Supplemental Information

Title: Common neural responses to romantic rejection and acceptance in healthy adults

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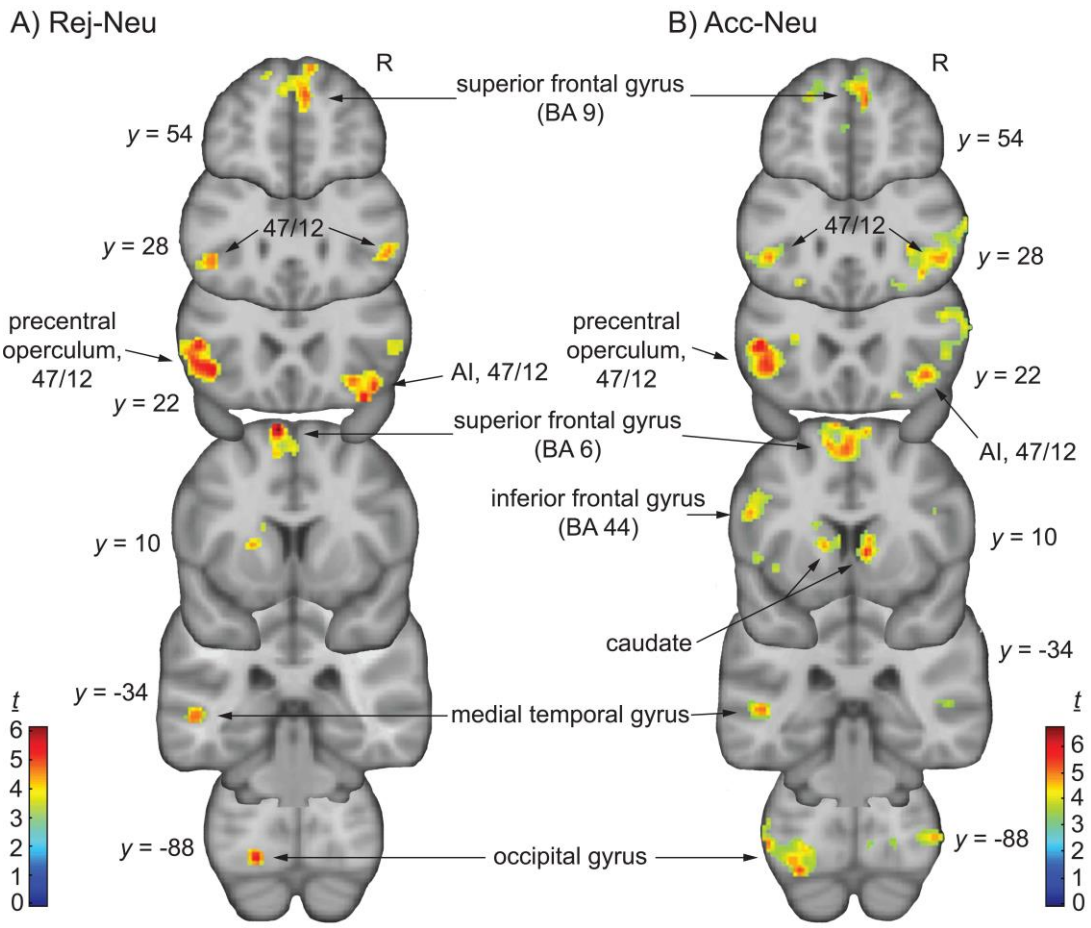
Supplemental Data

Contrast	Region	Brodmann Area	*MNI coordinates (x,y,z) mm*	k_E *(voxels)*	*t*
Rejection -Neutral (Rej-Neu)	L Superior Frontal Gyrus	6	*-8, 10, 68*	240	6.13
	L Ventrolateral Prefrontal Cortex (vlPFC) (includes Operculum)	47/12	*-42, 22, -4*	475	5.46
	R Superior Frontal Gyrus	9	*10, 50, 44*	549	5.46
	L Occipital Gyrus	18	*-20, -88, -12*	60	5.36
	R vlPFC/Anterior Insula (AI)	47/12	*28, 18, -12*	220	5.28
	R Occipital Gyrus	19	*28, -84, -18*	23	4.83
	L Medial Temporal Gyrus	21	*-54, -30, -4*	154	4.82
	L Medial Frontal Gyrus	6	*-44, 0, 52*	155	4.77
	R vlPFC	47/12	*50, 28, 2*	111	4.49
	L Supramarginal Gyrus	39	*-56, -50, 30*	38	4.37
	L Putamen		*-22, 10, 8*	19	4.30
	R Superior Frontal Gyrus	6	*10, 22, 62*	32	4.28
	L Occipital Gyrus	19	*-34, -70, -18*	22	4.26
	L Precentral Gyrus	6	*-46, -2, 36*	14	3.96
	L Superior Frontal Gyrus	8	*-10, 36, 50*	14	3.96
	L Medial Temporal Gyrus	21	*-46, -48, 10*	18	3.94
	L Caudate		*-16, 4, 18*	18	3.92
	L Cerebellum		*-14, -82, -22*	10	3.78
Acceptance -Neutral (Acc-Neu)	L Occipital Gyrus	19	*-30, -78, -12*	958	6.72*
	L Inferior Frontal Gyrus	45	*-48, 22, 8*	1303	5.93
	includes L vlPFC (Operculum)	47/12	*-42, 20, -2*		5.60
	R vlPFC (includes AI)	47/12	*40, 24, -6*	740	5.58
	R Caudate		*8, 8, 2*	220	5.48
	L Superior Temporal Gyrus	21	*-54, -44, 8*	238	5.33
	R Superior Frontal Gyrus	9	*8, 54, 24*	236	5.12
	L Superior Frontal Gyrus	6	*-2, 10, 58*	613	5.12
	L Caudate		*-14, 12, 6*	200	4.92
	L Fusiform Gyrus	37	*-38, -46, -16*	75	4.82
	R Superior Frontal Gyrus	8	*12, 20, 38*	15	4.80
	Cerebellum		*0, -54, -32*	43	4.69
	R Fusiform Gyrus	37	*32, -52, -16*	95	4.62
	R Occipital Gyrus	18	*24, -92, 2*	336	4.59
	L Superior Frontal Gyrus	10	*-22, 54, 26*	58	4.51
	L Caudate		*-16, -2, 20*	66	4.41
	L Superior Frontal Gyrus	9	*-2, 40, 28*	151	4.38
	R Superior Temporal Gyrus	22	*50, -18, -8*	75	4.37
	L Posterior Orbital Gyrus	47	*-26, 26, -16*	13	4.26

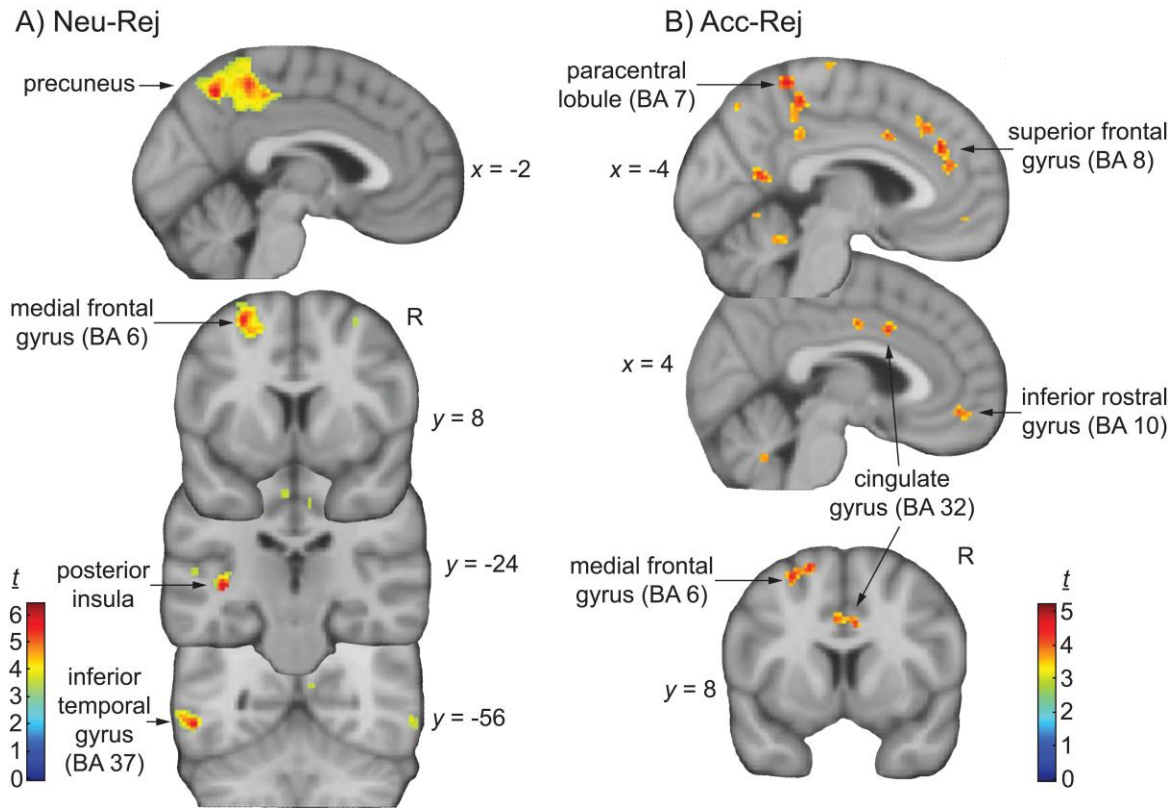
	L Superior Frontal Gyrus	8	*-14, 40, 48*	54	4.16
	L Frontal Operculum	45	*-30, 24, 14*	11	4.11
	R Precentral Gyrus	6	*54, -4, 38*	15	3.96
	R Superior Frontal Gyrus	8	*8, 40, 48*	15	3.92
	R Precentral Gyrus	44	*46, 6, 26*	10	3.91
	L Substantia Nigra		*-8, -12, -16*	12	3.90
	L Sup. Transverse Frontopolar	10	*-2, 58, 10*	24	3.85
	Gyrus	17	*8, -94, 0*	24	3.78
	R Occipital Gyrus	39	*-46, -50, 28*	14	3.75
	L Superior Temporal Gyrus	6	*42, 2, 40*	21	3.68
	R Precentral Gyrus		*-20, -4, -12*	17	3.66
	L Amygdala	6	*46, 6, 50*	11	3.54
	R Precentral Gyrus				
Neu-Rej	L Precuneus	7	*-4, -60, 48*	1705	6.41*
	L Posterior Insula	13	*-38, -24, 0*	82	5.75
	L Inferior Temporal Gyrus	37	*-56, -56, -6*	158	5.51
	L Medial Frontal Gyrus	6	*-28, 8, 58*	204	5.42
	R Parietooccipital Area	39	*46, -72, 40*	50	4.57
	L Parietooccipital Area	19	*-42, -82, 26*	58	4.43
	R Postcentral Gyrus	1	*30, -42, 62*	33	4.25
	L Parietal Operculum	40	*-48, -34, 20*	63	4.19
	R Medial Temporal Gyrus	37	*58, -54, -2*	27	4.17
	L Parietal Operculum	41	*-66, -12, 10*	60	4.15
	R Medial Frontal Gyrus	6	*30, 12, 54*	12	4.13
	L Parietooccipital Transition Zone	19	*-34, -86, 36*	12	4.10
	L Parahippocampal Gyrus	36	*-32, -42, -8*	22	4.05
	L Angular Gyrus	39	*-38, -52, 38*	10	4.01
	L Occipital Gyrus	18	*-12, -68, 24*	45	3.95
	R Superior Frontal Gyrus	9	*28, 38, 36*	20	3.90
	R Superior Frontal Gyrus	31	*8, -22, 44*	10	3.86
	R Superior Parietal Lobule	7	*16, -48, 70*	31	3.80
	R Precuneus	31	*8, -60, 18*	15	3.74
	R Superior Frontal Gyrus	6	*18, -6, 68*	11	3.74
Neu-Acc	R Precuneus	31	*6, -44, 52*	17	4.08
	R Superior Frontal Gyrus	6	*28, 20, 62*	10	3.85
Rej-Acc	*No clusters*				
Acc-Rej	L Paracentral Lobule	7	*-6, -46, 66*	260	5.21
	R Medial Temporal Gyrus	37	*58, -54, -4*	36	5.02
	L Parietooccipital Transition Zone	19	*-40, -86, 24*	28	4.82
	L Superior Frontal Gyrus	8	*-2, 36, 30*	69	4.77
	L Medial Frontal Gyrus	44	*-40, 14, 28*	35	4.62
	R Inferior Frontal Gyrus	45	*60, 30, 12*	13	4.60
	R Cingulate Gyrus	24	*6, -8, 38*	45	4.58
	R Intermediate Orbital Gyrus	11	*20, 42, -12*	17	4.52
	L Superior Parietal Lobule	7	*-18, -42, 62*	49	4.42
	L Superior Frontal Gyrus	8	*-24, 34, 46*	13	4.38
	L Medial Frontal Gyrus	6	*-28, 8, 58*	73	4.34
	L Superior Parietal Lobule	7	*-6, -72, 52*	16	4.32
	L Pretectal Area		*-8, -30, -8*	19	4.29
	L Cingulate Gyrus	23	*-4, -58, 14*	110	4.26
	R Cingulate Gyrus	32	*6, 8, 34*	55	4.25
	L Parietal Operculum	40	*-42, -32, 22*	37	4.22

L Superior Frontal Gyrus	6	*-10, -18, 64*	21	4.16
L Fusiform Gyrus	19	*-10, -64, -8*	24	4.10
L Cerebellum		*-10, -50, -22*	57	4.09
R Inferior Rostral Gyrus	10	*12, 48, -10*	97	4.08
L Superior Frontal Gyrus	8	*-4, 30, 40*	34	4.03
L Superior Temporal Gyrus	22	*-66, -40, 18*	14	4.01
L Precentral Gyrus	8	*-34, 2, 32*	13	3.99
L Caudate		*-8, 14, 0*	18	3.95
L Parietooccipital Transition Zone	7	*-28, -80, 42*	12	3.93
R Superior Frontal Gyrus	6	*24, -2, 62*	11	3.91
L Cerebellum		*-18, -40, -24*	13	3.90
L Occipital Gyrus	18	*-40, -90, 6*	15	3.90
R Frontal Operculum	44	*44, 16, 4*	14	3.87
R Cerebellum		*4, -54, -34*	16	3.79
R Cingulate Gyrus	32	*10, 18, 36*	11	3.77
L Cingulate Gyrus	23	*-4, -38, 36*	21	3.77
R Frontal Operculum	1	*44, -16, 18*	17	3.70
L Superior Frontal Gyrus	6	*-2, -20, 74*	16	3.68

Supplemental Table S1. Activation in the entire brain (no masking) in the entire sample (n = 36). One-sample t-tests were performed for each contrast, controlling for sex and age. Whole-brain uncorrected threshold was set at $P < 0.001$ with minimum extent threshold of $k_E > 10$ voxels. Voxel-wise peaks are listed in MNI standard space (Montreal Neurological Institute). *Whole-brain family-wise error (FWE)-corrected $P < 0.05$ (2-tailed).



Supplemental Fig. S1. Distribution of neural activation. A) Rej-Neu and B) Acc-Neu contrasts (controlling for sex and age) from Table S1. R, right; Coordinates in Montreal Neurological Institute stereotactic space. Contrast *t* map displayed at $P < 0.001$ (one-sample *t*-tests, whole-brain uncorrected, no masking), $k_E > 10$.



Supplemental Fig. S2. Distribution of neural activation. A) Neu-Rej and B) Acc-Rej contrasts (controlling for sex and age) from Table S1. R, right; Coordinates in Montreal Neurological Institute stereotactic space. Contrast *t* map displayed at $P < 0.001$ (one-sample *t*-tests, whole-brain uncorrected, no masking), $k_E > 10$.

Activation in the precuneus

An exploration of significant whole-brain voxel-wise activation ($k_E > 10$, whole-brain FWE-corrected $P < 0.05$, two-tailed) yielded an unexpected finding of significant *de*activation in the left precuneus during rejection (Neu-Rej) ($t = 6.41$, $P_{FWE\text{-}whole\text{-}brain} = 0.034$; $k_E = 1705$; peak activation: *-4, -60, 48*; **Table S1, Fig. S2C**). Previous work has shown that the precuneus, which is part of the "default mode" network[1], is involved in self-related mental representations during rest[2] and reflection of one's own personality traits[2]. Thus, it is possible that during Neu blocks, when participants are viewing their own picture plus a picture of a person who had "not completed" their ratings, participants were left with more of an opportunity for self-reflection compared to blocks when they were rejected. Although it is not clear why activation in the precuneus was not found during Neu-Acc, it is possible that being accepted caused more first-person self-reflection similar to Neu, whereas being rejected caused more engagement of goal-directed actions, which is associated with reductions in default mode of brain function[1]. Given that the finding in the precuneus was unexpected, and no data on self-reflection was collected, our interpretation of this finding is speculative and requires further study.

Contrast	ROI	*MNI coordinates (x,y,z) mm*	*t*	k_E *(voxels)*	$P_{unadjusted}$	$P_{adjusted}$
Rej-Neu	L Dorsal Anterior Cingulate Cortex (dACC)	*No clusters*				
	R dACC	*No clusters*				
	L vlPFC	*-42, 22, -4*	5.46	131	0.0018	0.036*
	R vlPFC	*38, 22, -20*	5.24	190	0.0032	*ns*
	L AI	*-40, 20, -4*	4.91	12	0.0032	*ns*
	R AI	*28, 18, -12*	5.28	20	0.0013	0.026*
	L Nucleus Accumbens (NAcc)	*No clusters*				
	R NAcc	*No clusters*				
	L Amygdala (AMY)	*No clusters*				
	R AMY	*No clusters*				
Acc-Neu	L dACC	*-2, 36, 26*	3.77	16	0.049	*ns*
	R dACC	*10, 18, 36*	3.81	4	0.063	*ns*
	L vlPFC	*-42, 20, -4*	5.53	125	0.0016	0.032*
	R vlPFC	*40, 24, -6*	5.58	299	0.0014	0.028*
	L AI	*-40, 20, -2*	5.36	59	0.0010	0.020*
	R AI	*38, 22, -4*	4.36	39	0.0124	*ns*
	L NAcc	*No clusters*				
	R NAcc	*8, 10, -2*	3.77	6	0.0106	*ns*
	L AMY	*-20, -4, -12*	3.66	15	0.037	*ns*
	R AMY	*No clusters*				
Neu-Rej	*No clusters within any ROI mask*					
Neu-Acc	*No clusters within any ROI mask*					

Supplemental Table S2. Activation in individual ROI masks in the entire sample (n = 36). One-sample t-tests were performed for each contrast, controlling for sex and age. Whole-brain uncorrected threshold was set at $P < 0.001$ with minimum extent threshold of $k_E > 10$ voxels, followed by small volume correction for each ROI mask (K_E values in some ROI masks were less than 10 if clusters spread across more than one ROI mask). Voxel-wise peaks are listed in MNI standard space (Montreal Neurological Institute). P values (FWE-small volume corrected, SVC) are listed as unadjusted, or Bonferroni-adjusted for a two-tailed test (x2) across 10 ROI masks (x10). *No clusters* indicate no clusters present at the set threshold; *$P < 0.05$; *ns*, not significant.

Relationship Status

Similar to our previous study[3], relationship status was examined by comparing those who were single (n = 24) with those who were in a relationship or married (n = 11). Group-level, voxel-wise two-sample t-tests were conducted for each contrast. No significant clusters were found in the ROI mask (threshold $P_{FWE\text{-}SVC} < 0.05$), or in the whole brain (threshold $P_{FWE\text{-}whole\text{-}brain} < 0.05$).

Region	Brodmann Area	Center of mass, MNI coordinates *(x, y, z)*	*Voxels*
L vlPFC (includes Precentral Operculum)	47/12	*-48, 20, 5*	385
	47/12	*49, 27, 4*	92
R vlPFC (includes Precentral Operculum)	47/12	*37, 24, -9*	70
R vlPFC (includes AI)			
R Superior Frontal Gyrus	9/10	*4, 54, 29*	182
L Superior Frontal Gyrus	6/8	*-7, 10, 63*	177
L Medial Frontal Gyrus	6	*-43, -1, 52*	105
L Middle and Superior Temporal Gyrus	22/21	*-51, -36, 1*	71
L Occipital Gyrus	18	*-23, -86, -11*	50
L Superior Frontal Gyrus	8	*-10, 48, 44*	15

Supplemental Table S3. Conjunction of Rej-Neu & Acc-Neu contrasts controlling for sex and age (whole-brain, no masking).

Contrast	Region	Brodmann Area	Center of mass, MNI coordinates *(x, y, z)*	*Voxels*
Rej-Neu	Superior Frontal Gyrus	9	*0, 51, 37*	344
	R vlPFC (includes AI)	47/12	*35, 21, -14*	150
	L Medial Temporal Gyrus	21	*-52, -33, -3*	83
	L Interior Frontal Gyrus	45	*-54, 21, 1*	64
	L Superior Frontal Gyrus	6	*-9, 17, 61*	56
	L Medial Frontal Gyrus	6	*-48, 4, 51*	47
	L Superior Temporal Gyrus	39	*-57, -48, 29*	34
	R Superior Frontal Gyrus	6	*9, 25, 61*	31
	L Putamen		*-21, 9, 8*	18
	R Inferior Frontal Gyrus	45	*55, 24, 5*	15
	L Superior Temporal Gyrus	21	*-48, -49, 11*	14
	L vlPFC (includes Precentral Operculum)	47/12	*-42, 23, -9*	11
Acc-Neu	L Occipital Gyrus	18	*-35, -83, -7*	896
	L Precentral Gyrus	44	*-45, 9, 25*	798
	R vlPFC (includes Precentral Operculum)	47/12	*43, 27, 1*	578
		6	*-1, 12, 58*	433
	L Superior Frontal Gyrus	18	*33, -90, -2*	321
	R Occipital Gyrus		*10, 11, 6*	220
	R Caudate		*-9, 5, 6*	199
	L Caudate	21	*-50, -40, 6*	163
	L Superior Temporal Gyrus	32	*-4, 39, 25*	151
	L Cingulate Gyrus	37	*35, -53, -20*	95
	R Fusiform Gyrus	37	*-38, -50, -17*	75
	L Fusiform Gyrus	22	*49, -26, -1*	75
	R Superior Temporal Gyrus	10	*-18, 55, 29*	58
	L Superior Frontal Gyrus		*-17, 1, 20*	55
	L Caudate		*1, -53, -35*	43
	R Cerebellum	8	*-13, 39, 48*	33
	L Superior Frontal Gyrus	10	*7, 60, 17*	27
	R Frontopolar Gyrus	10	*-1, 58, 9*	24

L Frontopolar Gyrus	17	*8, -93, -2*	24
R Striate Area	6	*42, 4, 40*	21
R Precentral Gyrus		*-20, -5, -13*	17
L Amygdala	8	*10, 19, 38*	15
R Superior Frontal Gyrus	6	*54, -4, 39*	15
R Medial Frontal Gyrus	47/12	*-26, 27, -15*	13
L vlPFC		*-7, -14, -16*	12
L Substantia Nigra	45	*-29, 23, 12*	11
L Frontal Operculum	8	*48, 7, 50*	11
R Medial Frontal Gyrus			

Supplemental Table S4. Non-overlapping clusters of Rej-Neu & Acc-Neu contrasts controlling for sex and age (whole-brain, no masking).

Supplemental Methods

The SFT did not involve deception, however participants were asked to imagine that the profiles they were rating and the feedback they received were real. A previous study showed that social exclusion was aversive even when participants knew that they were being excluded by a computer during Cyberball, or when they knew that others (unseen and unmet) were following a script to exclude them[4]. In several pilot studies, we maximized the emotional impact of the SFT without using deception by 1) having participants pre-select their most-liked profiles, thus personalizing the task for each participant and 2) having participants submit their own photo, which was presented during the task (**Fig. 1**). These procedures helped to create an immersive experience and made it easy for participants to access genuine emotional responses from the feedback, without using deception. Our manipulation checks (see Results) showed that without deception, the mean response was above "moderately" for all three manipulation check questions, suggesting that the SFT produced emotional responses that were more than moderately similar to real-life situations. The SFT without deception has been used in our previous studies[3,5–7]. To ensure that participants understood the meaning of the feedback, participants were given the following instructions prior to performing the task:

> 'You will see a picture of yourself, followed by a picture of someone you liked. Below his/her picture, you will see whether or not s/he likes you, based on your picture and the information that you provided about yourself. His/her answer to the question "Would I like this person?" are categorized as follows:
>
> "very likely no" or "definitely no" = this person does not like you.
> "very likely yes" or "definitely yes" = this person likes you.
> "not completed" = this person left the study early and did not complete the profile ratings.'

References

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