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Jealousy: Novel Methods and Neural Correlates

Eddie Harmon-Jones and Carly K. Peterson
Texas A&M University

Christine R. Harris
University of California–San Diego

Because of the difficulties surrounding the evocation of jealousy, past research has relied on reactions to hypothetical scenarios and recall of past experiences of jealousy. Both methodologies have limitations, however. The present research was designed to develop a method of evoking jealousy in the laboratory that would be well controlled, ethically permissible, and psychologically meaningful. Study 1 demonstrated that jealousy could be evoked in a modified version of K. D. Williams' (2007) Cyberball ostracism paradigm in which the rejecting person was computer-generated. Study 2, the first to examine neural activity during the active experience of jealousy, tested whether experienced jealousy was associated with greater relative left or right frontal cortical activation. The findings revealed that the experience of jealousy was correlated with greater relative left frontal cortical activation toward the "sexually" desired partner. This pattern of activation suggests that jealousy is associated with approach motivation. Taken together, the present studies developed a laboratory paradigm for the study of jealousy that should help foster research on one of the most social of emotions.

Keywords: jealousy, approach motivation, asymmetrical frontal cortical activity

Jealousy has powerful consequences—relationship dissolution, spousal abuse, and even homicide (Daly & Wilson, 1988; Harris, 2003b). Yet, empirical studies of jealousy are limited. Study of many emotions has been promoted by the development of controlled laboratory paradigms for eliciting the emotion. For jealousy, however, this goal has remained elusive because the elicitation of jealousy requires complex social interactions, and creating such a situation presents ethical challenges (e.g., manipulations might damage a relationship). The lack of straightforward methods of actively eliciting jealousy in real time in the laboratory has also limited the ability to look at other aspects of jealousy such as its neural underpinnings and functionality.

The first purpose of the present research was to develop a method of evoking jealousy in the laboratory that would be well controlled, ethically permissible, and psychologically meaningful. The second purpose was to use this method to examine possible neural correlates of jealousy.

Theoretical Approaches

Jealousy requires a social triangle, occurs over the perception that another (even if only imaginary) poses a threat to an important relationship, and differs from other types of rejection in that one's interpersonal loss is another's gain (Parrott & Smith, 1993; Salovey & Rothman, 1991; White & Mullen, 1989). Emotions such as anger, fear, or sadness can occur in jealousy-evoking situations. One hypothesis is that jealousy is a blend of these other emotions (Hupka, 1984; Sharpsteen, 1991; White & Mullen, 1989). Another hypothesis is that jealousy is a distinct emotional state that may be associated with other emotions. But jealousy differs from other associated emotions as it functions to motivate behaviors that will break up, psychologically or physically, the threatening liaison between an important other and a rival and maintain the primary relationship (Harris, 2003b). It is important to note that this motivational state would not be created automatically by other emotions that are frequently offered as the more essential emotional components of jealousy, such as anger (motivation to fight). This functional account would suggest that jealousy belongs in the family of "approach emotions" (Lazarus, 1991). Research on infants also suggests that the most predictable response to jealousy evocation is approach behavior (Hart, Carrington, Tronick, & Carroll, 2004). Although infants show various types of negative affect, they show great consistency in mother-directed visual attention and proximity-seeking behaviors during jealousy evocation.

Most work on adult jealousy has focused on romantic relationships. However, several theorists have argued that the same basic emotional process is involved in jealousy across a wide range of relationships (DeSteno, Valdesolo, & Bartlett, 2006; Harris, 2003b). Relationships, romantic/sexual or not, provide many important benefits (Baumeister & Leary, 1995; House, Landis, & Umberson, 1988) that need to be protected from potential usurpers. Jealousy may be particularly strong when the threatened relationship involves a person toward whom one is sexually attracted and is likely to occur during early stages of relationships when relationship stability is uncertain (White & Mullen, 1989).

Jealousy Research Methods

Given ethical constraints, jealousy research has generally relied on hypothetical scenarios in which participants attempt to predict

Eddie Harmon-Jones and Carly K. Peterson, Department of Psychology, Texas A&M University; Christine R. Harris, Department of Psychology, University of California–San Diego.

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Correspondence concerning this article should be addressed to Eddie Harmon-Jones, Department of Psychology, Texas A&M University, 4235 TAMU, College Station, TX 77843. E-mail: eddiehj@gmail.com

their reactions or on retrospective recall of jealous experiences. Such approaches have limitations. Reactions to hypothetical scenarios that do little to engage the participant may be poor proxies for emotional responding in real situations, as research suggests that people are inaccurate in predicting feelings in a variety of situations (Wilson & Gilbert, 2005). People are particularly poor at predicting their reactions to hypothetical events involving jealousy and infidelity. Such responses have little correspondence with responses to real infidelity as measured through recall or behavior (Harris, 2002, 2003a). Hypothetical measures may show poor validity because they evoke complex inferential thinking rather than immediate emotional reactions (e.g., DeSteno, Bartlett, Braverman, & Salovey, 2002; DeSteno & Salovey, 1996; Harris & Christenfeld, 1996). The second research method, retrospective recall, has the virtue of being based on actual past emotional experiences rather than participants' ability to imagine people, relationships, and events that do not exist. However, recall is subject to limitations such as memory failure or bias.

Controlled experimental paradigms for evoking jealousy are almost nonexistent in the adult literature. One notable exception is work that examined coping reactions to a rival in established romantic relationships via phone calls (Mathes, Adams, & Davies, 1985). Recently, DeSteno and colleagues (2006) elicited jealousy in the lab through orchestrated social encounters in which a participant is rejected by a partner (a confederate) in favor of a third person. This work provided direct evidence for the role of self-esteem threat in the elicitation of jealousy and further documented the link between jealousy and interpersonal aggression.

Current Work

Jealousy is theorized to be intricately connected with rejection, specifically rejection by the object of one's desires in favor of someone else. Our work builds on experimental methods to examine other types of reactions to social rejection (Eisenberger, Lieberman, & Williams, 2003; Williams, Cheung, & Choi, 2000), particularly a paradigm in which participants were either ostracized or included during Cyberball—a cyber analogue of a ball-tossing game—by two other players (Williams, 2007). This work demonstrated that rejection threatens fundamental psychological needs and produces negative feelings. Exclusion even by imaginary computer-generated players produces negative reactions (Williams, 2007; Zadro, Williams, & Richardson, 2004). However, previous work with this paradigm has not manipulated or measured jealousy.

In Study 1, we sought to create a "minimal" paradigm that would be sufficient to evoke jealousy. Under the guise of making the experience easier to imagine in real life, participants selected one of the other two players from a set of female (or male) photos. Then, they played a Cyberball game while photographs of the selected player and another player of the same sex as the participant were displayed. After being included for a few minutes, participants continued to be included or were ostracized by the same-sex or opposite-sex player they had chosen earlier. Because jealousy results from threatened loss of a relationship, we expected individuals to become jealous when rejected by another person, and to feel particularly jealous when ostracized by an opposite-sex individual.

The current work extends jealousy research by providing a paradigm that actively elicits jealousy in real time in the laboratory without potentially risking negative influences on the participant's actual relationships. It provides greater experimental control than is possible with interpersonal interactions that use scripts and confederates in a face-to-face interaction. Finally, it examines whether jealousy can be evoked under minimal psychological circumstances where the social rejection occurs via computer and not by an actual person.

Study 1

Method

Participants were 80 male and 82 female introductory psychology students who received course credit for participation. After informed consent, participants completed a questionnaire, indicating how they had felt during the past few weeks on a number of emotion words including the word *jealous* (1 = *very slightly or not at all*, 7 = *extremely*). They then viewed photos of eight potential players and were given the opportunity to choose one player "to make the experience easier to imagine in real life." Half of the participants selected one player from among only male photos, whereas the other half selected one player from among only female photos. The third (nonchosen) player in the Cyberball game was always the same gender as the participant.

As in Zadro et al. (2004), participants were told that the study was to "test the effects of practicing mental visualization on task performance." Participants then played the Cyberball game by pressing the *left shift* key to throw to the player on the left and the *right shift* key to throw to the player on the right. All participants were included during the first 2 min of the game. Then, half of the participants were ostracized during the second half of the game (the ball was not thrown to them). When the ostracism occurred, the chosen partner's eyes, which were previously fixated on the participant, moved so that they now gazed at the other player. This was done to enhance the emotional impact of the ostracism (see Figure 1). Finally, participants completed a questionnaire to assess emotions and other reactions they had during the game (see Zadro et al., 2004).

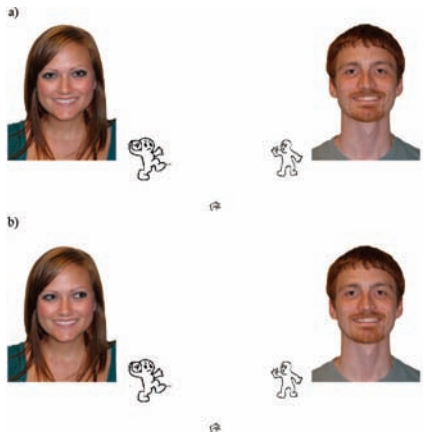

Figure 1. a) Example of female player in possession of the ball while the participant is being included; b) Example of female player possessing the ball while the participant is being ostracized. Printed with permission of Raymond Serra and Aimee Howarth.

Results and Discussion

A 2 (same vs. opposite sex from participant) × 2 (ostracism vs. inclusion) analysis of covariance (ANCOVA) was conducted, with baseline jealousy serving as the covariate. It produced the predicted interaction, $F(1, 154) = 5.24$, $p = .02$, partial $\eta^2 = .03$. As shown in Figure 2, participants felt more jealous when ostracized than when included, and they felt more jealous when ostracized by an opposite-sex partner as compared to a same-sex partner, ps $< .05$. Additional analyses revealed that male and female participants did not differ from each other in the jealousy they felt, ps $> .10$.

Replicating past research, ostracism, as compared to inclusion, caused more anger and lower feelings of inclusion, belonging, control, self-esteem, and meaningful existence, all Fs > 19.50. No interactions with same versus opposite sex of target occurred, Fs < 1.95. Thus, the effects of same/opposite sex and inclusion/ostracism were specific to jealousy. Additional ANCOVAs controlling for the effects of these other outcome variables revealed that the Same/Opposite Sex × Inclusion/Ostracism interaction on jealousy remained significant, all Fs > 4.03, ps $< .05$, partial η^2s $> .03$. Across conditions, zero-order correlations revealed that the change in jealousy was correlated positively with anger ($r = .41$, $p < .01$) and negatively with feelings of inclusion, belonging, control, and meaningful existence (all rs $< -.22$, ps $< .01$). Previous research and theory have suggested that situations that evoke jealousy also threaten self-esteem and increase other negative affects (DeSteno et al., 2006; Hupka, 1984; Sharpsteen, 1991; White & Mullen, 1989). However, the current experiment suggests that the Same/Opposite Sex × Inclusion/Ostracism interaction continued to predict jealousy even when controlling for these other states.

As predicted, ostracism by a computer-generated opposite-sex partner caused greater feelings of jealousy than ostracism by a same-sex partner. Moreover, both types of ostracism caused more jealousy than inclusion by any partner. That jealousy was evoked in such a paradigm is important and suggests new insights into the nature of jealousy. We would suggest that some attraction existed in the opposite-sex conditions as individuals chose which opposite-sex person with whom to work. However, we do not believe that our results are relevant to the issue of sex differences in response to sexual infidelity (which is debated; Harris, 2003b) because there was no sexual infidelity. The ostracizing person simply did not throw the cyberball to the participant. Such could just as easily be interpreted as emotional infidelity. Thus, this manipulation does not readily lend itself to being categorized by either sexual versus emotional infidelity (nor do many acts for that matter). However, what is important is that the situation did have elements of some kind of attraction and people did report feeling jealousy.

Study 2

In Study 2, we examined some of the neural circuitry involved in jealousy. In particular, we were interested in assessing whether the experience of jealousy was associated with greater relative left or right frontal cortical activation. Much research has revealed that the prefrontal cortex is asymmetrically involved in approach–withdrawal motivation, with greater relative left frontal activation being associated with approach motivation and greater relative right frontal activation being associated with withdrawal motivation (see review by Coan & Allen, 2004). For instance, experiments revealed that both approach-motivated positive affects (Davidson, Saron, Senulis, Ekman, & Friesen, 1990) and approach-motivated anger cause greater relative left frontal cortical activity than appropriate control conditions (Harmon-Jones, Lueck, Fearn, & Harmon-Jones, 2006). Other experiments revealed that withdrawal-oriented negative affects such as disgust

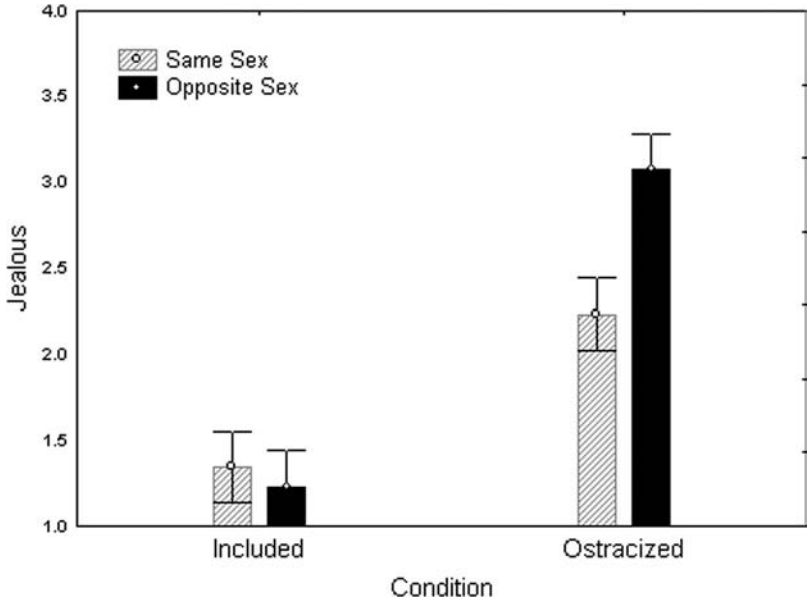

Figure 2. Self-reported jealousy as a function of inclusion or ostracism by same-sex or opposite-sex target (Study 1).

and sadness cause greater relative right frontal cortical activity than appropriate control conditions (Jones & Fox, 1992).

These asymmetrical activations are more likely to be observed using individual differences approaches when the situational manipulations are relatively weak. For instance, relative left frontal activation was observed only to *mild* anger cues in individuals high in trait anger (Harmon-Jones, 2007). Also, relative left frontal activation was observed only to mildly positive approach-motivating stimuli (pictures of desserts) in individuals who had not recently eaten and in individuals who find desserts particularly likable (Gable & Harmon-Jones, 2008).

The association of the experience of jealousy with the basic motivational impulse to approach or withdraw from the evoking stimulus has, to our knowledge, yet to be examined empirically. Lazarus (1991) proposed that jealousy activates angry impulses to attack as well as action tendencies associated with yearning and love, all of which are approach-oriented action tendencies. Thus, we predicted that jealousy in a minimal paradigm would be associated with greater relative left frontal activation, particularly among individuals who feel more jealous. This prediction is predicated on the idea that jealousy is associated with action tendencies of approach.

Method

Methods were identical to Study 1 with the following exceptions. Because of our interest in examining the neural correlates of the jealousy experience, EEG was recorded throughout the game and only the condition that evoked "sexual" jealousy was run (i.e., the participant was rejected by the female partner he had chosen in favor of another male). Ten right-handed introductory psychology male students participated.

EEG was recorded with 59 tin electrodes mounted in a stretch-lycra electrode cap (Electro-Cap, Eaton, OH). The ground electrode was on the midline between the frontal pole and the frontal site. The reference electrode was placed on the left ear, and data were also acquired from an electrode on the right ear, so that an offline, averaged ears' reference could be computed. Vertical and horizontal eye movements (EOG) were also recorded to facilitate artifact correction of the EEG. All electrode impedances were under 5,000 ohms, and homologous sites were within 1,000 ohms of each other. EEG and EOG were amplified with Neuroscan Synamps (El Paso, TX), bandpass filtered (0.05 to 100 Hz) and digitized at 500 Hz (an analog 60-Hz notch filter was enabled).

Signals were visually scored and portions of the data that contained artifacts were removed. Then, a regression-based eye movement correction was applied, after which the data were again visually inspected. All epochs 1.024 s in duration were extracted through a Hamming window. A fast Fourier transform was used to calculate the power spectra, which were averaged across epochs of each player's possession of the ball during each Cyberball game. Because recent research has revealed motivationally relevant asymmetrical frontal cortical activations to be more strongly associated with power in the high alpha band (10.5–13 Hz; Pizzagalli, Sherwood, Henriques, & Davidson, 2005), our analyses focused on this. An average frontal asymmetry index (AF3/4, F3/4, F7/8, F5/6, FC5/6) was created, based on past research with fewer electrodes that focused on F3/4 and F7/8. A comparison asymmetry index over the parietal region was also created (P3/4, P5/6, P7/8, CP3/4, PO5/6). This index was included as in past research to test whether hemispheric effects are specific to the frontal regions. Because alpha power is inversely related to cortical activity, higher scores indicate greater left hemisphere activity. To examine the asymmetrical activations in response to jealousy alone, we created all asymmetry variables by subtracting the activity observed during the inclusion portion of the game from the activity observed during the exclusion portion of the game. Self-reported emotional responses were processed similarly, by subtracting baseline emotion reports from emotion reports collected at the end of the game.

Results and Discussion

As expected, jealousy was associated with greater relative left frontal activation when the female player held the ball and was rejecting the participant (female rejection), $r = .71$, $p = .02$. Also, relative left frontal activation during female rejection was associated with greater anger, $r = .72$, $p = .02$, and lower inclusion, $r = -.67$, $p = .03$. This asymmetry index was not significantly associated with other responses to ostracism. Additional regressions were conducted to examine whether entry of these two significant variables would eliminate the relationship between relative left frontal activation and jealousy. Neither variable eliminated the left frontal–jealousy relationship, partial rs $> .57$, ps $< .05$ (one-tailed, which is justified given the directionality of the prediction).

In addition, relative left frontal activation during male rejection was not significantly associated with any variables; it was, however, marginally and inversely associated with anxiety, $r = -.60$, $p = .07$, suggesting that greater relative right frontal activation during male rejection was associated with feelings of anxiety. In this study, the male participants chose the female player but did not choose the male player. It is likely that this act of choosing the female partner created more of a budding relationship than simply being assigned a partner. This greater investment would cause the participants to feel more jealousy over the rejection and to be more approach motivated toward the female player than the male player.

In contrast to the frontal asymmetry, the parietal asymmetry index during female rejection was inversely (and nonsignificantly) correlated with jealousy, $r = -.48$, $p = .16$. It was also nonsignificantly correlated with all other responses except feelings of control, $r = .64$, $p = .05$. Parietal asymmetry during male rejection was not associated with any responses except belonging, $r = .82$, $p = .004$. These two correlations suggest that greater relative right parietal activation was associated with lower feelings of control during female rejection and lower feelings of belonging during male rejection. Although research on parietal asymmetries is not as established as the frontal asymmetry literature, some work has found relatively greater right parietal activity to be associated with depression (see review by Bruder, 2003). The current findings are consistent with this research on depression.

Zero-order correlations among variables revealed that the change in jealousy was not significantly correlated with any other variables. However, jealousy did correlate in expected directions with some of the variables: It was positively correlated with anger, $r = .50$, $p = .14$, negatively correlated with feelings of inclusion, $r = -.44$, $p = .20$, and negatively correlated with self-esteem, $r = -.57$, $p = .09$. That jealousy is correlated with

other types of negative affect and self-esteem is not surprising, as discussed previously. However, the current work suggests that jealousy is associated with greater relative left frontal activity even when controlling for these other states.

General Discussion

The present research was designed to develop a controlled and psychologically meaningful way of evoking jealousy in the laboratory free of ethical concerns. The results of the two studies suggest that this goal was accomplished. In addition, Study 2 was designed to examine whether jealousy was associated with neural circuitry involved in approach or withdrawal motivation. Based on past research suggesting that relative left frontal cortical activity is associated with approach motivation and on past theories suggesting that jealousy would be associated with approach motivation, we predicted and found that jealousy is associated with relative left frontal activity. These results are consistent with theories that propose that the primary motivational state in jealousy, at least initially, is one of approach (Lazarus, 1991). More specifically, these approach inclinations may manifest in behaviors aimed at breaking up the threatening liaison or reestablishing the primary relationship (Harris, 2003b). These neurophysiological results also suggest that the self-reported responses obtained in Study 1 were not simply due to demand characteristics.

A final purpose of the present studies was to develop a well-controlled, minimal laboratory paradigm to which additional variables could readily be added in further research examining how various factors affect the intensity of jealousy. We believe that our paradigm accomplished such and hope that it will be used in further research on interpersonal relationships, emotions, and the neural circuits involved in such psychological processes.

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