relationship for at least 6 months at the time of the experiment (M = 25.8 months, SD = 17.2 months, range: 6–60 months) and were in love with their partner (but not married). All of the participants were heterosexual. After receiving a detailed description of the study, all of the participants provided written informed consent in accordance with the Declaration of Helsinki and the guidelines approved by the Ethical Committee of Kyoto University.

Stimuli

For the target category stimuli of the IAT, we used 50 color pictures that included one male and one female (see Fig. 1) from public websites. All of the images were downloaded and were edited with Adobe Photoshop to produce greater uniformity across the photographs. A separate group of 10 volunteers who did not participate in the present study used a 7-point scale to rate the 50 pictures in terms of whether the picture implied "monogamy" or "adultery" (1 = *strongly monogamous*, 7 = *strongly adulterous*). Based on these ratings, we chose six pictures that strongly represented monogamy (M = 1.60, SD = 0.09) and six that strongly represented adultery (M = 5.87, SD = 0.61). The difference in the mean scores between these two sets was statistically significant, $t(10) = -16.89$, 95% confidence interval (CI) = [−4.83, −3.70], $p < .001$, $d = 9.76$). The six monogamy and six adultery pictures were further subdivided into two sets of three pictures each. The difference in the scores between the two sets in either category was not significant. For the attribute categories of the IAT, we used six positive words (*kind, tolerant, honest, obedient, faithful,* and *cheerful*) and six negative words (*brutal, heartless, hostile, violent, frivolous,* and *hasty*) based on their desirability scores as reported by Hayashi (2001). The 12 words were all adjectives and were matched for length in Japanese. We confirmed that the difference in mean desirability scores between the positive and negative words was significant, $t(10) = -22.19$, CI = [−5.01, −4.09],

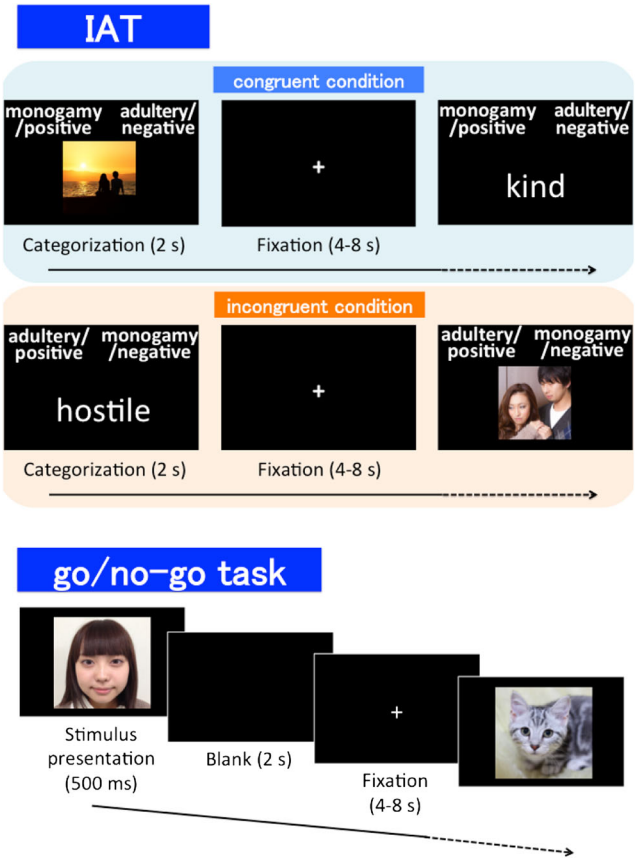

Fig. 1 The IAT and the go/no-go task. In the IAT, the participants were asked to categorize each stimulus by pressing a button. The study included six practice phases and four test phases. Two of the four test phases were the "congruent condition," in which the participants responded to monogamous images and positive words with the left button and responded to images of adultery and negative words with the right button. The remaining two phases were the "incongruent condition," in which the target concepts (monogamy or adultery) were not paired with their associated attributes (positive or negative). In the go/no-go task, participants were instructed to respond to animal images by pressing the button with right forefinger (go trial) and to withhold responses to female images by refraining from pressing the button (no-go trial)

$p < .001$, $d = 12.81$. The six positive and six negative words were further subdivided into two sets of three words each. No significant difference in desirability scores was observed between the two sets of words in either category.

For the date-rating task, we obtained 300 female facial photographs from public websites. All of the images were downloaded to a computer and were edited with Adobe Photoshop to produce greater uniformity across the photographs. Ten adult male volunteers who did not participate in the present study rated these 300 photographs using an 8-point scale of attractiveness, happiness, and facial orientation. Based on mean attractiveness ratings, we selected 24 attractive faces (M = 5.44, SD = 0.25) and 24 unattractive faces (M = 3.30, SD = 0.12). A t test confirmed a significant difference between the mean attractiveness rating of the two sets of faces, $t(46) = 38.04$, CI = [2.03, 2.25], $p < .001$, $d = 10.98$; however,

no significant difference was found for the mean ratings of happiness or facial orientation.

For the go/no-go task, we prepared 72 animal images for "go" trials and 24 attractive female facial images for "no-go" trials (mean attractive ratings = 5.43/8, based on the mean attractiveness ratings in the pilot study, n = 10). No facial image that had been used in the date-rating task was used in the go/no-go task.

General procedures

The experiment consisted of an fMRI scanning session and a post-fMRI session. In the fMRI scanning session, participants completed the IAT and then completed the go/no-go task. Figure 1 shows the schematic diagrams of these two tasks. In the post-fMRI session, the participants completed the date-rating task outside of the scanner. After the completion of these three cognitive tasks, the participants were asked, "How long have you been in a romantic relationship with one partner?" (mean length of relationship with past/current partners), which provided data on real-life behavior. The mean length of relationships was 19.7 months (*SD* = 15.2 months, range: 6–60 months), and the mean number of partners including in the past was 2.6 (*SD* = 2.0, range: 1–10).

IAT

We used a variation of the IAT (Greenwald et al., 1998) that included "monogamy" and "adultery" as the target categories and "positive" or "negative" as the attribute categories. Consistent with previous studies (Greenwald et al., 1998; Luo et al., 2006), the IAT used here consisted of two series of three practice phases and two test phases (i.e., a total of 10 phases; see Table 1). The order of test phases was counterbalanced across participants; half of the participants received the order "congruent," "incongruent," "incongruent," and "congruent," while the other half of the participants received the order "incongruent," "congruent," "congruent," and "incongruent." The order of practice phases was fixed across participants.

For each phase, participants were asked to categorize each stimulus as quickly and accurately as possible by pressing the appropriate buttons: The left button was pressed with the right forefinger, and the right button was pressed with the right middle finger. In the congruent condition, in which images and words were presented randomly, the participant judged whether the stimuli were monogamy images/positive words (left) or adultery images/negative words (right); thus, the target concepts (monogamy/adultery) were paired with their associated attributes (positive/negative). In the incongruent conditions, the participant judged the randomly presented images and words as adultery images/positive words (left) or monogamy images/negative words (right); thus, the target concepts (monogamy/adultery) were not paired with their associated attributes (positive/negative). Each stimulus was presented for 2 s, and trials were separated by a variable fixation interval (4–8 s) to maximize the efficiency of the event-related design (Dale, 1999). Each phase consisted of 24 trials. In the practice phases, six stimuli (three positive words and three negative words, or three monogamy images and three adultery images) were presented four times. In the test phases, 12 stimuli (three positive words, three negative words, three monogamy images, and three adultery images) were presented twice. All of the stimuli were presented in random order. The combination of each stimulus set was counterbalanced across participants. Error trials were excluded from the behavioral data analysis.

Go/no-go task

Similar to previous studies (Casey et al., 2011; Lopez et al., 2014), we used a go/no-go task that was modified to measure the neural activation associated with the suppression of responses to alluring cues. We prepared 72 animal images for "go" trials and 24 attractive female facial images for "no-go" trials. This procedure was inspired by a study of the ability to suppress food desires using pictures of high-calorie foods as alluring cues (Lopez et al., 2014). In each trial, the animal images or female facial images were presented one by one. The participants were instructed to respond to animal images as quickly and accurately as possible by pressing a button with the right forefinger (go trial) and to refrain from responding to female images by not pressing the button (no-go trial). Each image was presented for 500 ms, followed by a blank screen for 2 s. Trials were separated by a variable fixation interval (4–8 s).

Date-rating task

After the completion of the IAT and go/no-go tasks, participants completed the date-rating task outside of the scanner. In this task, the 48 photographs (24 attractive and 24 unattractive faces) were presented individually in random order. Participants were asked to rate the degree to which they would be interested in dating each female using an 8-point scale (1 = *very little* to 8 = *very much*). Each stimulus was presented for 2 s, followed by a fixation period (2 s).

Image acquisition and analysis

Participants were scanned using a 3.0-Tesla Siemens Magnetom Verio MRI scanner (Siemens, Erlangen, Germany) with a 32-channel head coil. A $T2^*$-weighted echo planar imaging (EPI) sequence that was sensitive to BOLD contrast was used for functional imaging with the following parameters: repetition time (TR) = 2,500 ms; echo time (TE) = 30 ms; flip angle = 80°; acquisition matrix = 64 × 64; field of

Table 1 Ten phases of the IAT

Phase 1: practice (images)	The participant categorized images as monogamy (left) or adultery (right).
Phase 2: practice (words)	The participant categorized words as positive (left) or negative (right).
Phase 3: test (congruent)*	The participant judged whether randomly presented words and images were monogamy images/positive words (left) or adultery images/negative words (right); thus, the target concepts (monogamy/adultery) were paired with their associated attributes (positive/negative).
Phase 4: practice (images)	The participant categorized images as adultery (left) or monogamy (right), the converse of that in Phase 1.
Phase 5: test (incongruent)*	The participant judged whether randomly presented words and images were adultery images/positive words (left) or monogamous images/negative words (right); thus, the target concepts (monogamy/adultery) were not paired with their associated attributes (positive/negative).
Phase 6: practice (images)	The participant categorized images as adultery (left) or monogamy (right), identical to Phase 4.
Phase 7: practice (words)	The participant categorized words as positive (left) or negative (right), identical to Phase 2.
Phase 8: test (incongruent)*	The participant judged whether randomly presented words and images were adultery images/positive words (left) or monogamy images/negative words (right).
Phase 9: practice (images)	The participant categorized images as monogamy (left) or adultery (right), identical to Phase 1.
Phase 10: test (congruent)*	The participant judged whether randomly presented words and images were monogamy images/positive words (left) or adultery images/negative words (right).

*Half of the participants performed the IAT in the following order: congruent, incongruent, incongruent, and congruent conditions; the other half of the participants performed IAT in the following order: incongruent, congruent, congruent, and incongruent conditions

view (FOV) = 212 mm; in-plane resolution = 3.3 × 3.3 mm; number of axial slices = 39; slice thickness = 3.2 mm; and interslice gap = 0.8 mm. A high-resolution (spatial resolution = 1 × 1 × 1 mm) structural image was also acquired with a T1-weighted magnetization-prepared rapid-acquisition gradient echo (MP-RAGE) pulse sequence. Head motion was restricted by the placement of firm padding around the head. Visual stimuli were projected onto a screen and viewed through a mirror that was attached to the head coil, and behavioral responses were recorded with a fiber optic response box.

For the IAT, the functional imaging data were collected in 10 runs that corresponded to each phase. We analyzed the data from four test phases (76 volumes each), and these image volumes were concatenated across sessions. The data from the remaining six practice phases were not analyzed. For the go/no-go task, data were collected in a single functional run of 308 volumes. The first four volumes in each session (four test phases in the IAT and the go/no-go task) were discarded to allow for T1 equilibration effects.

Data preprocessing and statistical analyses were performed using SPM12 (Wellcome Department of Imaging Neuroscience, London, UK). For preprocessing, the resulting images were first realigned to correct for small movements between scans. This process generated an aligned set of images and a mean image per subject. Then, all of the volumes that were acquired from each subject were corrected for different slice acquisition times. Each participant's T1-weighted structural MRI was coregistered to the mean of the realigned EPI images. Then, the coregistered T1 image was normalized to a template image that was based on the Montreal Neurological Institute (MNI) reference brain. Using the parameters from this normalization process, the EPI images were also normalized to the MNI template (resampled voxel size = 2 × 2 × 2 mm) and smoothed with an 8-mm full-width at half-maximum Gaussian kernel.

The fMRI data were analyzed using an event-related model. For each participant, activity that was associated with each experimental condition was modeled with a canonical hemodynamic response function that was temporally indexed by the stimulus onset (duration = 0 s). Trials with no response (2.0% of all trials) were excluded from the fMRI analyses of the IAT as no-interest effects. Movement parameters and session regressors were included as covariates of no interest. A high-pass filter (1/128 Hz) was used to remove low-frequency noise, and an AR (1) model was employed to correct for temporal autocorrelations.

The parameter estimates (betas) for each condition were calculated for all brain voxels, and the relevant contrasts of the parameter estimates were determined. These contrast images were then incorporated into second-level group comparisons using a random effects model. For the whole-brain subtraction analysis of the IAT, significant results were identified at an uncorrected threshold of $p < .001$ at the voxel level, and clusters were considered significant if they passed a cluster-level threshold of $p < .05$ after family-wise-error (FWE) correction. The peak voxels of clusters that exhibited reliable effects are reported in MNI coordinates.

For the subtraction analysis of the go/no-go task, we calculated the contrast of no-go versus go conditions, with the

anatomical constraint of the right VLPFC (inferior frontal gyrus) based on Individual Brain Atlas using Statistical Parametric Mapping software (IBASPM; Aleman-Gomez, Melie-García, & Valdés-Hernandez, 2006) implemented in the WFU PickAtlas (Wake Forest University, Winston-Salem, NC; Maldjian, Laurienti, Kraft, & Burdette, 2003). Here, based on our a priori prediction on right VLPFC activity during response inhibition, we used the statistical threshold of $p < .001$ (uncorrected for multiple comparisons) without cluster extent threshold. We used MarsBaR (Brett, Anton, Valabregue, & Poline, 2002) software to extract signal changes (%) of right VLPFC activity that was observed in the calculated contrast (no-go versus go trials; centered on reported coordinate 48, 24, 2, Z value = 3.49, cluster size = 28; see Fig. 2).

Results

Behavioral and fMRI data from the IAT

All of the statistical analyses were performed with R Version 3.1.1 (R Core Team, 2014) and the PROCESS SPSS macro (Hayes, 2013) when necessary. As predicted, participants showed significantly slower responses, $t(26) = 9.95$, CI = [0.16, 0.24], $p < .001$, $d = 0.95$, and more errors, $t(26) = 3.39$, CI = [1.34, 5.45], $p = .002$, $d = 0.71$, in the incongruent condition than the congruent condition (see Table 2). This result confirmed the reliability of the behavioral IAT effect in which participants exhibited greater hesitancy toward the association "adultery–positive" (or "monogamy–negative") compared with "adultery–negative" (or "monogamy–positive"). The imaging data from the contrast of the incongruent condition vs. the congruent condition revealed activation in certain regions, including the left DLPFC (i.e., the middle frontal gyrus) and VLPFC (i.e., the inferior frontal gyrus; see Table 3), which are consistent with the reports found in the existing literature regarding the association between these regions and the inhibition toward prepotent responses (Ames et al., 2014; Chee, Sriram, Soon, & Lee, 2000; Knutson, Mah, Manly, & Grafman, 2007; Knutson, Wood, Spampinato, & Grafman, 2006). The opposite contrast (congruent vs. incongruent) did not reveal a significant activation.

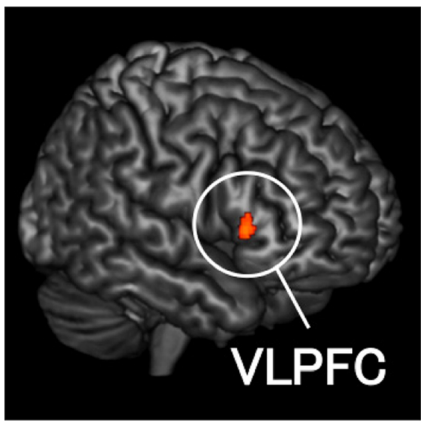

Fig. 2 Activation of the right ventrolateral prefrontal cortex (VLPFC) based on the contrast of no-go versus go trials during the go/no-go task. (Color figure online)

Each participant's IAT score (D) was calculated on the basis of their RTs in the test phases (Greenwald, Nosek, & Banaji, 2003). Smaller D values indicated less difficulty in responding to the association "adultery"–"positive" (or "monogamy"–"negative"). The correlation between the D scores and the right VLPFC activity during the go/no-go task was not significant ($r = .10$, CI = [−0.29, 0.47], $p = .61$), which indicated that these two measures are mutually independent.

We evaluated the brain activity associated with the behavioral IAT effects. Specifically, we examined whether individual differences in IAT effects were correlated with activity in emotion-related brain regions, such as the amygdala or the insula (Luo et al., 2006). Contrary to our prediction, no significant effect in those regions was found. Furthermore, even if we focused on the left DLPFC and VLPFC, no significant effects were found. We return to this point later in the discussion section.

Three-way multiple regression analysis

To test our hypothesis that the degree of temptation (i.e., the target's attractiveness) could moderate the relationship among implicit attitudes, executive control, and interest in extra-pair relationships, we performed multiple regression analyses. We entered the mean date-rating scores of each participant as the dependent variables and the dummy-coded date-rating condition (attractive females: 1, unattractive females: −1), the D scores from the IAT, and the right VLPFC activities during the go/no-go task of each participant as well as their interactions as the independent variables. All the variables were mean-centered prior to the analyses, and each participant's age was included as a nuisance variable. We included random intercepts for the participants (Barr, Levy, Scheepers, & Tily, 2013). This analysis was conducted using the packages lme4 (Bates, Maechler, Bolker, & Walker, 2014) and the lmerTest (Kuznetsova, Brockhoff, & Christensen, 2015) for the statistical software R (R Core Team, 2014). Consistent with our prediction, we found a significant three-way interaction ($B = −0.22$, $t = −2.63$, CI = [−0.38, −0.06], $p = .015$), which indicated that the target's attractiveness did moderate the relative impact of implicit attitudes and the executive control on the regulation of the interest in adultery. No other significant interactions were obtained (all ps > .109).

Table 2 Mean reaction times and the proportion of error responses in the IAT

Condition	Reaction time (ms)		Proportion (%) of error responses	
	Mean	*SD*	Mean	*SD*
Congruent condition	980	197	3.7	3.8
Incongruent condition	1,177	220	7.1	5.6

Two-way multiple regression analyses

We conducted follow-up regression analyses split by the date-rating conditions (i.e., attractive/unattractive). We entered the mean date-rating scores of each participant for attractive (Model A) or unattractive females (Model U) as the dependent variables, and the D scores from the IAT and the right VLPFC activities during the go/no-go task of each participant as well as their interactions as the independent variables in each model. All the variables were mean-centered prior to the analyses and were corrected for heteroscedasticity (Hayes, 2013; Hayes & Cai, 2007). Additionally, we included each participant's age as a nuisance variable. These analyses were conducted using the PROCESS SPSS macro (Hayes, 2013).

In Model A, $F(4, 22) = 6.47$, $p = .001$, $R^2 = .37$, the main effect of the D score was significant ($B = -1.46$, $t = -2.88$, CI = [−2.52, −0.41], $p = .009$), whereas the main effect of the right VLPFC activity was not significant ($B = -1.60$, $t = -0.66$, CI = [−6.63, 3.42], $p = .52$). Importantly, the interaction between the D score and the right VLPFC activation was significant ($B = -13.51$, $t = -2.50$, CI = [−24.71, −2.31], $p = .020$). Simple slope tests revealed that in participants with higher D scores, the VLPFC activity significantly predicted the regulation of their interest in extra-pair relationships ($B = -5.59$, $t = -3.16$, CI = [−9.25, −1.92], $p = .005$). However, in participants with lower D scores, the VLPFC activity had no effect on the date-rating scores ($B = 2.38$, $t = 0.64$, CI = [−5.29, 10.06], $p = .53$), which are illustrated in Fig. 3a. These results suggest that only individuals with higher executive control abilities and stronger negative attitudes toward adultery regulate their interest in extra-pair relationships with attractive females.

In Model U, $F(4, 22) = 2.47$, $p = .075$, $R^2 = .33$, only the main effect of the right VLPFC activity was significant ($B = -4.99$, $t = -2.56$, CI = [−9.04, −0.95], $p = .018$); the main effect of the D score ($B = -0.88$, $t = -1.44$, CI = [−2.16, 0.39], $p = .165$) and the interaction ($B = 4.24$, $t = 0.69$, CI = [−8.58, 17.06], $p = .50$) were not significant (see Fig. 3b). These results suggest that individuals with higher executive control abilities, regardless of their implicit attitudes, regulate their interest in extra-pair relationships with unattractive females.

Prediction of the real-life behaviors

Finally, we tested whether the IAT effect and the VLPFC activity during the go/no-go task also predicted the participants' real-life behaviors (i.e., the self-reported mean length of romantic relationships with past/current partners). Critically, a pattern similar to the results of Model A was obtained, $F(4, 22) = 2.56$, $p = .067$, $R^2 = .39$. A marginally significant interaction was observed between the D score and the right VLPFC activity ($B = 221.27$, $t = 2.02$, CI = [−6.43, 448.96], $p = .056$). The main effect of the D score was marginally significant ($B = 17.51$, $t = 1.89$, CI = [−1.75, 36.76], $p = .073$), but that of the right VLPFC activity was not significant ($B = 20.62$, $t = 0.49$, CI = [−65.86, 107.10], $p = .63$). Simple slope tests revealed that in participants with higher D scores, higher VLPFC activity significantly predicted longer relationships with past/current partners ($B = 85.89$, $t = 2.63$, CI = [18.25, 153.52], $p = .015$). However, in participants with

Table 3 Regions showing significant activation during the IAT

Contrast/Region (Brodmann's area)	Coordinates			Z value	Cluster size
	x	*y*	*z*		
Incongruent vs. Congruent					
Left precentral gyrus (extending to the middle/inferior frontal gyrus) (6/44/45)	−46	2	32	4.35	873
Left lingual gyrus (19)	−22	−58	−8	4.46	132
Left calcarine sulcus (17)	−14	−68	6	3.67	165
Right putamen	18	12	2	4.96	163
Congruent vs. Incongruent					
No suprathreshold voxels					

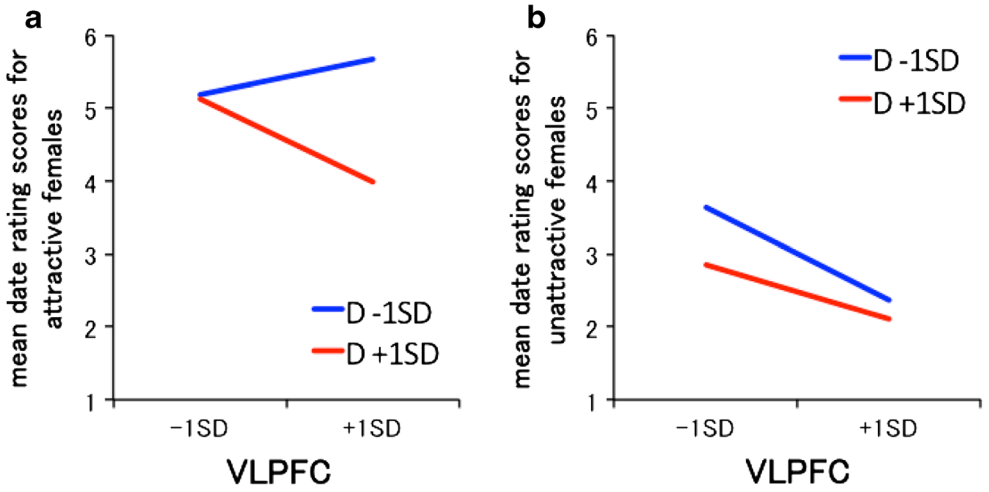

Fig. 3 Results of regression analyses to predict date-rating scores for (**a**) attractive females and (**b**) unattractive females according to the IAT effect and ventrolateral prefrontal cortex (VLPFC) activity during the go/no-go task. (Color figure online)

lower D scores, no effects of the VLPFC activity were shown (B = −44.65, t = −0.66, CI = [−183.95, 94.65], p = .51), as illustrated in Fig. 4. Taken together, these results show that the maintenance of long-term relationships depends on the combination of explicit executive control with implicit negative attitudes toward adultery.

Discussion

This study investigated the effects of implicit attitudes toward adultery and executive control on participants' ability to regulate interest in extra-pair relationships. The results confirmed our hypothesis: Implicit attitudes and executive control were predictive of the regulation of such interest, which was modulated by the alternative partner's attractiveness. The regulation of interest in extra-pair relationships with unattractive alternatives (less difficult because of a lower temptation) was only predicted by executive control, whereas the regulation of similar interest with attractive alternatives (more difficult because of a higher temptation) was predicted by the combination of implicit attitudes and executive control. Moreover, real-life behavior, as assessed by the participants' mean length of romantic relationships, was also predicted by the interaction between implicit attitudes and executive control, although these effects were marginal. To our knowledge, these results are the first to highlight the joint contributions of automatic implicit processes and deliberate explicit processes in the regulation of interest in extra-pair relationships.

Before discussing the implications of the present findings, one major limitation is worthy of mention. Contrary to our prediction, we found no significant correlation between IAT scores and activity in emotion-related regions, such as the amygdala or insula. Two possible reasons for this finding should be considered. First, the present IAT design might not fit well with the neuroimaging analysis. That is, the congruent and incongruent conditions included multiple features of stimuli (i.e., positive or negative words and monogamy or adultery pictures), which may have confounded the neural activity of interest. Second, the subtraction between incongruent trials and congruent trials was based on between-run comparisons, which might have reduced the sensitivity of the results. Whatever the case, other experimental paradigms may be better at reliably detecting neural signs of individual differences in implicit attitudes for extra-pair relationships. We leave this possibility as a topic for future research.

With this major limitation in mind, the present results illustrate the reconciliation between automatic and reflective views of monogamous attachment using temptation strength as a key modulating factor. Our results showed that date-rating scores for unattractive females were predicted only by prefrontal activity, which indicates that monogamous attachment can occur

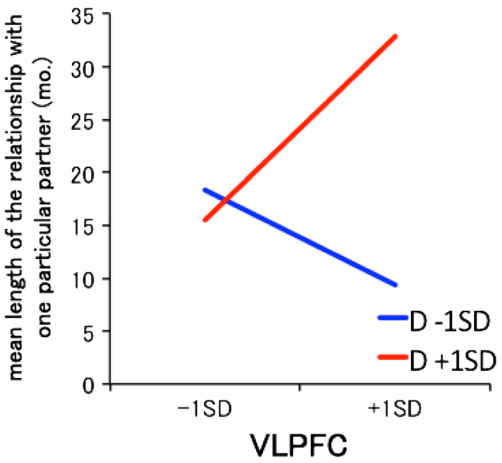

Fig. 4 Results of regression analysis to predict the mean length of relationships with past/current partners according to the IAT effect and ventrolateral prefrontal cortex (VLPFC) activity during the go/no-go task. (Color figure online)

as a consequence of behavioral control. Thus, when the temptation is low, explicit behavioral control can sufficiently regulate the motivation for unfavorable behaviors. These results are consistent with previous studies showing that executive control is sufficient when the target is less attractive (Friese, Hofmann, & Wanke, 2008; Hofmann, Friese, & Roefs, 2009; Lopez et al., 2014). The present results are also consistent with previous studies showing that the maintenance of a stable and long-term exclusive relationship is related to self-control (Ciarocco et al., 2012; Finkel & Campbell, 2001; Meyer et al., 2011; Pronk et al., 2011; Ritter et al., 2010).

Our data suggest that the reflective view on monogamous attachment is supported only in cases in which temptation is low; by contrast, when temptation is strong, the regulation of interest in extra-pair relationships with a single factor (i.e., implicit attitude or executive control) is difficult. Therefore, individuals with a large IAT effect and higher prefrontal activity can regulate their interest. We note that this finding is only partially consistent with the automatic view, which assumes that monogamous love is a result of automatic tendencies, whereas when temptation is strong, a combination of implicit and explicit inhibitory factors is required. This idea is highly consistent with the recent theoretical model of the role of executive control in romantic relationships (Pronk & Righetti, 2015), which assumes that executive control does not "blindly" lead to stable and long-term relationship but rather strongly depends on automatic and implicit attitudes. Furthermore, we found that these two factors interacted (although marginally) to predict the mean length of romantic relationships, which indicated that our results could be generalized to real-life situations. These findings may help explain why extra-pair relationships are so common despite the condemnation of such behavior (Thompson, 1983; Wiederman, 1997). The present results are also consistent with a dual-process model view of a limited-resource reflective system (Strack & Deutsch, 2004). However, we note that our primary results are correlational; no conclusions can be drawn regarding causal relationships between two inhibitory factors and interest in extra-pair relationships. Through the use of priming techniques that can affect implicit attitudes (e.g., Lowery, Hardin, & Sinclair, 2001), we might be able to determine whether changes in implicit attitudes can affect interest in extra-pair relationships. Similarly, ego-depletion techniques (e.g., Baumeister, Bratslavsky, Muraven, & Tice, 1998) or interference with the prefrontal control system using magnetic stimulation (e.g., Mattavelli et al., 2015) might provide further insights into amorous decision-making in terms of explicit behavioral control.

Several important topics that are associated with the present findings require further research. First, we must clarify individual differences in what facilitates interest in extra-pair relationships. One potentially critical factor is reward sensitivity, which has been repeatedly demonstrated to be linked to individual differences in psychopathic traits (Buckholtz et al., 2010) and immoral behavior, such as dishonesty (Abe & Greene, 2014). Conceivably, individual differences in reward sensitivity may also influence the relative contributions of implicit attitudes and executive control in the regulation of interest in extra-pair relationships. However, the reward system can also play key roles in the formation of romantic relationships and cause a "love is blind" bias that suppresses interest in other potential mates (for a review, see Fletcher, Simpson, Campbell, & Overall, 2015). Second, we studied only male volunteers, although the investigation of sex differences in behavioral patterns that are associated with adultery is important. For example, males generally desire romantic relationships with more individuals compared with females (Buss & Schmitt, 1993; Wiederman, 1997). Other studies have demonstrated that females' interest in extra-pair relationships is modulated by the menstrual cycle (Penton-Voak et al., 1999), with greater interest during the fertile phase. Third, the current relationship with a partner is an important factor to be pursued. For example, low relationship satisfaction (Buss & Shackelford, 1997) or less commitment to their partner (Drigotas, Safstrom, & Gentilia, 1999) could lead to participation in extra-pair relationships. Even individuals with higher control functions might tend to have serial short-term relationships, unless they are sufficiently satisfied with the current relationship. Finally, cultural differences should be examined, as different societies have different views on romantic love (Hatfield et al., 2010). In societies where social norms heavily restrict extra-pair relationships, people may feel a stronger negative emotion toward such behaviors. Cross-cultural studies can provide further insights into the influence of such norms on implicit and explicit aspects of romantic decision-making.

Acknowledgements We are grateful to Maki Terao for her assistance in data collection and James Anderson for his proofreading and insightful comments. This study was conducted using the MRI scanner and related facilities of the Kokoro Research Center, Kyoto University. This work was partly supported by JSPS KAKENHI Grant Numbers JP17J01776, JP16H05861, and the ImPACT Program of the Council for Science, Technology and Innovation (Cabinet Office, Government of Japan). Nobuhito Abe was supported by the Uehiro Foundation on Ethics and Education.

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