

# The Relationship Between Agency, Communion, and Neural Processes Associated with Conforming to Social Influence

## Supplemental Materials

The data and analyses scripts in R have been made publicly available at OPENISPSR (<https://www.openicpsr.org/openicpsr/project/184271/version/V1/view>). Neuroimaging data related to the exploratory whole brain analyses are available by request from the corresponding authors<sup>1</sup>.

## Methods

### Participants

All participants were right-handed, did not suffer from claustrophobia, were not currently taking any psychoactive medications, did not have a history of psychiatric or neurological disorders, had normal (or corrected to normal) vision, and did not have metal in their body that was contraindicated for fMRI. Six participants were excluded from the analyses. Three participants did not complete the self-construal scale and another three participants did not have sufficient fMRI data.

### Study Design

*Social influence task – initial ratings.* After participants gave consent to participate in the study, they were asked to complete initial ratings for the conformity task. Participants were told that they would be rating a series of puzzle game apps acquired from the iTunes App Store to better understand online marketing decisions. Actual game apps from the App Store were used to

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<sup>1</sup> Note: The current study was an exploratory secondary data analysis and was not preregistered. In addition, an *a priori* power analysis was not conducted because the current study was based on available secondary data. A post-hoc power analysis ( $\alpha=.05$ , power=.80, effect size=.09) was conducted in G Power using a two tailed linear regression with four predictor variables suggested a sample size of 87 was appropriate for the study.

maximize external validity and present a product that young adults are likely to buy and rate online in real life. In addition, all games were puzzle based games to reduce preferences for one game genre over another. Initial ratings were given before the fMRI brain scanning session. This involved giving preliminary recommendations on 80 mobile game apps (participants made ratings for 60 mobile phone apps in one of the fMRI samples but other elements of the task were the same) in response to a prompt asking “how likely would you be to recommend the game to a friend” from 1=“wouldn’t recommend” to 5=“would recommend” based on exposure to the app title, logo, and a brief description similar to information contained in the App Store (Figure 1). All apps were real puzzle-based game apps taken from the Apple Store. For the purposes of the study, we chose mostly unknown apps so that personal knowledge or experience with the apps would not influence the results of the study.

*Social influence task – social feedback.* Next, participants completed the social feedback portion of the social influence task. fMRI participants completed this portion of the task during the brain scanning session. Participants were told that they would be rerating the same game apps they had previously rated, however, this time they would also be shown how other peers in the study rated the apps in comparison to their initial rating to mimic online rating platforms. During the social feedback portion of the task, each trial consisted of three parts. Participants first were exposed to a reminder of the game using the title and logo along with a reminder of how they initially rated the game (2 seconds). Next participants were exposed to manipulated peer group recommendations relative to their own (3 seconds; Figure 2). The peer feedback consisted of four within-subject conditions where participants found out that peers made ratings that were *higher*, *lower*, or the *same* as the participant or they were given no social feedback as a control condition (participants that rated 80 apps were exposed to 20 trials for each feedback condition

and participants that rated 60 apps were exposed to 15 trials for each feedback condition). The summary description of the peer feedback was the only peer feedback provided. Finally, participants were asked to give a final recommendation for each game (3 seconds).

To confirm that conformity to peer feedback was not driven by the effect of regression to the mean we examined a mixed effects model used in Nook and Zaki (2015) with the second round (i.e., social feedback) ratings as the response variable, peer feedback and initial ratings were entered as fixed effects, and participant was entered as a random effect. Peer feedback type (higher, lower, same, not rated) remained significant ( $p < .001$ ), suggesting conformity to peer feedback was likely not the effect of regression to the mean.

*Self-construal scale.* As a part of both studies, participants were asked to complete the self-construal scale from Singelis (1994). The scale consists of 30 items total (15 measuring interdependence and 15 measuring independence, giving each individual a separate score on these two subscales). Participants were asked to rate each item based on how much it reflected their personality on a scale from 1="strongly disagree" to 7="strongly agree". An example of a statement measuring independence is "I enjoy being unique and different from others in many respects", where "Even when I strongly disagree with group members, I avoid an argument" is designed to measure interdependence.

### **fMRI Data Acquisition and Analyses**

*fMRI data acquisition.* MRI data were acquired using a 3 Tesla GE Siemens Trio MRI scanner. Functional images were recorded using a reverse spiral sequence (TR=1500ms, TE=25 ms, flip angle=70°, 54 axial slices, FOV=220 mm, slice thickness=3 mm; voxel size=3.00mm x 3.00mm x 3.00mm). We also acquired a high-resolution T1-weighted images (MPRAGE; 160 slices; slice thickness=.90mm x .90mm x 1.00mm) for use in co-registration and normalization.

*fMRI preprocessing.* Functional data were pre-processed and analyzed using Statistical Parametric Mapping (SPM12, Wellcome Department of Cognitive Neurology, Institute of Neurology, London, UK). For the stabilization of the BOLD signal, the first four volumes (eight seconds) of each run were discarded prior to analysis. Functional images were despiked using the 3dDespike program as implemented in the AFNI toolbox. Next, data were corrected for differences in the time of slice acquisition using sinc interpolation; the first slice served as the reference slice. Data were then spatially realigned to the first functional image. We then co-registered the functional and structural images using a two-stage procedure. First, in-plane T1 images were registered to the mean functional image. Next, high-resolution T1 images were registered to the in-plane image. After co-registration, high-resolution structural images were skull-stripped using the VBM8 toolbox for SPM8 (<http://dbm.neuro.uni-jena.de/vbm>), and then normalized to the skull-stripped MNI template provided by FSL (MNI152 T1 1mm brain.nii). Finally, functional images were smoothed using a Gaussian kernel (8 mm FWHM).

*fMRI statistical modeling.* Data were modeled at the single subject level using the general linear model as implemented in SPM12. Peer feedback conditions (not rated, same, lower, and higher) were combined with rating outcomes (changed their rating, did not change their rating) as regressors in the model. The initial rating reminder phase (2 seconds), group feedback phase (i.e., peer feedback; 3 seconds), and final rating (3 seconds) were modeled as separate boxcars. The current study focuses on the group feedback phase for the contrast (group feedback (higher + lower) + changed their rating > group feedback (higher + lower) + did not change their rating). Two combinations where participants changed their ratings in response to peer feedback (not rated, same) did not occur enough across participants to be modeled on their own and were included with trials that did not include a final rating under an “other” nuisance regressor

condition. We then modeled the six rigid-body translation and rotation parameters derived from spatial realignment were included as nuisance regressors. Thus, we included a total of 16 regressors. Data were high-pass filtered with a cutoff of 128s. Volumes were weighted according to the inverse of their noise variance using the robust weighted least squares toolbox (Diedrichsen et al., 2005).

*Region of interest (ROI) analyses.* Our functional ROIs were constructed from NeuroSynth (<https://neurosynth.org/>) using the association test maps for the following keywords: “value” and “mentalizing” (Figure 3). The NeuroSynth association test maps provide activation in neural regions that are consistently activated in research that report the cognitive function of interest compared to research that does not report the cognitive function, adjusting for the base rate of activation in each region (Yrkoni et al., 2011). ROI percent signal change scores were extracted during the group feedback phase (i.e., exposure to social feedback) during trials when participants changed their ratings to conform to divergent peer recommends versus when they did not change in response to divergent peer recommendations (conform vs. resisting conformity trials: being misaligned with peers + conforming > being misaligned with peers + maintaining one’s initial rating). Thus, ROI activity captured neural responses in value (including the VS, vmPFC, and subgenual cingulate) and mentalizing (including the TPJ, dmPFC, supplemental motor area, precuneus, postcentral cingulate, temporal pole, and mPFC) functional regions when participants conformed to peer opinions that differed from their own compared to when they maintained their initial ratings. For each ROI (value, mentalizing) independent self-construal (ROI = independent self-construal + gender + (independent self-construal \* gender) + study cohort) and interdependent self-construal (ROI = interdependent self-construal + gender + (interdependent self-construal \* gender) + study cohort) was independently examined.

*Whole brain analyses.* To examine activity across the entire brain in trials where participants changed their recommendations according to peer feedback (conform vs. resisting conformity), we estimated two multiple regression models in SPM12, pooling all participant-level maps. The first model included regressors of self-reported independence, gender, and their interaction, controlling for study. The second model included regressors of self-reported interdependence, gender, and their interaction, controlling for study. Results are reported for associations between individual differences and activation during the conform vs. resisting conformity contrast. All exploratory whole brain results are reported in MNI space at  $p < .001$ ,  $k > 50$ , uncorrected. Significant activity did not survive false discovery rate (FDR),  $p < .05$ ,  $k > 5$ . Thus, exploratory whole brain findings should be interpreted with caution.

## Results

*Self-construal.* On average, participants scored higher on independence than interdependence ( $t(86) = 3.15$ ,  $p = 0.002$ ,  $CI = [0.13, 0.57]$ ; Table S2), which is in line with known distributions of these traits in the U.S. population (Markus & Kitayama, 1991). In addition, we examined whether self-construal varied by gender. On average, men and women did not differ in independent ( $t(85) = -1.22$ ,  $p = 0.226$ ,  $CI = [-0.46, 0.11]$ ), nor in interdependent self-construal ( $t(85) = 0.010$ ,  $p = 0.917$ ,  $CI = [-0.30, 0.33]$ ) in this sample.

*Self-construal differences in conformity.* Next, we aimed to examine whether these findings were consistent in our larger independent behavioral sample ( $N = 150$ ). Our fMRI results were replicated, such that a stronger interdependent self was associated with greater conformity ( $r(148) = 0.28$ ,  $p < 0.001$ ), whereas a stronger independent self was not ( $r(148) = 0.01$ ,  $p = 0.937$ ). There were no significant interactions between gender and self-construal on conformity ( $t(145) = 0.66$ ,  $p = 0.508$ ,  $CI = [-0.03, 0.07]$ ;  $t(145) = 0.77$ ,  $p = 0.445$ ,  $CI = [-0.03, 0.07]$ , respectively).

Finally, we examined whether significant differences existed between the proportion of trials in which participants changed their rating in response to social feedback that was opposite to their own opinion (32.63%) compared to the proportion of trials when they changed their rating in response to social feedback that was consistent but more extreme than theirs (36.56%). However, no significant differences were found,  $F(1,361)=0.46, p=.498$ . In addition, we examined whether these differences in conformity were correlated with self-construal. Similar to above, no significant relationships between conformity and independent SCS by initial ratings ( $F(1,318)=0.84, p=.361$ ) or interdependent SCS by initial ratings ( $F(1,318)=0.84, p=.359$ ) was found.

*Self-construal and gender associated with neural correlates of confirmatory and no social feedback.* Finally, we examined whether neural activity associated with positive valuation and mentalizing when receiving social feedback that confirmed participants opinions (*same*) and no social feedback compared to rest. However, no significant relationships were found,  $p>.05$ .

### **Whole Brain Analyses**

*Relationship between conformity, self-construal, and gender.* In addition to conducting our theory-driven region of interest (ROI) analyses, we conducted exploratory whole brain analyses to examine whether regions beyond our hypothesized ROIs were associated with neural responses to conformity, self-construal, and gender. Given our primary ROI findings were associated with the interaction between gender and self-construal on neural processes associated with conformity we focused on parallel analyses. First, we examined whether neural activity was significantly associated with the interaction between gender and self-construal when conforming to divergent social feedback compared to resisting conformity. Findings indicated that independent self-construal and gender are associated with activity in the precuneus, cingulate

cortex, and postcentral gyrus during conformity to divergent social feedback (compared to resisting conformity). In addition, interdependent self-construal and gender are associated with activity in the dorsolateral prefrontal cortex (dlPFC), precuneus, superior and middle temporal gyrus, and postcentral gyrus during conformity to divergent social feedback (compared to resisting conformity). Full results are reported in Table S5 and shown in Figure S5.

*Relationship between conformity and self-construal among women.* Next, we examined the main effect of self-construal on neural activity associated with conformity vs. resisting conformity (i.e., being misaligned with peers and conforming > being misaligned with peers and not conforming) by gender. Results examining the relationship between independent self-construal and conformity among women were consistent with our ROI analysis demonstrating decreased activation in parts of the mentalizing system including the dmPFC. Next, we examined the relationship between interdependent self-construal and conformity among women. Activity in the TPJ and parahippocampal gyrus increased among women participants who reported having a higher interdependent self-construal. Full results are reported in Table S6 and shown in Figure S6.

*Relationship between conformity and self-construal among men.* Finally, we examined the main effect of self-construal on neural processes associated with conformity vs. resisting conformity trials (i.e., being misaligned with peers and conforming > being misaligned with peers and not conforming) among men participants. Results indicated that men who reported a higher independent self-construal displayed increased activity in the precuneus, among other regions. Further, men who reported a higher interdependent self-construal displayed decreased activity in the dorsolateral prefrontal cortex (dlPFC) when conforming to social feedback that



suggested they were misaligned with others. Full results are reported in Table S7 and shown in Figure S7.

### **Future directions and limitations**

First, it should be noted that the cognitive processes being tested using NeuroSynth are broad networks that include multiple brain regions that serve other functions. Although, the NeuroSynth association test maps provide activation in neural regions that are consistently activated in research that report the cognitive function of interest compared to research that does not report the cognitive function, adjusting for the base rate of activation in each region (Yrkoni et al., 2011). The current study was not able to correlate the tested cognitive processes (valuation, mentalizing) during conformity with individual differences in reward sensitivity or mentalizing or Theory of Mind. Thus, conclusions drawn based on these cognitive processes may not be the only plausible explanations.

In addition, future research should continue to examine how congruency and incongruency between self-perceptions and societal norms influence mentalizing processing during conformity to social influence and explore whether these results extend to processes involved in persuasion. In addition, though the current study had large sample size, men and women were not evenly distributed, and we only had participants who self-identified as men or women (no other categories). Therefore, future studies should aim to collect data with an even distribution of men and women, and include people of other genders, given the importance of gender in our results. In addition, past research has linked self-construal with other demographic and identity categories, such as socioeconomic status (SES) (Imamoğlu & Karakitapoğlu-Aygün, 2004; Kohn, 1987) and nationality (Markus & Kitayama, 1991; Singelis & Sharkey, 1995; Triandis, 2018). Future studies should explore how additional demographic and identity

categories that relate to agency and communion, or independence and interdependence, interacts with their self-construal and societal norms to understand how these people process and reflect on divergent social feedback.

Finally, results from the current study highlight the importance of considering how individual differences may influence neural processes underlying conformity. Previous research finds activity in the dACC, SMA, and dmPFC is associated with conformity and these regions have typically been associated with conflict detection (Berns et al., 2005; Klucharev et al., 2009, 2011; Lee et al., 2022; Levorsen et al., 2021). However, findings on the broader mentalizing network in the current study, including activity in the dmPFC and TPJ among other regions, suggest that dmPFC activity could be associated with mentalizing, in addition to conflict detection. Future studies should aim to address this possibility using Theory of Mind and conflict detection localizer tasks alongside conformity tasks.

## Tables

Table S1. Behavioral conformity by social feedback condition

	<i>M</i>	<i>SD</i>	min	max
Feedback suggesting participants were misaligned	37.32%	18.67%	0%	92.50%
Feedback suggesting participants were aligned	7.53%	10.96%	0%	50.00%
Feedback suggesting the group has not rated the stimulus	13.35%	13.35%	0%	53.33%

*Note:* Proportion of times participants conformed to the different social feedback conditions.

Table S2. Self-construal sample characteristics

	<i>M</i>	<i>SD</i>	min	max
Independence	5.12	0.63	3.20	6.47
Men	5.24	0.45	4.07	6.20
Women	5.07	0.69	3.20	6.47
Interdependence	4.77	0.68	2.33	6.20
Men	4.76	0.66	2.67	5.80
Women	4.78	0.69	2.33	6.20

*Note:* Self-construal items were rated from 1 “strongly disagree” to 7 “strongly agree”, where higher scores represented stronger independence and interdependence.

Table S3. Regions of interest associated with independent self-construal and gender

Variable	<i>t</i> (82)	<i>p</i>	<i>p</i> (FDR)	95% CI
Value Regions				
Independent SCS	2.21	0.030	0.060	[0.02, 0.22]
Gender	-1.58	0.118	0.118	[-0.09, 0.01]
Independent SCS x Gender	3.33	0.001	0.004	[0.07, 0.27]
Study Cohort	1.79	0.078	0.104	[-0.00, 0.09]
Mentalizing Regions				
Independent SCS	1.19	0.236	0.236	[-0.05, 0.20]
Gender	-1.35	0.181	0.236	[-0.10, 0.02]
Independent SCS x Gender	2.85	0.006	0.012	[0.05, 0.31]
Study Cohort	2.91	0.005	0.012	[0.03, 0.14]

*Note:* Regression models examining (ROI = SCS + gender + (SCS \* gender) + study cohort). *P*-values are presented with and without FDR correction.

Table S4. Regions of interest associated with interdependent self-construal and gender

Variable	<i>t</i> (82)	<i>p</i>	<i>p</i> (FDR)	95% CI
Value Regions				
Interdependent SCS	-0.40	0.691	0.691	[-0.09, 0.06]
Gender	-0.72	0.476	0.634	[-0.07, 0.03]
Interdependent SCS x Gender	-1.28	0.203	0.406	[-0.13, 0.03]
Study Cohort	1.37	0.174	0.406	[-0.02, 0.08]
Mentalizing Regions				
Interdependent SCS	-0.81	0.422	0.433	[-0.13, 0.05]
Gender	-0.79	0.433	0.433	[-0.09, 0.04]
Interdependent SCS x Gender	-2.18	0.032	0.064	[-0.19, -0.01]
Study Cohort	2.67	0.009	0.036	[0.02, 0.13]

Note: Regression models examining (ROI = SCS + gender + (SCS \* gender) + study cohort). *P*-values are presented with and without FDR correction.

Table S5. Relationship between self-construal x gender during conformity

Independent Self-Construal x Gender						
Region	Hemisphere	x	y	z	k	t
precuneus	R/L	-2	-50	55	239	-5.16
cingulate cortex	R/L	11	-23	55	71	-3.82
postcentral gyrus	L	-44	-33	55	167	-3.89
Interdependent Self-Construal x Gender						
Region	Hemisphere	x	y	z	k	t
dIPFC	R	29	26	40	96	4.26
dIPFC	L	-40	32	46	131	5.14
precuneus	R	18	-57	40	80	4.03
precuneus	R/L	-2	-81	49	57	4.19
superior temporal gyrus	L	-37	-40	10	58	4.26
middle temporal gyrus	L	-44	-60	1	81	3.90
middle temporal gyrus	R	46	-47	1	160	4.70
postcentral gyrus	R	46	-12	28	51	4.33
cerebellum	R	32	-36	-38	56	4.25
cerebellum	L	-9	-81	-20	63	3.88
cerebellum	R	32	-71	-23	68	3.68
cerebellum	R/L	-6	-43	-2	61	3.91

Note: Exploratory whole brain analyses examining the interaction between self-construal and gender when conforming to divergent social feedback compared to resisting conformity,  $p=0.001$ ,  $k>50$ , uncorrected. Significant activity did not survive false discovery rate (FDR),  $p<.05$ ,  $k>5$ .

Table S6. Relationship between self-construal and conformity among women

<b>Independent Females</b>						
<b>Region</b>	<b>Hemisphere</b>	<b>x</b>	<b>y</b>	<b>z</b>	<b>k</b>	<b>t</b>
dmPFC	R/L	5	60	34	62	-4.45
dmPFC	L	-13	26	61	76	-4.47
<b>Interdependent Females</b>						
<b>Region</b>	<b>Hemisphere</b>	<b>x</b>	<b>y</b>	<b>z</b>	<b>k</b>	<b>t</b>
TPJ	L	-26	-16	-23	62	4.25
parahippocampal gyrus	L	-37	-30	-5	78	4.35

*Note:* Exploratory whole brain analyses examining the interaction between self-construal when conforming to divergent social feedback compared to resisting conformity among women. Uncorrected at  $p=0.001$ ,  $k>50$ . Significant activity did not survive false discovery rate (FDR),  $p<.05$ ,  $k>5$ .

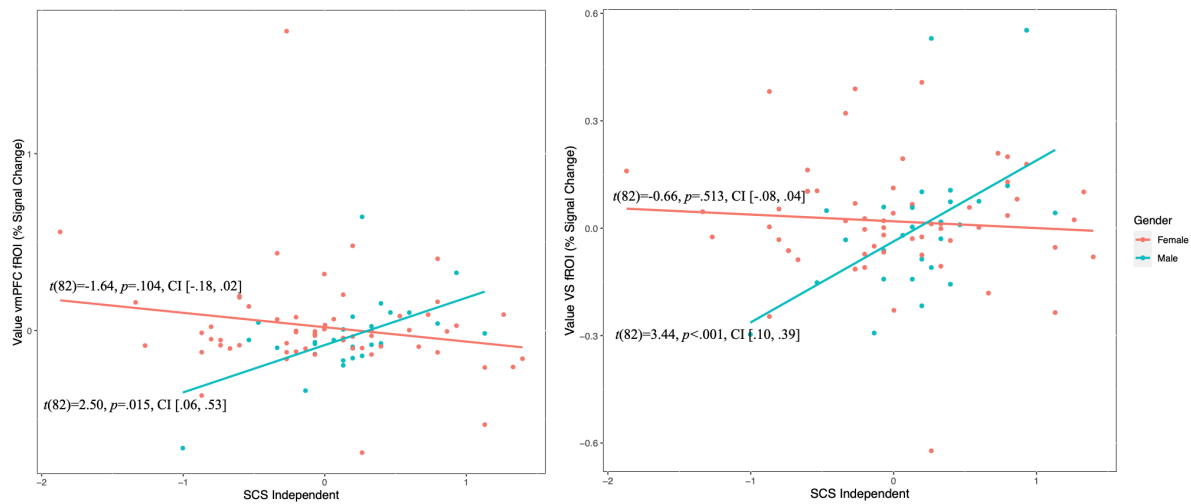
Table S7. Relationship between conformity and self-construal among men.

<b>Independent Males</b>						
<b>Region</b>	<b>Hemisphere</b>	<b>x</b>	<b>y</b>	<b>z</b>	<b>k</b>	<b>t</b>
precuneus	R/L	-2	-50	55	96	4.35
SMA	R	11	-23	55	50	3.98
<b>Interdependent Males</b>						
<b>Region</b>	<b>Hemisphere</b>	<b>x</b>	<b>y</b>	<b>z</b>	<b>k</b>	<b>t</b>
dIPFC	L	-40	32	46	105	-4.57

*Note:* Exploratory whole brain analyses examining the interaction between self-construal when conforming to divergent social feedback compared to resisting conformity among men. Uncorrected at  $p=0.001$ ,  $k>50$ . Significant activity did not survive false discovery rate (FDR),  $p<.05$ ,  $k>5$ .

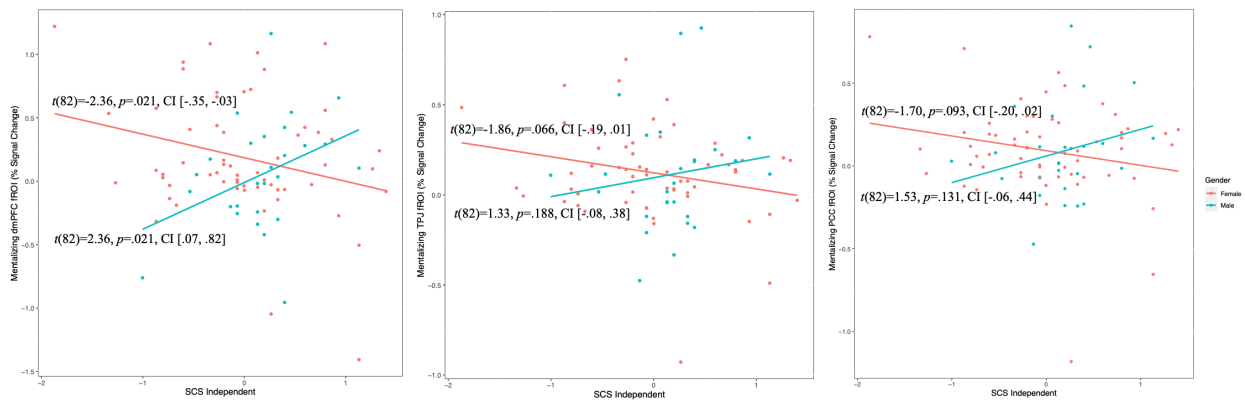
## Figures

Figure S1. Value ROI subregions and independent self-construal by gender



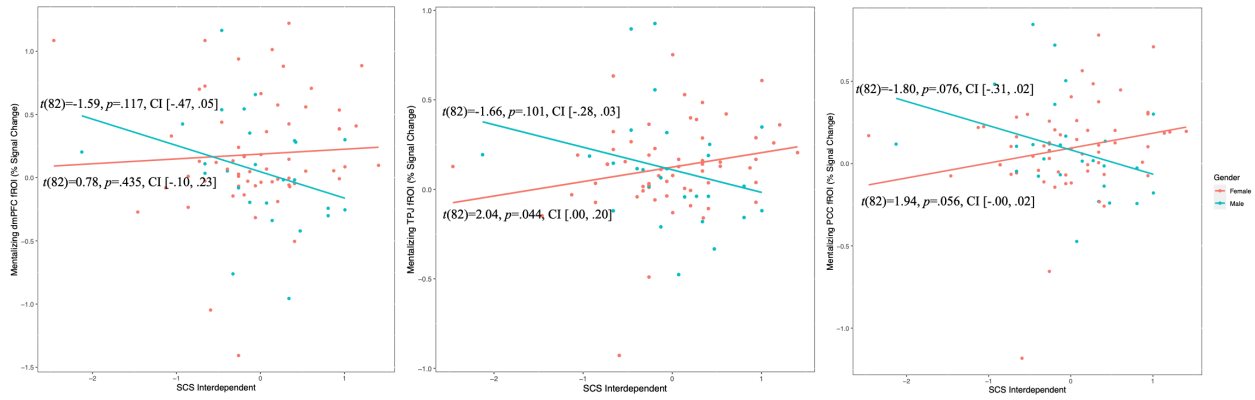
*Note:* Interaction between gender, independent self-construal and brain subregions tracking subjective value, including the vmPFC ( $t(82)=2.94$ ,  $p=0.004$ ,  $p(FDR)=0.016$ ,  $CI=[0.06, 0.32]$ ) and VS ( $t(82)=3.42$ ,  $p<0.001$ ,  $p(FDR)=0.004$ ,  $CI=[0.06, 0.21]$ ).

Figure S2. Mentalizing ROI subregions and independent self-construal by gender



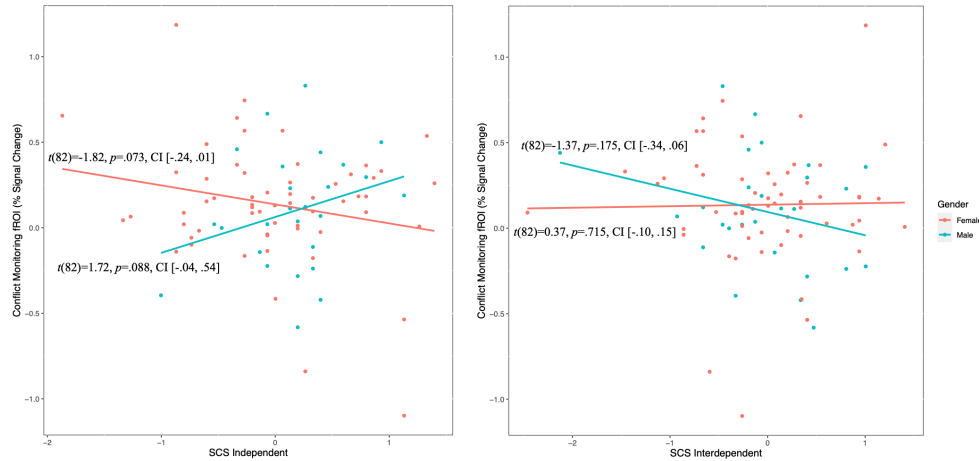
*Note:* Interaction between gender, independent self-construal and brain subregions tracking mentalizing, including the dmPFC ( $t(82)=3.10$ ,  $p=0.003$ ,  $p(FDR)=0.010$ ,  $CI=[0.11, 0.52]$ ), TPJ ( $t(82)=1.95$ ,  $p=0.054$ ,  $p(FDR)=0.108$ ,  $CI=[-0.00, 0.25]$ ), and PCC ( $t(82)=2.07$ ,  $p=0.042$ ,  $p(FDR)=0.168$ ,  $CI=[0.01, 0.28]$ ).

Figure S3. Mentalizing ROI subregions and interdependent self-construal by gender



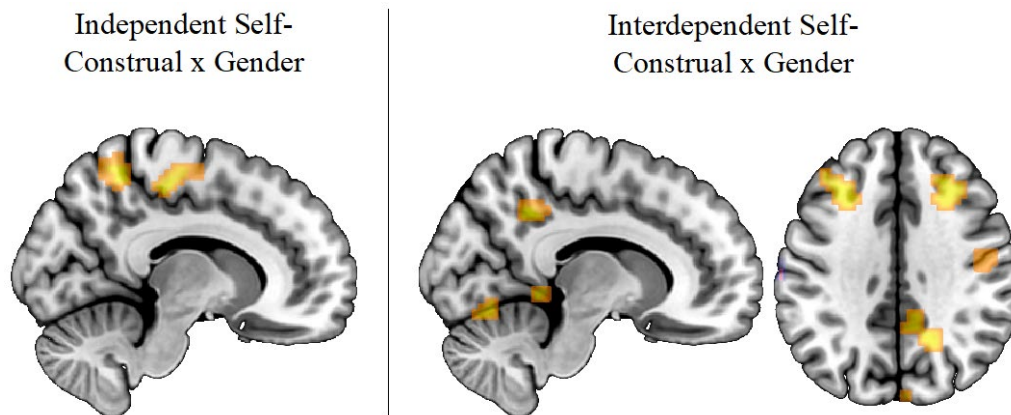
*Note:* Interaction between gender, interdependent self-construal and brain subregions tracking mentalizing, including the dmPFC ( $t(82) = -1.76, p = 0.082, p(FDR) = 0.164, CI = [-0.29, 0.02]$ ), TPJ ( $t(82) = -2.50, p = 0.015, p(FDR) = 0.030, CI = [-0.20, -0.02]$ ), and PCC ( $t(82) = -2.56, p = 0.013, p(FDR) = 0.052, CI = [-0.22, -0.03]$ ).

Figure S4. Conflict Monitoring ROI and self-construal by gender



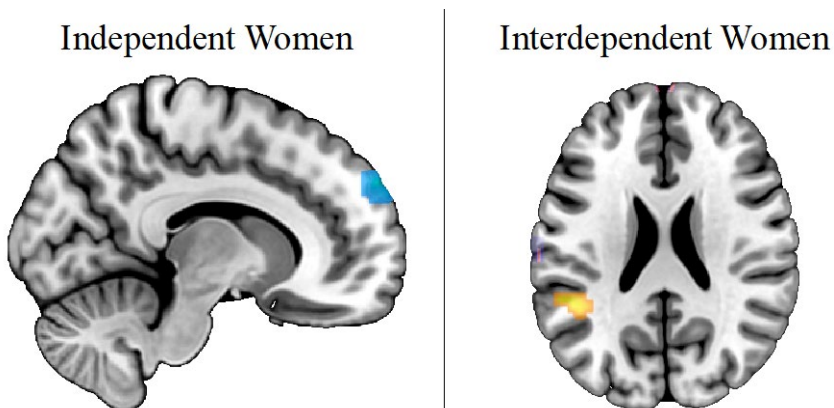
*Note:* Interaction between gender and self-construal (independent, interdependent) and brain regions tracking conflict monitoring (independent ( $t(82) = 2.30, p = 0.024, p(FDR) = .096, CI = [0.02, 0.34]$ ); interdependent ( $t(82) = -1.35, p = 0.181, p(FDR) = .362, CI = [-0.20, 0.04]$ )).

Figure S5. Relationship between self-construal x gender during conformity



*Note:* Exploratory whole brain analyses examining the interaction between self-construal and gender when conforming to divergent social feedback compared to resisting conformity,  $p=0.001$ ,  $k>50$ , uncorrected. Significant activity did not survive false discovery rate (FDR),  $p<.05$ ,  $k>5$ .

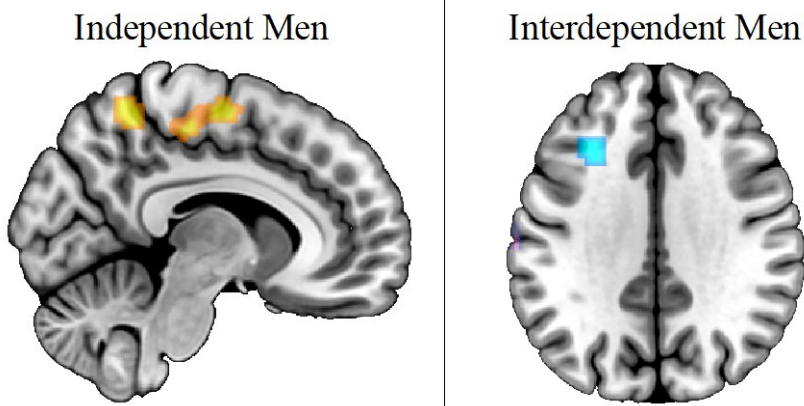
Figure S6. Relationship between self-construal and conformity among women



*Note:* Exploratory whole brain analyses examining the interaction between self-construal when conforming to divergent social feedback compared to resisting conformity among women,  $p=0.001$ ,  $k>50$ , uncorrected. Significant activity did not survive false discovery rate (FDR),  $p<.05$ ,  $k>5$ .



Figure S7. Relationship between conformity and self-construal among men.



*Note:* Exploratory whole brain analyses examining the interaction between self-construal when conforming to divergent social feedback compared to resisting conformity among men,  $p=0.001$ ,  $k>50$ , uncorrected. Significant activity did not survive false discovery rate (FDR),  $p<.05$ ,  $k>5$ .

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