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Anger, coping, and frontal cortical activity: The effect of coping potential on anger-induced left frontal activity

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The present research tested whether relative left midfrontal cortical activity would be greater when individuals believed they could engage in behaviour to ameliorate an anger-inducing situation as compared to when they believed they could do nothing. The research also examined whether relative left midfrontal cortical activity would relate to behaviors aimed at ameliorating the anger-inducing situation, when individuals believed they could do something. To test these primary hypotheses, university students who were opposed to a tuition increase at their university were exposed to a pilot radio editorial that argued for increased tuition, and their electroencephalographic (EEG) activity, self-reported emotions, and behavioural responses were then collected. Prior to hearing the editorial, participants were led to believe that the tuition increase would definitely occur or that the tuition increase may occur and that petitions were being circulated to attempt to prevent it. Results supported the primary hypotheses and also revealed that relative left midfrontal activity was associated with anger in response to the editorial and that the effects were specific to the midfrontal cortical regions.

Research has suggested that the prefrontal cortical regions are critically involved in emotional and motivational processes, with the left prefrontal cortical region involved in approach motivational and/or positive affective processes and the right prefrontal cortical region involved in withdrawal motivational and/or

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negative affective processes (for reviews, see Coan & Allen, in press; Davidson, 1995; Davidson, Jackson, & Kalin, 2000; Fox, 1991; Silberman & Weingartner, 1986). For instance, research has revealed that relatively greater left frontal activity at rest relates directly to trait positive affect (Tomarken, Davidson, Wheeler, & Doss, 1992) and trait behavioural activation sensitivity (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997), and it relates inversely to trait negative affect (Tomarken et al., 1992), depression (Allen, Iacono, Depue, & Arbisi, 1993; Henriques & Davidson, 1990, 1991; Jacobs & Snyder, 1996; Schaffer, Davidson, & Saron, 1983), panic disorder (Wiedemann, et al., 1999), and some forms of anxiety (Heller & Nitschke, 1998; Nitschke, Heller, Palmieri, & Miller, 1999). In addition, individuals with relatively greater left frontal activity at baseline respond with more joy, less disgust, and less fear to emotional films than do individuals with relatively greater right frontal activity (Tomarken, Davidson, & Henriques, 1990; Wheeler, Davidson, & Tomarken, 1993), and that modulations in asymmetrical frontal activity via biofeedback affect emotional responses to film clips in this same direction (Allen, Harmon-Jones, & Cavender, 2001). Similarly, research has revealed that relatively greater right frontal activity is directly related to a lower pain threshold (Pauli, Wiedemann, & Nickola, 1999). Other research has revealed that voluntary creations of positive emotional facial expressions are associated with increased left frontal activity and voluntary creations of negative emotional facial expressions are associated with increased right frontal activity (Coan, Allen, & Harmon-Jones, 2001; Ekman & Davidson, 1993). Still other research has demonstrated that imaging happy events evokes increased left frontal activity, whereas imaging fearful events evokes increased right frontal activity (Ahern & Schwartz, 1985). Moreover, the possibility of rewards increases left frontal activity and the possibility of punishment increases right frontal activity (Sobotka, Davidson, & Senulis, 1992).

Conceptual models of asymmetrical frontal activity

Several conceptual views of the relation between asymmetrical frontal cortical activity and motivational and emotional processes have been advanced. One view is that positive affect relates to increased left frontal activity and negative affect relates to increased right frontal activity (Ahern & Schwartz, 1985; Heller, 1990; Heller & Nitschke, 1998; Silberman & Weingartner, 1986). Another view is that approach motivation relates to increased left frontal activity and withdrawal motivation relates to increased right frontal activity (Davidson, 1995; Fox, 1991; Harmon-Jones & Allen, 1997, 1998; Sutton & Davidson, 1997). A final model has posited that left frontal activity is associated with positive affect and approach motivation, and right frontal activity is associated with negative affect and withdrawal motivation (Davidson, 1998). In past research, predictions derived from these models converged, as the emotions and motivations examined naturally confounded the valence of the emotion with the direction of

the motivation, such that only positive, approach-related emotions (e.g., joy) and negative, withdrawal-related emotions (e.g., disgust) were examined.

Anger and asymmetrical frontal activity

Some emotions, however, violate this relationship between emotional valence and motivational direction. Anger, for example, is considered an approach motivational tendency with negative emotional valence (Berkowitz, 1999; Buss & Perry, 1992; Darwin, 1872/1965; Harmon-Jones & Sigelman, 2001; Lazarus, 1991; Lewis, Alessandri, & Sullivan, 1990; Lewis, Sullivan, Ramsey, & Alessandri, 1992; McDougall, 1926; Mikulincer, 1988; Plutchik, 1980; Young, 1943). Supporting the model that proposes that asymmetrical frontal activity relates to approach and withdrawal motivation, recent research found that trait anger related to increased left frontal cortical activation (Harmon-Jones, 2002; Harmon-Jones & Allen, 1998), and that this relationship was not due to anger being regarded as a positive feeling (Harmon-Jones, 2002), Moreover, statistically adjusting for general positive and negative affect does not alter the relationship between left frontal activity and trait anger (Harmon-Jones, 2002). Other research has revealed that after persons are insulted, relative left frontal activity is increased, and those who respond with relative left frontal activity to an insult also report feeling more angry and behave more aggressively (Harmon-Jones & Sigelman, 2001). These results suggest that left frontal cortical activity is associated with approach motivation, regardless of the valence (positivity or negativity) of the emotion. Thus, these results support the motivational model of the functions of asymmetrical frontal activity and challenge the other models of the functions of asymmetrical frontal activity.

Effect of coping potential on asymmetrical frontal activity

According to the motivational model of asymmetrical frontal activity, approach motivation is related to left frontal activity and withdrawal motivation is related to right frontal activity. Thus, increased left frontal activation occurs in response to anger-inducing situations because the increase in relative left frontal activity increases approach motivational tendencies that would assist in behaviour that may rectify the anger-inducing situation. From this perspective, it follows that if no approach behaviour could be taken to deal with the anger-provoking situation, then this increase in relative left frontal activation should be less. In other words, if approach and withdrawal motivational tendencies do indeed underlie asymmetrical frontal activity, then alterations in motivational intensity should affect the degree of activation in the frontal cortical regions. Thus, according to this perspective, anger is associated with increased left frontal activity because anger arouses approach motivation. In situations where no action can be taken to remedy the negative situation, approach motivation will be less, as will left

frontal activation. However, the feeling of anger itself may not be reduced while the aversive situation persists.

Central to major motivational theories is the idea that expectancy of success or perceived task difficulty should affect motivational intensity (for reviews, see Brehm & Self, 1989; Wright & Kirby, 2001). For the emotion of anger, which often has approach motivational tendencies, if a situation creates anger and the individual believes that he/she can successfully act to alter the situation, then motivational intensity should be relatively high. If, on the other hand, the individual believes that no action can be taken, then motivational intensity should be relatively low.

A similar prediction follows from the idea of secondary coping (Lazarus, 1991). Negative emotions including anger, sadness, guilt, and fear occur when persons find themselves in aversive situations. According to Lazarus (1991), the type of negative emotion evoked by a situation may be determined by coping potential—how persons appraise their ability to deal with the aversive situation. If something can be done to ameliorate the situation, then anger, an active and negative emotion, should be aroused. In contrast, if nothing can be done to ameliorate the situation, then a passive and negative emotion, sadness, may be aroused. Theorists make similar predictions for appraisals of power (Roseman, 1991), power and control (Scherer, 1993), and likelihood of reinstatement of the goal state (Levine, 1995).[1]

Unfortunately, little research has explored the issue of whether appraisals of higher coping potential lead to more anger. However, research by Levine (1995) found that, when 5-year-old children were presented with scenarios in which a child experienced a negative outcome, they expected the protagonist to experience more anger and less sadness when they judged the possibility of goal reinstatement more likely and less anger and more sadness when they judged goal reinstatement less likely.

[1] Other emotion theorists disagree about the importance of coping potential in determining whether sadness or anger is experienced (Smith & Lazarus, 1993). Smith hypothesises that whether another person is to blame for the aversive situation is the most important determinant of emotion in a negative situation, with anger experienced when another person is at fault, guilt experienced when the individual him/herself is at fault, and sadness experienced when no one is to blame for the negative situation. Research finds that persons do expect more anger to be experienced when presented with hypothetical situations where a person is in a negative situation and another person is to blame for causing the situation (Ellsworth & Smith, 1988; Smith & Lazarus, 1993). Frijda (1993), however, hypothesises that the appraisal that another person's blameworthy actions produced the aversive situation is motivated by the emotion of anger rather than a cause of it. When a person experiences anger, he/she then looks for someone or something to blame and to aggress against. He presents convincing anecdotes of persons who aggressed against inanimate objects after hurting themselves. According to Frijda (1993), ''Anger for instance, involves the action readiness to remove an obstacle or a wrong; attributions can be understood as efforts to identify a responsible agent at which the actual removal efforts may be directed'' (p. 371). Therefore, the tendency to blame another person for anger-producing situations may also be in the service of action to alter the situation.

Research in the appraisal models of emotion has been criticised for relying on presentations of hypothetical scenarios and participants' self-reports of the emotions they would expect to experience if in the described situation. It has been suggested that this research provides reliable information about persons' beliefs and expectations of how emotions are created, but less reliable information about the actual antecedents of emotion (Parkinson & Manstead, 1993). In contrast, the present experiment aims to generate a real emotion of anger and to assess it by self-report, behavioural, and psychophysiological means.

Based on the integration of ideas from the motivational model of asymmetrical frontal activity with theories of motivational intensity and how coping potential relates to anger, we predicted that greater left frontal activation would occur in response to an anger-producing event when persons believe that there is something that can be done to ameliorate the situation as compared to when persons believe that nothing can be done. No previous research has tested this prediction.

The present research

In the present experiment, university students opposed to a tuition increase were exposed to an editorial that argued for a tuition increase. They were exposed to this counterattitudinal message, as a large body of research has suggested that exposure to such messages evokes negative affect (for a review, see Harmon-Jones, 2001). Moreover, pre-tests in our laboratory revealed that anger was the primary emotion evoked by such messages. The participants were randomly assigned to conditions. The conditions differed with regard to whether it was possible for participants to act to change the likelihood that tuition will be increased, to manipulate the expectation of acting to change the situation. In the action-possible condition, participants were told that the increase may occur in the future and that petitions were being circulated to attempt to prevent the increase. In the action-impossible condition, participants were told that the tuition increase would definitely occur.

The present research was designed to test the following specific hypotheses.

Hypothesis 1. Participants who expect to engage in the approach-related action of signing a petition to ameliorate the tuition-increase situation (action-possible condition) should evidence greater left frontal activity than participants who expect to be unable to engage in approach-related action. This prediction follows from research indicating that the expectation of success affects motivational intensity, and according to the motivational model of asymmetrical frontal activity, approach motivational intensity should be reflected in left frontal activity.

Hypothesis 1a. The effect predicted in the previous hypothesis is expected to be most likely to occur closer in time to the anger-inducing event. Because three

minutes of EEG were recorded following the tuition increase message, we expected that min 1 would produce the largest effect, min 2 would produce the second largest effect, and min 3 would produce the smallest effect.

Hypothesis 1b. Participants in the action-possible condition should evidence an increase in left frontal activity from baseline to immediately after the tuition increase situation. Such a finding would suggest that the manipulation stimulated an increase in approach motivation.

Hypothesis 2. The predicted effects of the possibility of action to prevent the tuition increase should be limited to frontal cortical regions and should not occur in other regions, as the motivational model suggests that the emotional effects are specific to the frontal regions.

Hypothesis 3. Within the action-possible condition, participants who evidence greater left frontal activity in response to the tuition increase message should also evidence greater self-reported anger, providing support for the idea that anger is often an approach-related emotional response (Harmon-Jones & Allen, 1998; Harmon-Jones & Sigelman, 2001). In the condition where action is not possible, greater left frontal activity might not relate to greater anger. This is because, although anger usually leads to approach motivation, when action is not possible, approach motivation should remain low, even if the level of angry feelings is high.

Hypothesis 4. Within the action-possible condition, participants who evidence greater left frontal activity in response to the tuition increase message should be more likely to engage in behaviours that would reduce the possibility of the tuition increase, by being more likely to sign a petition against the tuition increase and to take petitions with them for others to sign, as the motivational model suggests that left frontal activity is associated with certain emotions because those emotions evoke approach-related action tendencies. Greater approach motivation should be expressed as more action to correct the negative situation.

METHOD

Participants

Participants were 77 introductory psychology students who participated in exchange for extra credit in their psychology course. There were 39 women and 38 men, with approximately equal numbers of women and men within each condition. Participants paid at least 33% of their tuition by themselves (not with parental assistance) or with student loads, and moderately or strongly disagreed with a statement indicating that tuition should be increased by 10% at the university. Percentage of tuition paid and attitude were assessed in a mass survey session at the beginning of the semester. Participants were right-handed (score <= 17 on the Chapman & Chapman, 1987, handedness questionnaire), and reported no history of psychiatric disorder, neurological disorder, or brain

trauma. Only right-handed participants were invited to participate in the experiment because research suggests that right- and left-handed persons may differ in hemispheric specialisation of emotion (Heller & Levy, 1981). Three women and one man expressed doubts about the cover story, and their data were removed prior to all analyses, leaving 73 (36 women, 37 men) for final analyses, with 51 in the action-possible condition, and 22 in the action-impossible condition.[2] Two additional participants' electroencephalographic (EEG) data were discarded prior to analyses, one because of too much eye movement and muscle artifact and one because of equipment problems. In the end, there were 71 participants (34 women, 37 men) for EEG analyses.

Procedure

Prior to the experiment, a phone interview was conducted. Participants were informed that brain activity would be assessed with an electrode cap, that the study would last approximately two hours, and that the study concerned reactions to pilot radio broadcasts.

On the day of the experiment, participants were met at the waiting room, brought to the laboratory, and asked to sit in a comfortable chair in a dimly lit, sound-attenuated room. The experimenter informed participants that the study concerned reactions to pilot radio broadcasts. He explained that the study was being conducted by Professor Harmon-Jones as a service for WERN, an affiliate radio station of Wisconsin Public Radio, and that much of their broadcasting was targeted toward students, faculty, and staff at the University of Wisconsin-Madison (UW). He then explained that WERN was considering introducing two new programs: ''Bulletin Board'', a programme that announces activities and events at local universities and colleges and current editorials concerning issues on these campuses, and ''News from the Personal Side'', a news programme that goes beyond the facts of local individuals involved. He further explained that for several years, Professor Harmon-Jones, an expert on responses to mass media, had pilot-tested new programming ideas for WERN by trying them out on UW introductory psychology students. He finished the introduction by explaining that the participant would be randomly assigned to listen to two brief pilot broadcasts, one for Bulletin Board and one for News from the Personal Side, that there were several tapes for each broadcast, and that their emotional

[2] Within the action possible condition were two conditions, intended to manipulate the emotional relevance of the tuition increase. In one condition, the tuition increase was to occur in two years. This condition was expected to be emotionally relevant to participants, who would still be enrolled in college at this time. In the second condition, the tuition increase was to occur in six years. This condition was expected not to be emotionally relevant to participants, who should have completed their studies by this time. The data, however, revealed that participants found both conditions to be emotionally relevant, and the effects within these conditions were identical. Therefore, we collapsed these two conditions into one.

and evaluative responses to the broadcast would be assessed using questionnaires and brain wave activity. He then noted that the broadcast tape they would hear was prepared as a pilot for use in this study, so the quality was below normal broadcast standards. After hearing this introduction, participants read an introduction written on WERN letterhead that reiterated this information, and then read and signed a consent form.

Participants were then prepared for the EEG recording. Following the attachment of the electrodes, they completed a questionnaire that measured current emotional state using a scale of 0 (none) to 8 (the most in my life). Items were included to assess anger (mad, agitated, angry, annoyed, bothered, disgusted, irritated, frustrated; *Cronbach's coefficient alpha* = .90), sadness (sad, down, feeling low; *Cronbach's coefficient alpha* = .91), fear (tense and fear; $r = .29$, $p < .02$), and happiness (happy, good mood, relaxed, relief, content, amused, *Cronbach's coefficient alpha* = .78). Eight 1 minute epochs of baseline EEG were recorded, alternating eyes-open (O) with eyes-closed (C) trials, in one of two orders (C, O, O, C, O, C. C, O or O, C, C, O, C, O, O, C), as in previous research (Tomarken et al., 1992).

The participants then received one of the two possible written messages regarding the Bulletin Board broadcast. The messages were presented in a closed envelope so the experimenter was blind to the condition that the participant received. Each message began by explaining the Bulletin Board programme. It then read:

> You will be listening to an editorial concerning a tuition increase at the University of Wisconsin-Madison. The editorial has been recorded for possible broadcast on the Bulletin Board Programme at WERN. As a student, you may be aware that the UW Board of Regents has approved a 9.6% tuition increase as of this academic year.

This latter piece of information was included because tuition was increased just prior to the beginning of the study, and after much deliberation, we decided it was most appropriate to include this information so all students would be equivalent in their knowledge about this issue.

Then, the content of the message was manipulated, such that the message concluded with one of the following endings, depending on condition.

In the *action-possible condition*, the ending read: ''UW administrators and the state legislature are considering an additional increase of 10%, implemented by the fall of the year 2001 [2005], two [six] years from now. Petitions against this increase are currently being circulated''. See footnote 2 for an explanation of the bracketed information.

In the *action-impossible condition*, the ending read: ''UW administrators and the state legislature have also recently decided to definitely implement an additional increase of 10% by the fall of the year 2001, two years from now.

After much deliberation, the administration and legislature voted to increase UW-Madison tuition by 10%''.

The action-possible condition was created to provide participants for expectation of being able to act upon their anger. That is, within this condition, participants were informed of an opportunity to engage in action (i.e., signing a petition) to attempt to prevent a tuition increase. The action-impossible condition was created to provide participants no expectation of being able to act upon their anger. That is, within this condition, participants were informed that the tuition increase had been approved by university administrators and the state legislature, and hence, there was nothing they could do to prevent tuition from being increased.

All messages finished with instructions telling the participants to indicate when they were finished reading the instructions, and the researcher would start the tape.

Participants then listened to the 2 minute 13 second Bulletin Board pilot broadcast in which a well-trained male speaker made persuasive arguments in favour of a 10% tuition increase. The arguments for increasing tuition included: hiring more professors so that class sizes could be reduced, purchasing new and technologically advanced equipment and computers, improving university health services, and increasing salaries for professors. EEG was collected for 3 min following the completion of the broadcast. Before the broadcast began, participants were asked to reflect on how the broadcast made them feel for the 3 min immediately following the broadcast. They were also asked to remain still and keep their eyes open and focused straight ahead.

At the conclusion of the 3 min, participants were asked to complete questionnaires assessing their responses to the broadcast. The first questionnaire assessed reported emotions, and participants were asked to rate how they felt while they listened to the broadcast. Items were included to assess anger (the same items were used in the baseline emotion questionnaire; *Cronbach's coefficient alpha* = .95), sadness (*Cronbach's coefficient alpha* = .86), fear (r = .54, $p < .001$), and happiness (*Cronbach's coefficient alpha* = .83). The second questionnaire included an item that served as a manipulation check. In an open-ended format, it asked: ''What can you do to prevent the tuition increase?'' To bolster the cover story, the remaining questions assessed evaluations of the speaker (how good was the speaker's voice quality, how enthusiastic, competent, credible, unintelligent, likeable, untrustworthy, sincere, and friendly was the speaker; *Cronbach's coefficient alpha* = .82), and the programme (how hard was the editorial to follow, how interesting was it, how worthwhile are these kinds of programmes, and how likely would you be to listen to this type of programme). All questions were answered on scales ranging from 1 (not at all) to 9 (extremely).

The third questionnaire assessed attitudes toward the tuition increase. It began with the following: ''Tuition should be increased by 10% at the University of Wisconsin''. Participants responded on a scale ranging from 1 (strongly disagree) to 9 (strongly agree). Next, participants were asked to rate the statement, ''Tuition should be increased by 10% at the University of Wisconsin'', on three bipolar scales ranging from 1 (good, wise, unfavourable) to 9 (bad, foolish, and favourable, respectively; *Cronbach's coefficient alpha* = .72).

When the participants indicated that they had completed the packet, the experimenter collected the questionnaires and offered participants the opportunity to sign a petition protesting the tuition increase if they were in the action-possible condition. Participants were also offered the opportunity to take as many petitions as they desired with them to have them signed. Return mailing instructions were included on the bottom of each petition so that participants were given the impression that the petitions should be returned. The experimenter recorded whether the participants signed a petition and how many petitions participants took with them. Until providing participants with the opportunity to sign the petition, the experimenters were blind to conditions. However, at this point, they looked for a small ''X'' marked in pencil inside the envelope that gave the instructions concerning whether the tuition increase would occur to see if they were to present the petitions to the participant.

Participants were then given another written introduction concerning the ''News from the Personal Side'' broadcast, they listened to a broadcast, and then completed questionnaires assessing their reactions to the broadcast. Reactions to this broadcast were part of a separate pilot study on a different issue, so the results will not be reported here.

After the experimenter collected the questionnaire packet, the EEG cap was removed and participants were debriefed. During the debriefing the experimenter probed the participants regarding any suspicion that may have been present during the procedure, and then explained the purpose of the experiment.

EEG recording and analyses

To record EEG, 27 (22 homologous and 5 midline) electrodes mounted in a stretch-lycra electrode cap (Electro-Cap, Eaton, OH) were placed on the participant's head using known anatomical landmarks (Blom & Anneveldt, 1982). EEG was recorded from the frontal, central, temporal, parietal, and occipital regions of the brain (and regions in between), using the 10% electrode system (Chatrian, Lettich, & Nelson, 1985), which was based on the 10–20 international system (Jasper, 1958). The ground electrode was mounted in the cap on the midline between the frontal pole (Fpz) and the frontal site (Fz). The reference electrode was placed on the left ear (A1), and data were also acquired from an electrode placed on the right ear (A2), so that an off-line digitally derived, averaged ears' reference could be computed. Eye movements (EOG) were also

recorded to facilitate artifact scoring of the EEG. EOG was recorded from the supra- and suborbit of the left eye, to assess vertical eye movements, and from the left and right outer canthus, to assess horizontal eye movements. All electrode impedances were under 5000 ohms, and homologous sites (e.g., F3 and F4) were within 1000 ohms of each other. Electro-Gel (Eaton, OH) was used as the conducting medium. EEG and EOG were amplified with Neuroscan Synamps (Herndon, VA), bandpass filtered (0.1–100 Hz; 60 Hz notch filter enabled), digitised at 500 Hz, and stored on to the hard drive of a Pentium 200 MMX computer. Prior to running each participant, to assess the technical integrity of the recording system, 400 microvolts 20 Hz calibration signals were run and inspected.

The EEG and EOG signals were visually scored on a high-resolution computer monitor and portions of the data that contained eye movements, muscle movements, or other sources of artifact were removed. When artifact occurred in one channel at a point in time, data from all channels were removed at that point in time. Derived averaged-ears reference data were used for further data reduction, as past research has found it to be an appropriate reference (Hagemann, Naumann, Becker, Maier, & Bartussek, 1998). All artifact-free epochs that were 2.048 s in duration were extracted through a Hamming window, which was used to prevent spurious estimates of spectral power. Contiguous epochs were overlapped by 75%, to minimise loss of data due to Hamming window extraction. A fast Fourier transform (FFT) was used to calculate the power spectra. These power values were averaged across the 2.048 s epochs of a given trial. Because alpha power is inversely related to cortical activity (Davidson, Chapman, Chapman, & Henriques, 1990; Lindsley & Wicke, 1974), total power within the alpha (8–13 Hz) frequency range was obtained. The power values were log transformed for all sites, to normalise the distributions.

As in previous research (Harmon-Jones & Allen, 1997, 1998, 2001; Tomarken et al., 1990, 1992), a mid-frontal (F3 and F4) asymmetry index (natural log right minus natural log left alpha power) was computed for the resting baseline period and for each min of the 3 min following the tuition increase message. For comparison purposes, asymmetry indexes for the other sites (Fp1/2, F7/8, Ft7/8, Fc3/4, T3/4, T5/6, C3/4, Cp3/4, O1/2) were computed in a manner similar to that used for the midfrontal index. Because alpha power is inversely related to cortical activity, higher scores on the indexes indicate greater relative left hemisphere activity. For resting EEG, data were averaged across eyes-open minutes because the EEG assessed immediately after the tuition increase message was during an eyes-open period. An average of 356.13 artifact-free epochs comprised the resting baseline data, and all participants had greater than 129 artifact-free epochs. For EEG following the tuition increase message, an average of 91.85 artifact-free epochs comprised min 1, 94.34 comprised min 2, and 91.80 comprised min 3. All participants had greater than 22 artifact-free epochs for each min.

Statistical data analyses

According to *Hypothesis 1*, participants who expect to engage in the approach-related action of signing a petition to ameliorate the tuition-increase situation (action-possible condition) should evidence greater relative left frontal activity than participants who expect to be unable to engage in approach-related action. To test the prediction, we performed a planned comparison testing the effect of opportunity to take action to change the tuition increase. Therefore, it compared the action impossible condition (-1) to the action possible condition (1). Because this prediction was planned, one-tailed tests were appropriate. However, because we wanted to control for baseline levels, we used analysis of covariance (ANCOVA) to test the prediction and set the alpha level at .10. This alpha level is appropriate because an ANCOVA *F*-test equals a planned comparison for the current case because only two conditions are compared.

According to *Hypothesis 1a*, the effects on relative left frontal activity are expected to be most likely to occur closer in time to the anger-inducing event. Because three minutes of EEG were recorded following the tuition increase message, we expected that min 1 would produce the largest effect, min 2 would produce the second largest effect, and min 3 would produce the smallest effect. Thus, a family-wise alpha error of .05 (one-tailed) was used. To control for alpha-inflation caused by multiple tests, we used Holm's weighted sequential rejective procedure (Holland & Copenhaver, 1988), which also allows for attributing weights to a single hypothesis. Therefore, a weight of 3 was assigned to min 1, 2 to min 2, and 1 to min 3. The adjusted alphas for these tests were: .0022, .0170, and .0500.

According to *Hypothesis 1B*, participants in the action-possible condition should evidence an increase in left frontal activity from baseline to immediately after the tuition increase situation. The prediction was tested by comparing relative left frontal activity at baseline with relative left frontal activity immediately after the tuition increase message. A planned comparison was used and alpha was set to .05, one-tailed.

According to *Hypothesis 2*, the predicted effects of the possibility of action to prevent the tuition increase should be limited to frontal cortical regions and should not occur in other regions. Thus, this prediction was tested by comparing the action-possible condition to the action-impossible condition at each pair of homologous electrodes (alphas were two-tailed).

According to *Hypothesis 3*, within the action-possible condition, participants who evidence greater relative left frontal activity in response to the tuition increase message should also evidence greater self-reported anger. In the condition where action is not possible, greater left frontal activity might not relate to greater anger. These predictions were evaluated using regression analyses with one-tailed tests ($p < .05$).

According to *Hypothesis 4*, within the action-possible condition, participants who evidence greater left frontal activity in response to the tuition increase message should be more likely to engage in behaviours that would reduce the possibility of the tuition increase, by being more likely to sign the petition and to take petitions with them for others to sign. These predictions were evaluated using regression analyses with one-tailed tests ($p < .05$).

In conducting tests with asymmetrical cortical activity, we statistically adjusted for baseline asymmetrical cortical frontal activity to reduce variance and increase the power of our statistical tests, as research has demonstrated that baseline asymmetrical activity is influenced by both state and trait variables (Hagemann, 2000).

RESULTS

Manipulation checks and preliminary data analyses

Gender did not interact with any effects; thus, it will not be discussed. To check the effectiveness of the manipulation of whether or not action could be taken to change the tuition increase, we included an open-ended question asking what could be done to change the tuition increase. Most participants (90.14%) correctly answered this open-ended question. Of the participants who did not correctly answer this question, four were in the action-possible condition and five were in the action-impossible condition. The assessment of the effectiveness of the manipulation may have been more sensitive had we asked persons to choose one of several response options, but we chose not to include such assessments because we were concerned that this type of question would have created doubts about our cover story. In analysing the data, we performed two types of analyses, one with only those participants who correctly answered the open-ended manipulation check and one with all participants (i.e., those who correctly and incorrectly answered the manipulation check). The results of these two types of analyses were identical, so we report the results of the latter analyses in this article.

Between-condition analyses

EEG responses. The effect of condition on relative left frontal activity was assessed using an analysis of covariance (ANCOVA), with condition serving as the between-participants factor, resting baseline relative left frontal activity serving as the covariate, and relative left frontal activity during minute 1, 2, and 3 following the tuition-increase message serving as dependent variables. As predicted and as shown in Figure 1, the condition where action to change the tuition increase was possible evidenced greater relative left frontal activity than the condition where action was not possible in min 1 (adjusted $M = 0.0333$ vs. $M = 0.0006$), $F(1, 68) = 10.84$, $p = .0008$, Holm's adjusted = .0002, and min 2

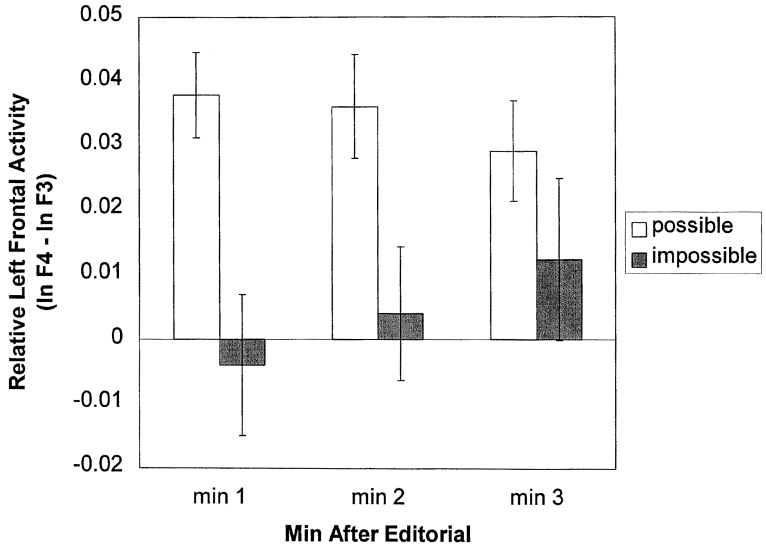

Figure 1. Means and standard errors of means for relative left frontal cortical activity as a function of action-possible condition and minutes after the end of the anger-arousing editorial.

(adjusted $M = 0.0310$ vs. $M = 0.0090$), $F(1, 68) = 3.76$, $p = .0283$, Holm's adjusted = 0.141), but not min 3, $F(1, 68) = 0.29$, $p = .25$, Holm's adjusted = .25. The finding that relative left frontal activity was greatest immediately after the tuition increase message is consistent with the idea that the neurophysiological effects would occur close in time to the anger-inducing event. Because left frontal activity was increased for mins 1 and 2, further analyses will be conducted using the average of these two mins, which were significantly correlated ($r = .68$, $p < .001$).

For the action-possible condition, relative left midfrontal activity increased from baseline ($M = 0.0205$) to after the tuition increase message ($M = 0.0370$), as revealed in a correlated t-test, $t(48) = 2.65$, $p = .0059$ (one-tailed). For the action-impossible condition, relative left frontal activity did not increase from baseline to after the tuition increase message, $t < 1.0$, $p > .65$.

As expected, asymmetrical activity in other regions did not differ as a function of condition, ts < 1.10, ps > .25. However, asymmetrical activity in the lateral frontal and frontal central regions approached significance, $t(68) = 1.86$, $p = .07$ (two-tailed) and $t(68) = 1.96$, $p = .05$ (two-tailed), although neither showed an increase from baseline to after the tuition increase message in the action-possible condition, ps > .10.

Taken together, the results suggest that greater relative left midfrontal activity occurred in response to an anger-inducing event when action was

possible but not when action was impossible. Moreover, these effects were specific to the midfrontal cortical region, as asymmetrical activity in other regions did not differ as a function of experimental condition.

Self-reported emotional responses. Baseline self-reported emotions were used as changing covariates in a repeated-measures ANCOVA, with emotional responses to the tuition increase message serving as the within-participants variable and condition serving as the between-participants variable. In this analysis, Statistica's ANCOVA module was used with a ''changing covariate'' specification. This module assumes that the covariate changes with the dependent variable across levels of the independent variable, correlating the change in the covariate with the change in the dependent variable and subsequently analysing the residual variance in a standard ANOVA. The population parameters in this analysis are estimated using ordinary least squares. In this analysis, there was a significant effect of emotion, $F(3, 210) = 8.72$, $p < .001$. Anger was reported as being more intense than any other emotion, as revealed in a planned comparison that compared anger (+3) to each of the other emotions ($-1, -1, -1$), $t(71) = 5.87$, $p < .0001$. The main effect of condition and the emotion by condition interaction were not significant, Fs < 1.20, ps > .25.

Results also revealed that anger increased from baseline to after the tuition increase message, $t(72) = 10.94$, $p < .001$. Happiness decreased from baseline to after the tuition increase message, $t(72) = 10.12$, $p < .001$. Neither fear nor sadness changed from baseline to after the tuition increase message, ts < 1.22, ps

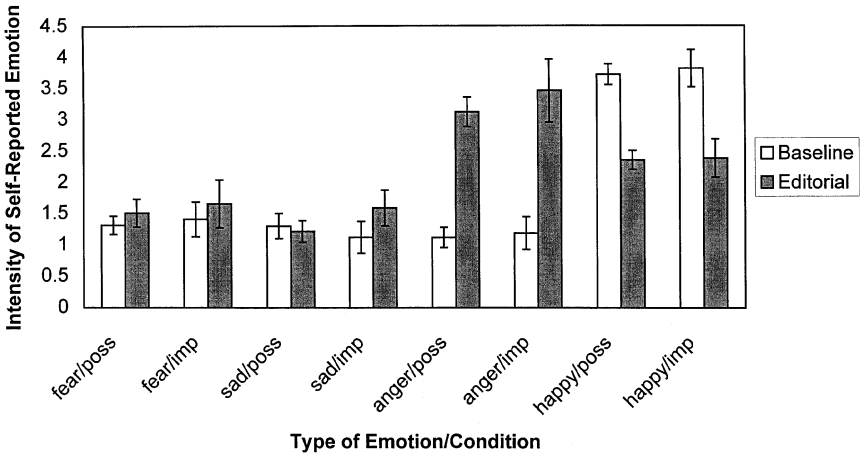

Figure 2. Means and standard errors of means for intensity of self-reported emotions as a function of time (at baseline vs. after the anger-arousing editorial) and action-possible condition (poss = possible; imp = impossible).

> .25. These effects indicate that the tuition increase message increased anger in both conditions, that anger was the predominant emotional response to the tuition increase message, and that only anger increased from baseline to after the tuition increase message (see Figure 2).

Behavioural responses. The action-possible condition was given the opportunity to sign a petition against the tuition increase and to take petitions with them. Within this condition, 80.39% of the participants signed the petition, and on average, 0.33 petitions were taken.

Attitudinal and other responses. We made no predictions regarding the effects of condition on attitudinal responses. For the average of the three bipolar items, a one-way ANOVA revealed no significant effect ($p > .14$; grand $M = 5.95$). Responses to the one item assessing agreement with the statement that tuition should be increased did not differ as a function of condition ($p > .50$; grand $M = 2.82$). In addition, evaluations of the speaker did not differ as a function of condition ($p > .40$; grand $M = 5.05$).

Correlational analyses

To assess the relationship between relative left midfrontal activity after the tuition increase message and emotional and behavioural responses, we performed regression analyses in which reported emotional and behavioural responses were regressed onto resting baseline frontal asymmetry and frontal asymmetrical activity following the tuition increase message. For these analyses, the average of mins 1 and 2 of EEG immediately after the tuition increase message was used as the predictor, as the results revealed that these two min were affected by the manipulation. Within the action-possible condition, reported anger in response to the tuition increase message was predicted by relative midfrontal activity in response to the tuition increase message over and above baseline anger and baseline midfrontal asymmetry, *beta* = .37, $t(45) = 2.29$, $p = .0133$, $R^2 = .51$, R^2 *change* = .09, *partial r* = .32; the simple correlation of anger and left midfrontal activity, not controlling for baseline responses, was $r = .22$, $p = .0606$, all one-tailed. The only other emotional response to be affected by the tuition increase message was happiness. Therefore, a regression analysis similar to the one performed with anger was conducted. Happiness in response to the tuition increase message was not significantly associated with relative left mid-frontal activity ($t(45) < 1.2$, $p > .25$).

In contrast, in the action-impossible condition, relative left midfrontal activity immediately after the tuition increase message was not associated with anger, *beta* = .14, $t(18) = 0.46$, $p = .65$, $R^2 = .44$, R^2 *change* = .007, *partial r* = .11 (the simple correlation of anger and left midfrontal activity, not controlling for baseline responses, was $r = -.14$) or happiness, *beta* = −.32, $t(18) = 1.17$,

$p = .26$, $R^2 = .50$, R^2 *change* $= .04$, *partial* $r = -.27$ (the simple correlation of happiness and left midfrontal activity, not controlling for baseline responses, was $r = -.03$).

Relative left midfrontal activity in response to the tuition-increase message related to an increased likelihood of behaving in a manner to ameliorate the anger-inducing situation. This effect was revealed in two analyses. In the analysis of whether or not the petition was signed, the criterion variable was dichotomous; hence, nominal logistic regression was used (Tabachnick & Fidell, 1996). In this analysis, relative left midfrontal activity after the tuition increase message predicted signing the petition (*Wald* = 4.50, $B = 35.64$, $p = .0170$, controlling for baseline; *Wald* = 2.29, $B = 14.36$, $p = .065$, not controlling for baseline; all tests were one-tailed). In addition, in the analysis for number of petitions taken, relative left midfrontal activity after the tuition increase message predicted number of petitions taken, *beta* = .51, $t(46) = 2.98$, $p = .0023$, $R^2 = .16$, R^2 *change* = .16, *partial* $r = .40$, controlling for baseline; $r = .34$, $p = .0076$, not controlling for baseline; all tests were one-tailed.

DISCUSSION

As predicted, individuals who expected the opportunity to engage in approach-related action to ameliorate the anger-arousing situation evidenced greater relative left frontal activity than participants who expected to be unable to engage in approach-related action (Hypothesis 1).[3] Moreover, these effects were specific to the frontal regions of the cortex, supporting the regional specificity hypothesis (Hypothesis 2). Also as predicted, within the action-possible condition, participants who evidenced greater left frontal activity in response to the anger-arousing message evidenced greater self-reported anger (Hypothesis 3), and were more likely to engage in behaviours that would reduce the possibility of the anger-arousing event from occurring (Hypothesis 4). Taken together, these results provide support for the motivational model of the frontal cortical asymmetry.

It is possible that the possibility of preventing the anger-arousing event (i.e., the tuition increase) aroused hope and this hope was responsible for the increased left frontal activity. Without an assessment of hope in the present study, it is impossible to know. However, we would not be surprised at finding an increase in hope. Indeed, anger associated with the expectation of being able to resolve the anger-arousing situation may evoke a type of hope, instead of the hopelessness associated with sadness and depression (e.g., Abramson, Metalsky, & Alloy, 1989). ''Hope'' may be what other emotion theorists refer to as coping

[3] Anger may automatically evoke approach behavioral tendencies if the organism is not aware of the coping potential present in a situation. In the present experiment, participants learned of the coping potential opportunity prior to experiencing anger.

potential (Lazarus, 1991), likelihood of goal reinstatement (Levine, 1995), power (Roseman, 1991), or efficacy. In accordance with this interpretation, anger did correlate with relative left frontal activity and relative left frontal activity correlated with action taken to resolve the anger-arousing event.

The emotion of anger may serve the function of increasing approach motivation when an individual finds him/herself in an aversive situation. This increase in approach motivation may facilitate the individual's efforts to correct the negative situation. However, the data we have presented here indicate that angry feelings may not lead to an increase in approach motivation if no opportunity exists to act to correct the negative situation. Other emotion theorists would predict that, in this case, the emotion experienced would be sadness rather than anger (Levine, 1995; Smith & Lazarus, 1993). Our data did not support this view. Instead, the self-reported anger was just as high in the condition where action was not possible as in the condition where action was possible, and sadness did not differ between conditions.[4]

Appraisals and anger

Several theorists have suggested that perceived coping potential should influence the intensity of anger. The present research did not provide support for this prediction on measures of self-reported anger. Support, however, was found on EEG measures of relative left frontal activity. That the physiological responses were more influenced by coping potential than were the self-report responses is congruent with past research that assessed cardiovascular responses as a function of perceived coping potential (e.g., Wright, Shaw, & Jones, 1990). These findings point to the importance of assessing multiple measures of emotional response in testing predictions.

Physiological Differentiation of Emotions

Much past research has been aimed at associating different emotions with different patterns of physiological activity. For instance, researchers have examined differences between emotions in the autonomic nervous system (e.g., Ax, 1953; Ekman, Levenson, & Friesen, 1983; Schachter, 1957; Schwartz, Weinberger, & Singer, 1981) and the central nervous system, using EEG (e.g., Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Ekman & Davidson, 1993) and haemodynamic imaging (e.g., Breiter et al., 1996; Lane et al., 1997). Much of this research may be viewed as being guided by the goal of finding particular physiological ''signatures'' of various emotions. In the present research, self-reported anger was

[4] The average anger reported by participants was approximately 3.5 on a 9-point scale where 8 meant ''the most in my life''. Although participants were not extremely angry, this reflected an average increase of 250% over baseline. It is possible that different results might have been found for anger that was either more or less intense than that evoked in this study.

increased in both coping conditions but relative left frontal activity was only increased in the condition in which coping was possible. These results suggest that the ''emotion'' of anger, as measured by self-report, is not inevitably associated with relative left frontal activity. We suspect that the same may be true of emotions in general. That is, emotions are complex phenomena, involve several processes, and inevitably serve multiple functions. As such, the physiology underlying and/or associated with an emotion is complex and probably depends more on the nature of the particular emotion—its cause, coping potential, etc.—than on the emotion label *per se* (e.g., anger). In other words, anger may not always be anger. There are likely varieties of anger, and the particular anger is determined by its antecedents, coping potential, etc. Each variety may be associated with particular physiological response patterns. In the present case, anger associated with high coping potential increased relative left frontal activity, whereas anger associated with low coping potential did not. Such a perspective is consistent with research by Stemmler (1989) that has demonstrated that the emotion-eliciting context (real life vs. imagery) plays a significant role in the pattern of autonomic and somatic responses evoked even when self-reported emotional intensity is equivalent between the different contexts.

Relationship of present results to cognitive dissonance processes

The manner in which anger was evoked in the present experiment is similar to the manner in which cognitive dissonance has been aroused in much past research (Harmon-Jones, 2001). Thus, the present experiment can be evaluated in terms of dissonance theory. The present experiment demonstrates that exposure to counterattitudinal information, which presumably arouses cognitive dissonance, also arouses angry feelings, suggesting that cognitive dissonance can arouse specific types of negative affect in addition to general and diffuse negative affect (Harmon-Jones, 2001). In addition, the present results demonstrate that relative left frontal activity is only increased when individuals believe they can take action to resolve the dissonance-arousing situation. This finding is consistent with predictions derived from the action-based model of cognitive dissonance, which predicts that relative left frontal activation may be involved in the implementation of actions that are part of cognitive dissonance reduction (Harmon-Jones & Harmon-Jones, 2001).

Conclusion

The present research adds to a growing body of evidence that provides support for the motivational model of the functions of asymmetrical frontal cortical activity. Moreover, it extends past research by demonstrating that anger aroused by exposure to a counterattitudinal message is associated with increased left frontal activity, and that left frontal activity is increased only when individuals

expect an opportunity to act upon their anger. That is, when individuals believed that there was something they could do to resolve the anger-arousing situation, they responded with increased left frontal activity. In contrast, when they believed there was nothing they could do to resolve the situation, they did not respond with increased left frontal activity. These findings are consistent with predictions derived from several motivational theories (e.g., Brehm & Self, 1989). The present study is the first to integrate predictions derived from these motivational theories with the motivational model of asymmetrical frontal cortical activity.

Much past research has pointed to the negative consequences of anger. It has been associated with aggression toward others (e.g., Berkowitz, 2000) and increased chances of cardiovascular disease and morbidity due to cardiovascular disease (e.g., Barefoot, Dodge, Peterson, Dahlstrom, & Williams, 1989; Lane & Jennings, 1995; Smith, 1992; Suls & Wan, 1993). However, the present research suggests that anger can be associated with approach-related behaviour that may result in positive consequences to the individual (i.e., action that may prevent a tuition increase). Anger may also be the source of reactions to social injustices. These angry, approach-related reactions may lead to positive consequences for society in general. As Malcolm X, one of the persons credited with improving the conditions of African Americans, said, ''They called me 'the angriest Negro in America'. I wouldn't deny that charge. I spoke exactly as I felt. I *believe* in anger'' (Haley & X, 1964/1966, p. 366). Thus, anger, because of its ability to evoke approach motivation, has the potential to create positive and negative consequences for individuals and societies.

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