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Unilateral Hand Contractions Produce Motivational Biases in Social Economic Decision Making

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Objective: Unilateral hand contractions have been shown to induce relative activation of the contralateral hemisphere, which is in turn associated with distinct motivational states. Specifically, right hand contraction increases relative left activation and promotes an approach state, and left hand contractions promote relative right activation and withdrawal states. Using the same hand clenching technique, the present study extends this research to examine the incidental role of motivational tendency on interactive economic decision making. ***Method:*** A total of 75 right-handed participants were randomly assigned to 1 of 3 conditions, including withdrawal/left-hand contractions, approach/right-hand contractions, and control/no contraction. Participants completed 2 well-known economic tasks, namely the Ultimatum Game (UG), Dictator Game (DG). ***Results:*** In the UG, we found that relative to individuals in the withdrawal condition, those in the approach (right-hand contraction) condition made higher monetary offers to human partners who could either accept or reject these offers. Moreover, those in the approach condition rejected significantly more unfair offers from human partners. ***Conclusions:*** This study provides the first evidence that hemispheric activation, using unilateral muscle contractions, may play a causal role in biasing social economic decision making. Overall, there results suggest that greater relative left frontal activation promotes reward-maximizing strategies, consistent with an approach motivation, and relative right frontal activation may decrease such strategic tendencies.

Keywords: motivational tendency, decision making, unilateral hand contractions, frontal asymmetry, ultimatum game

The experience and expression of emotion has been linked to a lateralized functioning of the cerebral hemispheres (Davidson, 2003; Silberman & Weingartner, 1986). Although some research supports the valence hypothesis (i.e., right and left hemisphere activations associated with negative and positive emotions respectively), this lateralization may more accurately reflect the dissociation of withdrawal and approach motivational tendencies (Davidson, 2003; Harmon-Jones, 2003). Specifically, greater relative left frontal activity promotes an approach motivation, including both positive (e.g., happiness) and negative (e.g., anger) emotional states, and greater relative right frontal activity has been linked to withdrawal (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997).

Collectively, this research suggests that manipulating frontal hemispheric activity may prove useful in examining the role of motivational tendencies in guiding behavior. Unilateral muscle contractions have been successfully used to increase relative activity in the contralateral frontal hemisphere (Peterson, Shackman, & Harmon-Jones, 2008; Schiff, Guirguis, Kenwood, & Herman, 1998; Shepherd, 1988) and to facilitate its function in various cognitive tasks, including visual perception/attention (Schiff & Truchon, 1993) and memory (Propper, McGraw, Brunye, & Weiss, 2013). Importantly, this manipulation has been shown to prompt motivational states consistent with the expected direction of frontal asymmetry (Peterson et al., 2008; Schiff et al., 1998). For instance, in right-handed individuals, right-hand contractions (promoting greater relative left activity) led to both greater persistence in attempting to answer insoluble problems and also promoted aggressive responses (Peterson et al., 2008), consistent with an approach-based motivation.

In this behavioral study, we used a similar approach to assess the effect of induced motivational tendency on social economic decision making. We employed two well-studied interactive tasks, namely the Ultimatum Game (UG; Güth, Schmittberger, & Schwarze, 1982) and the Dictator Game (DG; Kahneman, Knetsch, & Thaler, 1986). In both games, one player (the "proposer") makes an offer to the other player (the "responder") as to how an amount of money provided by the experimenter should be split. In the UG, the responder can either accept the offer, in which case the money is split as proposed, or reject the offer, in which case neither player receives anything. Typically about 50% of unfair offers are rejected by responders (Camerer, 2003), which may be mediated by increased arousal and anger to these types of offers

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(van't Wout, Kahn, Sanfey, & Aleman, 2006). In contrast, responders in the DG must accept any offer made, which promotes lower offers from proposers because their payoffs do not depend on their partner's decisions (Camerer, 2003). This research suggests that human players do not solely rely on a strategy maximizing economic returns (e.g., in which case any nonzero offer should be accepted), but that other types of "social" rewards may contribute to guiding decisions (e.g., satisfaction from maintaining equitable earnings between self and partner). Thus, in the DG, making lower offers is congruent with an opportunistic approach to maximize economic profits, whereas higher offers would be more consistent with an altruistic equality-maximizing approach. Interestingly, a recent study (Harlé & Sanfey, 2010) showed that players were more likely to reject unfair UG offers following mood induction promoting disgust and serenity (two withdrawal-based emotions) than when in an angry or amused state (two approach-based emotions). In contrast, no behavioral differences were observed when contrasting positive versus negative emotions, suggesting that motivational tendency, relative to emotional valence, may better predict such decision biases.

Based on this literature and findings linking approach tendency with heightened perseverance (Schiff et al., 1998) and reward maximizing behavior (Pizzagalli, Sherwood, Henriques, & Davidson, 2005), we predicted that right-hand contractions would promote an approach motivation leading to reward-maximizing decisions, relative to left-hand contractions (promoting withdrawal motivation). In economic terms, such strategic shift may be reflected by more profit-maximizing decisions such as higher proposer offers in the UG (i.e., maximizing likelihood of acceptance and thus positive payoff) and lower proposer offers in the DG (i.e., keeping a higher share). In addition, based on previous research (Harlé & Sanfey, 2010), priming withdrawal motivation may promote higher rejection rates (i.e., consistent with avoidant reward-minimizing action) in the UG, and approach motivation should increase acceptance rates.

Alternatively, from a social reward-maximizing perspective, approach motivation may promote maintenance of equality between partners, that is, more equitable offers in both UG and DG, and more rejections of unfair offers, and withdrawal priming may be associated with more detachment from equality maximizing goals.

Method

Participants

Eighty-four undergraduate students participated in this study. To control for potential handedness effects on frontal activation (Davidson, 1988), and given that most studies of EEG frontal asymmetry have been conducted in right-handed samples (Coan & Allen, 2003), only right-handed individuals were included. Each participant was randomly assigned to one of the three experimental conditions (withdrawal, approach, control). Nine participants (in the avoidance and approach conditions) were excluded for being unable to complete the entire hand contraction task due to fatigue and/or pain. Nine additional subjects were ran and randomly assigned to the approach and avoidance conditions to meet a final target sample size of 75 (67% female; age 18–29 years, $M = 19.2$, ± 1.8) for data analyses (including 25 participants per condition). Participants received course credit for completing the experiment, and to ensure they were sufficiently motivated to make real decisions, they were paid their actual earnings in cash for a randomly selected trial from one of the experimental tasks (i.e., $4 to $7).

Procedures

Participants were informed that the experiment was designed to study the relationship between muscular activity and decision making (Schiff et al., 1998), and were given general instructions about the decision tasks (UG and DG). They were told that they would be playing with real and randomly matched participants who had already completed the experiment and made their respective decisions earlier that day. Participants then filled out a short questionnaire assessing their understanding of the games and various baseline measures including the Positive and Negative Affect Scale[1] (PANAS; Tellegen, Watson, & Clark, 1988) and the Behavioral Inhibition System/Behavioral Activation System scales (BIS/BAS; Carver & White, 1994).

The experimental sequence was as follows: 4 min of hand contraction (left, right, or none), 10 UG proposer trials, 4 min of hand contraction, 10 DG trials, 2 min booster hand contraction, 20 UG responder trials). Before each decision task, participants read self-paced instructions on the computer screen and completed two practice trials. After the experimental tasks, they completed an exit questionnaire, were paid, and debriefed. No participants guessed the real purpose of the hand contraction manipulation.

Hand Contraction Manipulation

The same procedures as used by Schiff, Guirguis, Kenwood, and Herman (1998) were followed. Participants in the contraction conditions squeezed a 2-in. diameter rubber ball in either their left or right hand. They were instructed to squeeze the ball as hard as they could while laying the other hand flat on a table, palm facing down. In the no-contraction condition, participants rested their hands on the table in a relaxed state with the palms open and facing each other, while gently holding the ball between their open palms. Participants in all conditions alternated between performing the contractions for 45 s and then relaxing for 15 s (i.e., they did this either four times or two times for booster). For all conditions, participants read the instructions and saw a picture of the required contraction movements on the computer. The experimenter asked participants to demonstrate the response once to ensure it was executed correctly.

Decision Tasks

Participants first played as "proposers" in the DG and DG against human partners. For each trial type (UG or DG), they made 10 randomly presented one-time offers to split $10 with a different partner (for a total of 20 trials). Participants first saw a silhouette and identification number of their partner (4 s). They then had up

[1] Based on a substantial behavioral literature suggesting that making one aware of an emotional state can in itself bias the extent to which such mood state may be incorporated into other cognitive processes (Schwarz, 2004), PANAS measures were not explicitly measured during the UG/DG tasks or hand contraction manipulation, but rather at the onset of the experiment before training/instructions and immediately after all tasks were completed.

to 8 s to make their offer by scrolling through each possible amount (i.e., \$0–\$10) and submitting their offer by means of button press. The outcome for each trial was not presented.

Participants then played the UG as “responders,” each receiving 10 offers from human partners and 10 computer offers. All participants saw the same set of 20 offers presented in random order, which ranged from equitable to “unfair” (4 × \$5, 4 × \$4, 4 × \$3, 4 × \$2, and 4 × \$1 offers). For each trial, they first saw their partner’s offer under the partner’s silhouette (human or computer), and had up to10 s to decide to either accept or reject the offer with a button press. The outcome of the trial then appeared for 4 s, and the next offer sequence followed.

All data analyses were conducted using the R statistical package (R Development Core Team, 2008). For dependent variables with repeated measures (i.e., offers, responder decisions, and RTs), we conducted hierarchical generalized mixed-effect linear models treating subject as a random factor (with varying intercepts and slopes over trial type). For significant main effects and interactions, we report change in log likelihood ratio (chi-square distribution) and regression coefficients of interest with corresponding *p* values.[2]

Results

Baseline Sample Profile and Variable Control

Four separate one-way ANOVAs were conducted to assess any group difference for the three BAS (drive, fun seeking, and reward responsiveness) subscales and the BIS scale. No significant group difference was revealed ($p > .05$; $M_{\text{drive}} = 2.1$, SEM = .06; $M_{\text{funseek.}} = 1.9$, SEM = .06; $M_{\text{rewardresp.}} = 1.4$, SEM = .04; $M_{\text{BIS}} = 2.0$, SEM = .06). Any significant group difference in decision making is thus unlikely to originate from a difference in baseline motivational tendencies, based on this measure which has been shown to correlate with the respective resting EEG frontal hemispheric asymmetry (Coan & Allen, 2003; Harmon-Jones & Allen, 1997). Similarly, there were no group differences on baseline mood measures from the PANAS positive affect (PA: $M = 3.0$, SEM = .09) and negative affect (NA: $M = 1.4$, SEM = .06) scales ($p > .05$). For posttask PANAS measures, a main effect of time revealed a significant decrease in PA across all three conditions, $F(1, 70) = 22$, $p < .001$. Importantly, neither main effect of condition nor Condition × Time interactions were statistically significant for either PA or NA ($p > .05$). Posttask PANAS scores did not differ across conditions (PA: $M = 2.6$, SEM = .10; NA: $M = 1.5$, SEM = .05). Taken together, these results suggest that any baseline or manipulation-related group differences in affective state are unlikely to have significantly confounded the results of this experiment.

UG/DG Offers

A mixed-effects linear model was fit to participants’ offers in the proposer and dictator trials with condition (i.e., approach, withdrawal, control) and trial type (dictator or UG proposer) as independent variables. As expected, the main effect of trial type was statistically significant ($\chi^2 = 124.8$, $df = 1$, $p < .001$), with participants offering higher amounts on UG relative to DG trials. The condition main effect did not reach statistical significance ($\chi^2 = 1.7$, $df = 2$, $p = .42$). However, a significant Trial Type × Condition Interaction was observed ($\chi^2 = 12.7$, $df = 2$, $p = .001$). Relative to those in the withdrawal condition, participants in the approach condition offered significantly higher amounts in UG proposer trials (B = +\$.313, $p < .01$; see Figure 1). No group difference was observed for dictator trials.

UG Responder

Binary responder decisions (i.e., reject vs. accept) were fit to a mixed-effects generalized linear model with a logit link function, with offer type (fair \$4–\$5, unfair \$1–\$3), partner type (computer, human) and condition (right hand/approach, no contraction/control, left hand/withdrawal) as independent variables. As expected, a main effect of offer type was statistically significant ($\chi^2 = 782$, $df = 1$, $p < .001$), with participants more likely to accept a fair than an unfair offer. A significant Offer Fairness × Partner Type × Condition Interaction was also observed ($\chi^2 = 21.9$, $df = 7$, $p = .002$). To unpack this interaction, two separate generalized linear models were fit to assess the interaction of offer fairness and condition for each partner type. No group difference was found for either fair or unfair computer offers. For human offers, a significant difference was observed for acceptance of unfair offers between the withdrawal and approach conditions. Relative to those in the withdrawal condition, participants in the approach condition were less likely to accept unfair offers (odd ratio = 0.35, $p < .05$; see Figure 2).

Reaction Times

Two mixed-effects linear models were fit to RTs for each task (UG/DG proposer and UG responder). For proposer RTs, trial type (UG vs. DG) and condition were included as independent variables. A main effect of trial type was statistically significant ($\chi^2 = 25.1$, $df = 1$, $p < .001$), with participants being slower at making offers on UG proposer trials relative to DG trials. However, neither the condition main effect nor the Trial Type × Condition Interaction reached statistical significance ($p > .05$). For responder RTs, offer fairness (fair vs. unfair) and condition were included as independent variables and neither significant main effects nor interaction were observed ($p > .05$). Collectively, these results suggest minimal group differences in psychomotor speed and hand contraction fatigue across experimental conditions and decision tasks.

Discussion

The goal of this experiment was to examine the role of frontally mediated motivational tendency, an action-based dimension of emotion, on decision making. We manipulated motivational states

[2] Because there is no current agreement on how to estimate degrees of freedom for mixed-effect GLMs, *p* values for regression coefficients of interest were estimated with two methods leading to very similar values and to the same statistical conclusions. One estimates degrees of freedom by subtracting the number of fixed effects from the total number of observations for each parameter. The second one (*p* values reported here) uses a bootstrapping Markov Chain Monte Carlo method to generate confidence intervals from the posterior distribution of the parameter estimates (Baayen, Davidson, & Bates, 2008).

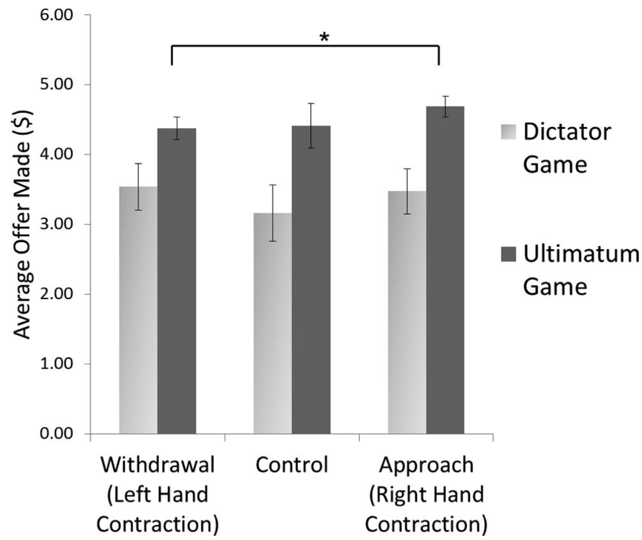

Figure 1. Average offer amount by trial type (UG vs. DG) and motivational tendency/hand contraction condition; error bars represent SEM. In this task, participants played as "proposers" against human partners. For each trial type (UG or DG), they made 10 one-time offers to split $10 with a different partner (for a total of 20 trials).

(approach and withdrawal) using unilateral hand contractions, a method shown to increase relative frontal activity in the contralateral hemisphere (Peterson et al., 2008; Schiff et al., 1998) and to prime the respective motivational state (Davidson, 2003; Peterson et al., 2008). Our results provide the first evidence that unilateral muscle contractions can produce behavioral shifts in social economic decision making, and are consistent with the hypothesis that increased approach motivation (via relative left frontal activation) promotes reward maximizing behavior. In addition, they argue against a valence mediated effect of hemispheric asymmetry manipulation on decision making. We outline the reasons for this conclusion below.

First, in the UG, we found that right-hand contractions resulted in higher proposer offers relative to left-hand contractions. Proposer offers in the control (no contraction) condition were on average lower than those in the left-hand/withdrawal condition and higher than those in the right-hand/approach condition (albeit not significantly). In contrast, no group difference was observed in the DG. These results are consistent with relative left frontal activation enhancing an approach motivational state in the context of appetitive potential outcomes (i.e., monetary reward). Specifically, in the proposer role, individuals primed with an approach tendency were more likely to make decisions *maximizing* potential reward, as higher offers increase the likelihood these offers will be accepted (thus leading to a positive financial payoff). Because no effect of motivational tendency was observed in the DG (i.e., where offers must be accepted and are therefore not contingent on partners' decisions), these results point to a context-dependent strategic effect of approach motivation rather than a general promotion of altruistic behavior (which would lead to higher offers in both UG and DG proposer conditions). This is consistent with previous findings linking higher scores on the BAS drive and reward responsiveness subscales to a greater discrepancy between DG and UG proposer offers (Scheres & Sanfey, 2006).

When playing as responders in the UG, individuals in the right-hand contraction/approach condition rejected unfair offers to a higher degree than those in the left-hand contraction/withdrawal condition. This higher rejection rate is consistent with a punishing stance, a long-term reward-maximizing strategy. Indeed, rejecting unfair offers signals to potential partners that their offers are too low and that higher offers are expected. In addition, this strategy avoids a negative/punishing outcome (i.e., unfair treatment from a peer). At first, this finding may seem at odds with previous work showing that relative to withdrawal-based emotional states (e.g., disgust), induced approach-based emotions (e.g., anger) were as-

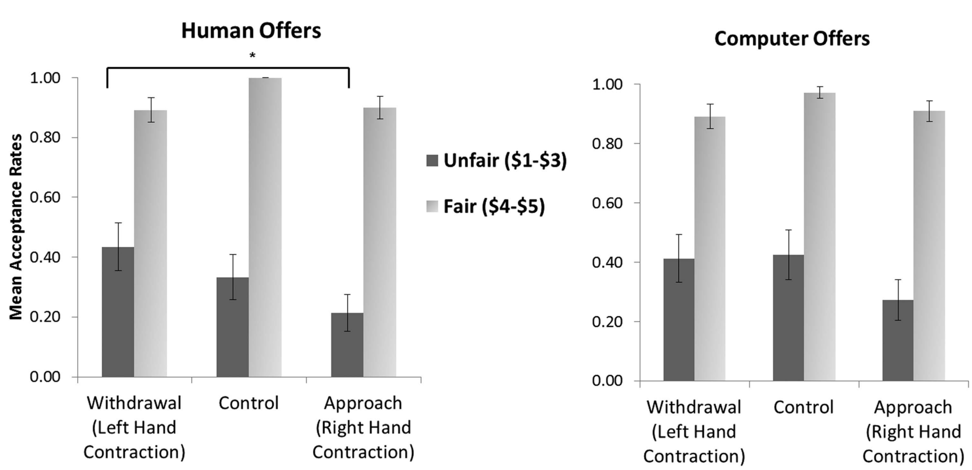

Figure 2. Average acceptance rates (UG responder) by partner type (human vs. computer) and motivational tendency/hand contraction condition; error bars represent SEM. In this task, participants played the UG as "responders," each receiving 10 offers from human partners and 10 computer offers. All participants saw the same set of 20 offers presented in random order, which ranged from equitable to "unfair" (4 × $5, 4 × $4, 4 × $3, 4 × $2, and 4 × $1 offers).

sociated with lower rejection rates of unfair UG offers (Harlé & Sanfey, 2010). However, the present experiment did not manipulate mood (as confirmed by the absence of group effects on mood ratings), whereas this other study induced specific mood states with movie clips (Harlé & Sanfey, 2010). The latter manipulation may provide additional semantic context with which basic action tendencies could interact (e.g., prompting different goals or selective attention toward mood-congruent stimuli). Thus, the present results highlight potentially distinct biasing effects of explicit mood states versus more "valence neutral" motivational tendencies. The absence of condition effects on emotional experience is also consistent with previous research showing that unilateral muscle contractions can lead to behavioral biases without changes in mood (Schiff & Lamon, 1989; Schiff & Truchon, 1993). However, we acknowledge this may be due to the limitations of retrospective, self-report measures, as others have found mood changes congruent with the expected motivational bias (e.g., Harmon-Jones & Allen, 1997).

In further support of this hypothesis, although higher proposer offers would also be consistent with induced positive emotion (also linked to left frontal activation; Davidson, 2003), the higher rejection rates observed in the responder task are *not* consistent with a carryover effect of positive emotion (which would be expected to promote more acceptance and less sensitivity to offensive unfair offers). The observed pattern instead suggests the facilitation of an aggressive, punishing stance toward unfair proposers (i.e., a negatively valenced yet approach-based response). This is congruent with previous studies showing that higher relative left frontal activity (induced with the same hand-contraction method) can increase aggressive responses in interactive situations where social norms are violated (Peterson, Gravens, & Harmon-Jones, 2011; Peterson et al., 2008). Thus, although right-hand contractions may promote more reward-maximizing strategy via increased relative left frontal activation, such behavioral effects could stem from more indirect affective changes (e.g., increased feelings of dominance or aggression). We note, however, that the higher average offers made in this condition are somewhat at odds with this interpretation as lower offers would be expected from a dominating stance. Finally, the observed effect is consistent with previous findings that clinical depression, a condition associated with *decreased* relative left frontal activation (Allen, Iacono, Depue, & Arbisi, 1993; Henriques & Davidson, 1991), is associated with deficits in approach and reward seeking mechanisms (Disner, Beevers, Haigh, & Beck, 2011), including higher acceptance rates of unfair UG offers despite a negative emotional reaction (Harlé, Allen, & Sanfey, 2010).

One limitation of this study is that EEG data were not directly collected to verify that the targeted changes in frontal asymmetry were induced by the hand contraction manipulation. However, we used the exact same method previously validated with EEG frontal asymmetry across several studies (Peterson et al., 2008; Schiff et al., 1998). Importantly, our between-groups and random assignment design, combined with control of handedness and baseline emotional variables (suggesting no preexisting group differences in motivational states) reduce the potential impact of confounding variables. Nevertheless, this study would ideally be replicated with direct frontal asymmetry measurement to further elucidate the specific role of each hemisphere in biasing social economic decision making.

In summary, the present study assessed the role of unilateral hand contractions (and their putative effect on frontal activation asymmetry and associated motivational state) on social economic decision making. This work is consistent with research linking greater relative left frontal activation with an approach action tendency, which was demonstrated here by a propensity toward reward-maximizing strategies. This study suggests that unilateral muscle contractions, a simple and noninvasive manipulation, may be a useful tool to study emotion and decision-making interactions. Building on previous neural and interoceptive accounts (Damasio, 1994), this framework offers a biological link between affect and behavior, which may help refine our understanding of how emotion can provide a heuristic strategic compass to guide decision making.

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