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Neural and behavioral associations of manipulated determination facial expressions

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ABSTRACT

Past research associated relative left frontal cortical activity with positive affect and approach motivation, or the urge to move toward a stimulus. Less work has examined relative left frontal activity and positive emotions ranging from low to high approach motivation, to test whether positive affects that differ in approach motivational intensity influence relative left frontal cortical activity. Participants in the present experiment adopted determination (high approach positive), satisfaction (low approach positive), or neutral facial expressions while electroencephalographic (EEG) activity was recorded. Next, participants completed a task measuring motivational persistence behavior and then they completed self-report emotion questionnaires. Determination compared to satisfaction and neutral facial expressions caused greater relative left frontal activity relative to baseline EEG recordings. Facial expressions did not directly influence task persistence. However, relative left frontal activity correlated positively with persistence on insolvable tasks in the determination condition. These results extend embodiment theories and motivational interpretations of relative left frontal activity.

1. Introduction

Starting from observations that lesions to the left vs. right frontal cortex influenced emotive responses (Goldstein, 1939), much research has revealed that greater relative left frontal cortical activity is associated with positive affect and/or approach motivation, whereas greater relative right frontal cortical activity is associated with negative affect and/or withdrawal motivation (Silberman & Weingartner, 1986; for a more recent review, see Harmon-Jones, Gable, & Peterson, 2010). Because most research prior to 2000 had confounded affect with motivation by examining, for example, only positive affects high in approach motivation, it was unclear whether positive affect or approach motivation was the psychological variable that best related to asymmetric frontal cortical activity. To address this confound, research over the last decade has examined anger, a negatively valenced state that is often associated with approach motivation (Harmon-Jones, 2003, 2004). This research has revealed that anger is associated with greater relative left frontal cortical activity, suggesting that asymmetric frontal cortical activity is best characterized by motivational direction rather than affective valence. The present research sought to extend this past research by examining motivational intensity within positive affective states.

1.1. Positive affects that vary in approach motivational intensity

Positive affects vary in approach motivation, with some being lower and some higher in approach motivation or the urge to move toward a stimulus (Harmon-Jones, Harmon-Jones, & Price, 2013). Researchers often make a distinction between high approach, appetitive, or pre-goal positive states as being different from low approach, consummatory, or post-goal positive states, which can be conceptualized as the difference between "wanting" and "liking" (Berridge, 2007). The feeling of determination is an example of a positive affective state that is high in approach motivation. Determination is a word on the widely used Positive Affect sub-scale of the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). Situations that evoke positive approach motivation also cause individuals to report feeling determined (Harmon-Jones, Schmeichel, Mennitt, & Harmon-Jones, 2011, Study 1).

The feeling of satisfaction, on the other hand, is an example of a positive affective state that is lower in approach motivation. Satisfaction is often thought of as a positive, yet distinct emotion (i.e., dissimilar from other positive emotions). Satisfaction has been defined as a positive emotional response to obtaining some desired goal or event (Ortony, Clore, & Collins, 1988). As such,

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satisfaction occurs once a goal has been accomplished, that is, post-goal (Harmon-Jones, Gable, & Price, 2012).

1.2. Preliminary EEG asymmetry evidence for low vs. high approach positive affect

Although some correlational studies provide evidence suggesting a link between approach-motivated positive affect and asymmetric frontal cortical activity (Gable & Harmon-Jones, 2008; Harmon-Jones & Gable, 2009), only one experiment has tested whether positive affective states varying in approach motivational intensity influence relative left frontal cortical activity. In this experiment, participants were assigned to one of three mindset conditions: a positive action-oriented (think of steps toward a goal; implemental mindset of Gollwitzer, 1990), neutral (describe normal day), or positive non-action condition (think of good past event without personal action; Harmon-Jones, Fearn, Sigelman, & Johnson, 2008, Experiment 2). As expected, self-reported positive affect was greater in the action and non-action positive conditions compared to the neutral condition. More importantly, relative left frontal cortical activity was greater in the positive action condition compared to the positive non-action and neutral conditions.

One could question whether the emotive state induced by the positive-action-oriented mindset manipulation or another aspect of this cognitive manipulation, such as planning (which may not be associated with approach motivation), caused the differences in relative left frontal activity in this experiment. In emotive research, it is imperative to utilize multiple manipulations of emotive states. This insures that the emotive state, and not another aspect of the manipulation, is causing the differences.

1.3. Embodying low vs. high approach positive affect

One way to deal with this issue is to use embodied emotional manipulations. James (1890) proposed that bodily manipulations, such as facial expressions, share inherent connections with emotions. The facial feedback hypothesis (Laird, 1974), furthermore, suggests that manipulated facial expressions of emotion cause emotional changes. It is important to note, however, that most research supporting the facial feedback hypothesis measured self-reported emotional responses to mildly affective stimuli (e.g., cartoons; Strack, Martin, & Stepper, 1988). Also, a meta-analysis of studies assessing self-reported emotional reactions found that the effect size was only small to moderate in magnitude (Matsumoto, 1987). Emotive bodily manipulations have also been found to influence cognitive processes related to emotions (Price & Harmon-Jones, 2010).

Studies have also assessed the effects of manipulated facial expressions on psychophysiological responses (e.g., Levenson, Ekman, & Friesen, 1990). For instance, approach-oriented facial expressions (e.g., joy and anger) manipulated with directed facial action tasks (as in Levenson et al., 1990) have been found to cause greater relative left frontal cortical activity (Coan, Allen, & Harmon-Jones, 2001). Withdrawal-oriented facial expressions (e.g., sadness and disgust) have been found to cause less relative left frontal activity (Coan et al., 2001). This past experiment did not compare positive facial expressions varying in approach motivation, however. Thus, in the present study, we addressed this lacuna in research by manipulating low vs. high approach positive affect via facial expressions of satisfaction vs. determination.

1.4. Molar behaviors associated with approach motivation

In addition, we tested whether the manipulation of approach positive affect would influence molar motivational behaviors, something rarely done in past research on asymmetric frontal cortical activity. One molar motivational behavior related to approach is task persistence on insolvable tasks. Consistent with this idea, slumped/helpless postures, which are associated with lower approach motivation, caused less persistence on insolvable tasks, compared to more upright and expansive postures. The two postures did not produce differences on solvable task performance (Riskind & Gotay, 1982). Thus, in the present study, we tested if emotive facial expressions varying in positive approach motivational intensity would influence persistence on insolvable tasks. In line with past research, we anticipated that they would have no effect on solvable tasks, as their completion is often relatively quick without much variance across participants. In addition to examining if these facial expressions influence task persistence, we will examine the relationship between relative left frontal cortical activity and task persistence.

In accordance with motivational interpretations of asymmetric frontal cortical activity (Harmon-Jones et al., 2010) and previous work on determination (Harmon-Jones, Schmeichel, et al., 2011) and satisfaction (Ortony et al., 1988), three primary predictions were tested. Determination facial expressions should cause greater relative left frontal activity compared to satisfaction and neutral facial expressions, which should not differ from one another (consistent with the results of Harmon-Jones et al., 2008). Determination facial expressions should cause greater persistence compared to satisfaction and neutral expressions, which should not differ from one another. Finally, relative left frontal activity should be directly related to behavioral persistence, especially for participants in the determination facial expression condition.

2. Method

2.1. Participants

Forty-nine (31 women) right-handed university students aged 18–24 years participated. One participant in the satisfaction condition was excluded from EEG analyses due to excessive noise in baseline EEG recordings. One participant in the determination and satisfaction conditions lacked self-report data. The total sample sizes for each condition were as follows: determination ($n = 16$, 5 men, 11 women), satisfaction ($n = 15$, 7 men, 8 women), neutral ($n = 18$, 6 men, 12 women).[1]

2.2. Materials and procedures

The participant was informed that the experiment involved facial expressions, cognitive tasks, and brain activity. After providing informed consent, the participant was fitted with an EEG electrode cap and a stereo headset with attached microphone. This allowed the experimenter to hear participant's responses from an adjacent control room. Each participant sat in a stationary chair. In front of them, there was a table with four stacks of puzzle tasks labeled 1–4 [in order from first to last consistent with Glass and Singer (1972): insolvable, solvable, insolvable, solvable] and a computer monitor on a separate desk. Tasks were face down, printed on three by five inch cards, with 30 puzzles in each stack. In this experiment, participants attempted to solve the one puzzle from each stack of the four stacks.

The experimenter explained that the participant would attempt to solve four different puzzles. Participants (1) could not retract any lines or lift their pen from the card while working on a puzzle, (2) could take as many attempts (max 30) as desired at a particular puzzle (if they were unable to complete a puzzle, they could move on), and (3) could not return to a previously attempted puzzle stack. Individual puzzle attempts were limited to 30 s (see Glass & Singer, 1972). Participants were directed to say the number of a stack each time they took a card from it, "Solved" upon solving a puzzle, and "I'm finished" after their last desired attempt at the fourth puzzle. Finally, participants were told to wait to begin working on tasks until instructed to do so. After answering any questions, the experimenter left the room and closed the door. The experimenter entered the adjacent control room. At this point, the experimenter randomly assigned participants to condition via a randomization sheet. Thus, the experimenter was blind to condition while interacting with the participant.

The participant then saw on the computer monitor text instructions that restated details of the tasks. Participants were then asked to make and maintain a

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[1] The current sample sizes are consistent with other research examining the effects of between-subjects emotion embodiment manipulations on relative left frontal cortical activity (Harmon-Jones, 2006).

neutral facial expression for one min while brain activity was recorded. This served as a baseline measure of relative left frontal activity. Then, the participant made a determination, satisfaction, or neutral facial expression for an additional one min of EEG recording. Computer screen instructions asked participants to, “Please express the emotion as clearly as you can. Try to make an expression so that absolutely anyone would be able to recognize what emotion you are communicating. Please make a (determination, satisfaction, or neutral) expression now.” (see Harmon-Jones, Schmeichel, et al., 2011). In past research, participants were able to make these expressions based on these instructions and their expressions were recognized by other perceivers (Harmon-Jones, Schmeichel, et al., 2011). Furthermore, this manipulation was selected over directed facial action tasks (Coan et al., 2001), which ask participants to contract specific facial muscles, because determination and anger facial expressions are perceived as similar by other individuals even though they are experienced differently in valence by the individual possessing them (Harmon-Jones, Schmeichel, et al., 2011). Directing participants to contract facial muscles to make a determination expression without an emotion label, therefore, might cause some participants to experience anger, which we wanted to avoid.

The participant could no longer see the experimenter, but the experimenter closely monitored the participant through a hidden video monitor in the control room. Being aware of the condition, the experiment then could rate the quality of the facial expressions of the participant. The experimenter then rated how well participants made facial expressions on a 1 (not very well) to 7 (extremely well) scale using exemplary pictures of determination and satisfaction facial expressions taken from Harmon-Jones, Schmeichel, et al. (2011). In general, the participants’ facial expressions appeared to be of moderate quality, as mean ratings of the expressions were above the mid-point of the scale. However, neutral facial expressions appeared to be of higher quality than satisfaction and determination facial expressions, as revealed in a significant one-way ANOVA for facial expression quality, $F(2, 46) = 6.59$, $p = .003$, partial eta squared = .12. Follow-up tests indicated that participants were rated as better at making neutral ($M = 6.55$, $SD = .78$) as compared to satisfaction ($M = 5.4$, $SD = 1.5$, $p = .01$) and determination ($M = 4.93$, $SD = 1.65$, $p < .01$) facial expressions. More importantly, determination did not differ from satisfaction facial expression quality, $p = .34$.

Next, text instructions reminded participants to maintain their assigned facial expressions throughout the tasks. Participants were then directed to take a puzzle from the first stack and begin working. After each 30 s interval of working on a specific puzzle, pre-recorded audio reminders informed participants to discard their card, say aloud the stack number they were taking their next card from, and continue making the target facial expression. These audio reminders insured task compliance. The experimenter, furthermore, monitored that participants maintained the target facial expression; all participants were capable of maintaining their target facial expression throughout the experiment. When participants said aloud “Solved” pre-recorded audio clips informed them to move to the next stack of tasks.

Next, participants completed the PANAS-X (Watson & Clark, 1994) by indicating “to what extent you feel this way right now.” It was administered after the persistence task because past research has suggested that the completion of emotion questionnaires can alert participants to their emotional state, which can influence emotion-related behavioral changes (Berkowitz, 2000). Thus, self-reports were measured after behavioral persistence, in order to give the facial manipulation the greatest chance of impacting behavioral persistence. Participants also responded to a one-item measure asking them to rate the difficulty of making the target facial expression on a 1 (very easy) to 7 (very difficult) point scale. A one-way ANOVA for task difficulty ratings was non-significant, $p = .17$. Means and standard deviations were as follows: determination ($M = 3.12$, $SD = .23$), satisfaction ($M = 3.07$, $SD = .25$) and neutral conditions ($M = 2.55$, $SD = .22$). The experimenter then returned to the room and probed participants for suspicion; none could correctly guess the hypotheses.

2.3. EEG assessment and processing

To obtain EEG data, a stretch-lycra cap (Electro-Cap, Eaton, OH) with 32 tin electrodes was placed on the participant’s head and filled with conductive gel (Electro-Gel) until impedance values were less than 5 kilo-ohms. One electrode was placed on the participant’s left earlobe to provide a reference, and one was placed on the right earlobe so that the EEG could be re-referenced using an off-line average of ears. Signals were amplified using Neuroscan Synamps (El Paso, TX), bandpass filtered (0.1–100 Hz with a 60 Hz notch filter), and digitized at 500 Hz.

Data were hand scored to remove artifacts, then a regression-based eye movement correction was applied to correct for vertical eyeblinks (Semlitsch, Anderer, Schuster, & Presslich, 1986). Next, all epochs, each 1.024 s in duration, were extracted through a Hamming window (50% taper of distal ends) and re-referenced using an average ears reference. Consecutive epochs were overlapped by 50% to minimize data loss due to windowing. A fast Fourier transform calculated power spectra. Power values within the alpha band (8–13 Hz) were averaged across epochs for each min of data. The usable number of epochs for the baseline min recording for each condition was as follows: determination ($M = 67.70$, $SD = 20.48$), satisfaction ($M = 73.11$, $SD = 13.53$), and neutral ($M = 70.68$, $SD = 18.72$). For the emotional min recording: determination ($M = 75.15$, $SD = 22.80$), satisfaction ($M = 73.75$, $SD = 16.86$), neutral ($M = 69.54$, $SD = 19.87$). Each participant had at least 42 epochs for each min. Conditions did not differ in mean number of accepted epochs, $F(2, 45) = 1.3$, $p = .28$. In addition, power values in the EMG band (70–90 Hz) were extracted from the power spectra for the second min of data (with emotional facial expressions) to examine the contribution of muscle activity (Coan et al., 2001).

Asymmetry indexes (log right minus log left) were computed for all sites, but predictions focused on midfrontal (F4/3) and lateral frontal (F8/7) sites based on past research. Cortical activity during the resting, first neutral facial expression min (for homologous sites, e.g., F3/F4) were covariates in all analyses of covariance (ANCOVAs). Relative left frontal cortical activity during the second facial expression min was the dependent measure. Because alpha power is inversely related to cortical activity, higher scores indicated greater left than right activity (Allen, Coan, & Nazarian, 2004). Statistical tests that were predicted, directional, based on theory, and specified in advance were evaluated with planned contrasts and a one-tailed criterion of significance (Rosenthal, Rosnow, & Rubin, 2000). Given the directional prediction, the determination condition was contrast coded +2, whereas satisfaction and neutral conditions were each coded −1 in planned contrasts.[2]

3. Results

3.1. EEG asymmetry as a function of facial expressions

As predicted, a significant planned contrast emerged for midfrontal sites, $t(44) = 2.21$, $p = .01$, $r_{effect\ size} = .30$, indicating that participants had greater relative left midfrontal activity in the determination (least squared $M = -.03$, $SD = .11$) compared to satisfaction ($M = -.13$, $SD = .11$) and neutral ($M = -.10$, $SD = .12$) conditions. Follow-up tests revealed that determination differed from the satisfaction condition, $p = .02$, $r_{effect\ size} = .29$, and was marginally different from the neutral condition, $p = .058$, $r_{effect\ size} = .22$; satisfaction did not differ from the neutral condition, $p = .55$. The contrast for lateral-frontal sites was not significant, $t(44) = .56$, $p = .28$. All other asymmetry indices produced nonsignificant effects, $ps > .24$. No interactive effect of gender and facial expression condition on relative left midfrontal activity emerged, $F(2, 41) = 1.41$, $p = .25$. Statistically controlling for muscle artifacts, difficulty ratings, and expression quality [$t(41) = 2.33$, $p = .01$] did not change the outcome of facial expressions on relative left midfrontal activity.

This difference between conditions revealed by the previous ANCOVA results was due to midfrontal asymmetry changing from baseline to the facial expression condition for participants in the determination facial expression condition ($t = 2.43$, $p = .02$, $r_{effect\ size} = .33$; baseline $M = -.17$, $SD = .19$; expression $M = -.09$, $SD = .19$) but not for participants in the satisfaction facial expression condition ($t = -1.12$, $p = .28$; baseline $M = -.04$, $SD = .19$; expression $M = -.08$, $SD = .19$) or neutral facial expression condition ($t = -.05$, $p = .95$; baseline $M = -.09$, $SD = .19$; expression $M = -.09$, $SD = .19$).

3.2. Persistence as a function of facial expressions

Total attempts and total time working on the two solvable ($r = .89$, $p < .001$) and two insolvable ($r = .84$, $p < .001$) tasks were highly correlated with one another. Thus, total attempts and time were standardized and averaged together to obtain *persistence* for solvable vs. insolvable tasks. Means are presented in Table 1. As expected, facial expressions did not influence solvable-task persistence, $F(2, 46) = 1.54$, $p = .22$. Unexpectedly, facial expressions also did not influence insolvable-task persistence, $t(46) = .26$, $p = .39$, for the planned comparison.

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[2] Predictions are based on the motivational direction model of frontal asymmetry and past research that has found that low-approach positive affect does not differ from neutral affect on EEG frontal asymmetry (e.g., Harmon-Jones et al., 2008). That is, high approach emotions are associated with greater relative left frontal cortical activity, regardless of emotional valence (see review by Harmon-Jones et al., 2010). According to the motivational direction model and other theoretical perspectives, satisfaction is low in approach motivation and thus should be associated with similar levels of left frontal cortical activity as neutral states. As a result, we adopted a focused planned comparison approach to test our hypotheses.

Table 1
Means for persistence and self-reports.

	Determination	Neutral	Satisfaction
Insolvable task persistence[a]	.04 (.96)	.15 (.93)	−.23 (.89)
Solvable task persistence	.33 (.96)	−.07 (.93)	−.25 (.89)
Self-report measures[b]			
Positive Affect Subscales from Egloff et al. (2003)			
Joy	3.35 (.72)	3.12 (.67)	3.64 (.71)
Interest	3.68 (.56)	3.20 (.55)	3.40 (.56)
Activation	3.41 (.60)	3.34 (.59)	3.30 (.63)
Anger	1.53 (.77)	1.61 (.76)	1.57 (.78)

[a] Higher numbers indicate greater persistence on tasks (based on standardized scores of total time and total attempts).

[b] Higher numbers indicate higher scores on the composite self-report measures [on a 1 (very slightly or not at all) to 5 (extremely) scale].

Next, the association between relative left midfrontal activity and insolvable task persistence was examined by testing correlations between these two variables within facial expression conditions. Participants who made determination expressions persisted more on the insolvable tasks when they had greater relative left midfrontal activity, $r(16) = .62$, $p = .01$. There was no relationship between relative left midfrontal activity and persistence for participants who made satisfaction expressions, $r(15) = .06$, $p = .82$. Relative left midfrontal activity was negatively associated with persistence in the neutral condition, $r(18) = -.49$, $p = .03$. This latter effect is unexpected and addressed later. Fig. 1 shows scatterplots of correlations between relative left midfrontal activity and persistence on the insolvable tasks for each of the three conditions.[3]

The above correlational results were next tested with a step-wise linear regression model, to test if the association between relative left frontal activity and insolvable task persistence differed between groups (method: probability of F to enter <.05; probability of F to remove >.01). Relative left midfrontal activity scores were centered and interactions were calculated as the product of relative left midfrontal activity and the dummy variables (West, Aiken, & Krull, 1996). The determination condition was the critical condition, against which the other conditions were compared. Cohen's effect size (f) was calculated using the following formula: $f = R^2/(1 - R^2)$.

The overall model was significant, $F(3, 45) = 5.46$, $p = .002$, $R^2 = .26$, $f = .35$. Relative left midfrontal activity was a significant predictor of persistence in the determination condition, $b = 3.27$, $p = .003$. Significant dummy-coded interactions revealed that this relationship differed from both the satisfaction, $b = -3.02$, $p = .04$, and neutral conditions, $b = -6.29$, $p = .0002$. No other effects were significant ($ps > .41$).

3.3. *Self-report measures*

Next, we examined the effect of facial expressions on self-reported emotions, which were measured after task persistence and participants were instructed to indicate "to what extent you feel this way right now." Means and standard deviations are presented in Table 1. Because facial expressions were predicted to influence self-reported determination, a planned comparison tested the effect of facial expression condition on interest (*interested, strong, determined*), which is a PANAS subscale used by Egloff, Schmukle, Burns, Kohlmann, and Hock (2003) that best taps the experience of determination. It was significant, $t(44) = 2.12$, $p = .02$, $r_{effect\ size} = .30$. Follow-up tests indicated that participants reported higher interest in the determination as compared to the neutral condition, $p = .02$, $r_{effect\ size} = .34$. All other follow-up comparisons were non-significant, $ps > .19$. In addition, we examined if the satisfaction condition created more joy relative to the other conditions. A planned contrast was performed with satisfaction coded +2, determination coded −1, and neutral coded −1. This contrast was significant, $t(44) = 1.78$, $p = .04$, $r_{effect\ size} = .25$. Follow-up tests indicated that satisfaction elicited more joy than the neutral condition, $p = .02$, $r_{effect\ size} = .26$. All other comparisons were not significant, $ps > .27$. Finally, we examined if determination caused more anger, as measured by the PANAS-X, relative to the other two conditions. A contrast for anger ratings with determination coded +2, satisfaction and neutral both coded −1 indicated this was not the case, $t(44) = .23$, $p > .40$.

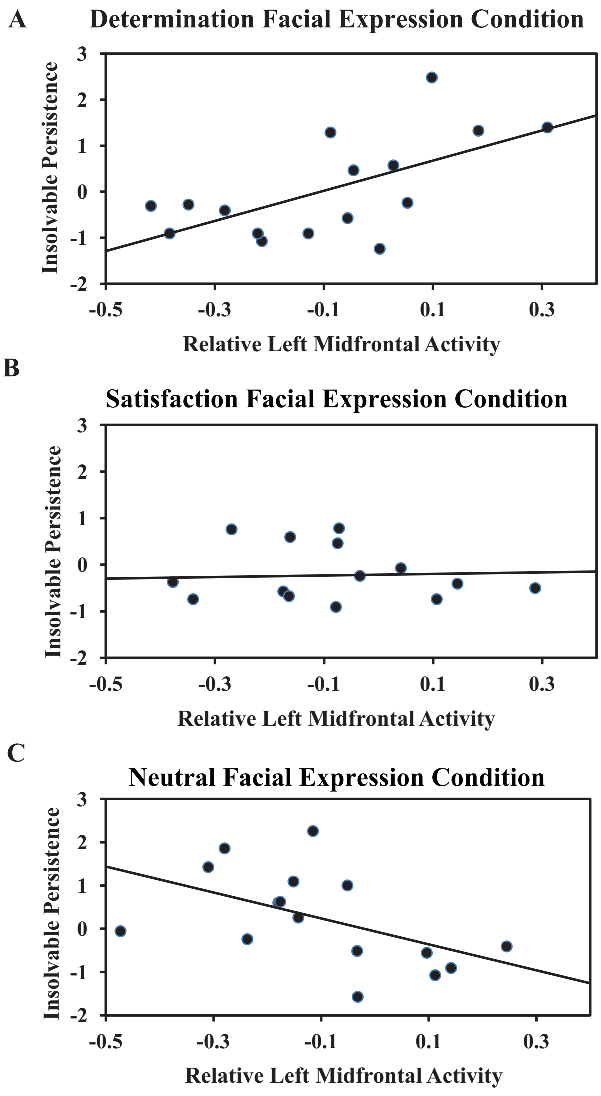

Fig. 1. The influence of relative left midfrontal activity on insolvable task persistence in each condition. Relative left midfrontal activity was positively related to insolvable persistence after participants made (A) determination [$r(16) = .62$, $p = .01$], not related after (B) satisfaction [$r(15) = .06$, $p = .82$], and negatively related after (C) neutral facial expressions [$r(18) = -.49$, $p = .03$].

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[3] Examining the difference score (task minus baseline midfrontal asymmetry) with persistence produced the following correlations: determination, $r(16) = .31$, $p = .23$, neutral, $r(18) = -0.18$, $p = .45$], and satisfaction, $r(14) = -0.46$, $p = 0.09$. Examining baseline midfrontal asymmetry with persistence produced the following correlations: determination, $r(16) = .41$, $p = 0.11$, neutral $r(18) = -0.44$, $p = 0.06$, and satisfaction $r(16) = 0.14$, $p = 0.63$.

4. Discussion

4.1. Overview and contributions of present results

As predicted, facial expressions of positive emotions differing in approach motivational intensity caused different patterns of relative left frontal activity, with determination facial expressions causing greater relative left frontal cortical activity than satisfaction and neutral facial expressions. This effect remained when covarying difficulty ratings for forming facial expressions. The effect also remained when covarying EMG activity. Observed differences in EEG alpha power as a function of emotional facial expressions, therefore, were not likely due to changes in asymmetric facial muscle movements (e.g., Coan et al., 2001). These findings extend neuroscientific embodiment research (Harmon-Jones, Schmeichel, et al. 2011; Price, Dieckman, & Harmon-Jones, 2012; Price, Peterson, & Harmon-Jones, 2012), and past work suggesting withdrawal-oriented facial expressions are associated with less relative left frontal activity than approach oriented facial expressions (Coan et al., 2001).

The present analyses also suggested relative left frontal activity was positively associated with insolvable task persistence in the high approach positive determination condition. This was not the case for the satisfaction condition. This suggests that relative left frontal activity associated with high approach positive facial expressions plays a role in persistence behaviors, an effect that has not been previously demonstrated.

Facial expressions also influenced self-reported emotions in the present experiment. Participants reported greater interest in the determination compared to the neutral expression condition, and greater joy in the satisfaction relative to neutral condition. The determination and satisfaction conditions did not differ significantly in self-reported interest or joy, although the means were in the expected direction. The lack of significant differences may be attributable to the fact that participants were not rating affective stimuli, as in most past facial feedback research, but simply reporting how they currently felt (e.g., Strack et al., 1988). Furthermore, self-reported emotions were measured after the persistence task by asking participants to rate how they felt “right now” (and not during the facial expression task), which may have weakened the self-reported emotions effects. As stated earlier, self-reported emotions were measured at this point because completing emotion questionnaires can dampen emotion-related behavioral changes (Berkowitz, 2000).

Facial expressions did not directly influence task persistence. Past research that has found that bodily manipulations to influence task persistence (Riskind & Gotay, 1982) had participants adopt different body postures before working on tasks for longer periods of time (8 min) relative to the present experiment (1 min with facial expressions). Because discomfort is likely to result when participants adopt facial expressions for long periods of time, these longer time frames are rarely used for facial expression manipulations (Coan et al., 2001).

One unexpected and counter-intuitive result to emerge was the negative correlation between relative left frontal cortical activity and task persistence in the neutral condition. Approach motivation measured by relative left frontal cortical activity should relate directly to approach behavior, assuming there are not competing motives. One may wonder, therefore, why relative left frontal cortical activity was not at least somewhat positively correlated with task persistence in the neutral condition. It is possible that the current measure of task persistence was not sensitive. Supporting this idea, facial expressions did not influence task persistence, but produced predicted differences on the sensitive measure of relative left frontal cortical activity. Nevertheless, when approach motivation is present in the form of a determination face combined with greater relative left frontal cortical activity, greater task persistence might be uncovered even in this insensitive behavioral measure. In addition, the fact that participants in the neutral facial expression condition were deliberately trying to make a neutral face may have eliminated the expected positive correlation between relative left frontal activity and task persistence. That the correlation was, however, negative is presently without explanation.

4.2. Comparing electrical and hemodynamic literatures on asymmetric frontal cortical activity and emotion processes

The predictions for the current research were derived from the motivational direction model of frontal asymmetry, which is based on much past work using EEG (e.g., Amodio, Devine, & Harmon-Jones, 2007; Harmon-Jones, 2006, 2007; Peterson, Shackman, & Harmon-Jones, 2008), ERP (e.g., Cunningham, Espinet, DeYoung, & Zelazo, 2005; Gable & Harmon-Jones, 2010, 2013), repetitive transcranial magnetic stimulation (rTMS; e.g., d’Alfonso, van Honk, Hermans, Postma, & de Haan, 2000; van Honk & Schutter, 2006), and transcranial direct current stimulation (tDCS; e.g., Hortensius, Schutter, & Harmon-Jones, 2012; Kelley, Hortensius & Harmon-Jones, 2013). However, the fMRI literature suggests a more complex picture regarding the relationships between affective valence, motivational direction, and asymmetric frontal cortical activity. That is, some fMRI evidence suggests that emotional valence is lateralized over dorsolateral prefrontal cortical regions (e.g., Herrington et al., 2005), other evidence suggests that motivational direction is lateralized over dorsolateral prefrontal cortical regions (e.g., Berkman & Lieberman, 2010), other evidence suggests that the frontal lateralizations associated with emotional valence and motivational direction are sometimes reversed depending on specific regions within the frontal cortex (Miller, Crocker, Spielberg, Infantolino, & Heller, 2013), and still other evidence suggests that neither emotional valence nor motivational direction are lateralized within any regions of the frontal cortex (e.g., Wager, Phan, Liberzon, & Taylor, 2003). Thus, the fMRI research paints a confusing picture. However, assuming that frontal lateralizations are present and sometimes reversed depending on the specific regions involved, the electrical measures (EEG, ERP) and manipulations (rTMS, tDCS) are too spatially insensitive to reveal this complexity.

On the other hand, it is also possible that the electrical measures are tapping different neuronal processes than the fMRI measures. EEG/ERP measures assess selective electrical activity associated with the summation of post-synaptic potentials, whereas fMRI assesses primarily metabolism and blood flow to brain areas recently involved in (most likely) action potential firing rates (Nunez & Silberstein, 2000).

In addition, EEG/ERP and fMRI may be assessing activity from different types or organizations of neurons. For example, cortical stellate cells occupy roughly spherical volumes and thus their associated synaptic sources provide a “closed field” structure. Therefore, these cells are electrically invisible to the EEG. Although they make up only about 15% of the neural population of neocortex (Braitenberg & Schuz, 1991; Wilson, O’Scalaidhe, & Goldman-Rakic, 1994), they contribute disproportionately to metabolic activity because of their higher firing frequencies of action potentials (Connors & Gutnick, 1990). Consequently, they appear as large signals in fMRI. In contrast, EEG signals can appear large while weak metabolic (fMRI) activity occurs. Such would occur if only a small percentage of neurons in each cortical column are “synchronously active”, if a large-scale synchrony among different columns produces a large dipole in which individual columns tend to be phase locked in particular frequencies. In this scenario, the majority of neurons in each intra-column population are relatively inactive, and thus minimal metabolic activity is produced.

Methodologically, fMRI and EEG differ in an important way, particularly for research on motivational processes. fMRI studies typically require participants to be in a supine position, whereas EEG studies typically require participants to be in an upright, sitting position. Research using EEG, ERP, and startle eyeblink methodologies has suggested that these body postures influence brain activity, with a supine posture leading to relatively less left frontal cortical activation as measured by EEG, lower amplitude ERP responses associated with motivational intensity, and startle eyeblink responses suggestive of lower appetitive motivational responding (Harmon-Jones & Peterson, 2009; Harmon-Jones, Gable, & Price, 2011; Price, Dieckman et al., 2012; Price & Harmon-Jones, 2011).

Finally, it is also possible that some of the complex and inconsistent results from past fMRI research may have resulted from failures to clearly define, measure, and manipulate psychological constructs and from the use of correlational rather than experimental designs to test the conceptual models. Although a complete discussion of all of these issues would detract from the primary point of the current paper, we will briefly mention a few key issues. In one study, Herrington et al. (2005) had participants identify the colors of pleasant and unpleasant words during functional magnetic resonance imaging (fMRI). Results indicated pleasant versus unpleasant words caused greater activation in the left dorsolateral prefrontal cortex. Although these results are consistent with the valence model, they also raise some questions. Do the pleasant words in Herrington et al. (2005) evoke feelings of positive affect and/or an appraisal of goal congruence? These are two ways in which positive affect has been traditionally defined (Lazarus, 1991), but it is not clear which, if either, aspect of positive affect caused the fMRI results. Do the pleasant words evoke approach motivation? If they did, then the fMRI results may be explained by motivational direction. Experiments often confound affective valence with motivational direction and such experiments support both valence and motivational interpretations of relative left frontal activity. Berkman and Lieberman (2010) dissociated motivational direction (approach, avoidance) from stimulus valence (pleasant, unpleasant) experimentally. They found increased left (vs. right) dorsolateral prefrontal activation during approach (vs. avoidance) actions regardless of affective valence.

Taken together, these factors may explain why the electrophysiological and hemodynamic imaging research literatures occasionally provide inconsistent results for the relationships between emotional valence, motivational direction, and asymmetric frontal cortical activity. In any event, much research using electrophysiological measures and manipulations has supported the motivational direction model, and the present research extends this body of work by suggesting that discrete positive emotions that differ in approach motivational intensity influence asymmetric frontal cortical activity as measured by EEG.

5. Conclusion

The present findings suggest that high approach compared to low approach positive facial expressions are associated with greater relative left frontal cortical activity. Relative left frontal activity was also associated with approach-related behavioral persistence when individuals were making facial expressions of determination, providing some of the first evidence linking relative left frontal cortical activity to molar behavioral measures. Together, these findings support motivational interpretations of relative left frontal cortical activity and emotive theories of embodiment.

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