

## Supplementary Material

Amygdala-midbrain connectivity indicates a role for the mammalian parental care system in  
human altruism

**Published in:** *Proceedings of the Royal Society B – Biological Sciences*

**Article DOI:** 10.1098/rspb.2017.1131

**Authors:** Kristin M. Brethel-Haurwitz<sup>a,1</sup>, Katherine O’Connell<sup>b</sup>, Elise M. Cardinale<sup>c</sup>, Maria Stoianova<sup>c</sup>, Sarah A. Stoycos<sup>d</sup>, Leah M. Lozier<sup>b</sup>, John W. VanMeter<sup>e</sup>, & Abigail A. Marsh<sup>c</sup>

### **Affiliations:**

<sup>a</sup>Department of Psychology, University of Pennsylvania, Philadelphia, PA 19104, USA

<sup>b</sup>Interdisciplinary Program in Neuroscience, Georgetown University Medical Center  
Washington, DC 20007, USA

<sup>c</sup>Department of Psychology, Georgetown University, Washington, DC 20057, USA

<sup>d</sup>Department of Psychology, University of Southern California, Los Angeles, CA 90089, USA

<sup>e</sup>Department of Neurology, Georgetown University Medical Center, Washington, DC 20007,  
USA

<sup>1</sup>Correspondence to: [kbreth@sas.upenn.edu](mailto:kbreth@sas.upenn.edu)

**Supplemental Text:**

The care-eliciting scenarios task administered during fMRI scanning was previously validated in a separate sample of 55 healthy adults (39 female), age 18-25 ( $M = 19.82$ ,  $SD = 1.42$ ). Participants completed sequences of preattentive facial expression/lexical decision-making tasks and read and responded with sympathy ratings to brief scenarios. Each participant read 40 scenarios, each describing a stranger in a situation designed to be care-eliciting or not. Scenarios were adapted from an earlier behavioural version of this paradigm (34). Scenarios were followed by question blocks, in which participants reported how much *sympathy* they felt for the protagonist on a 1 to 7 scale. Prior to viewing each scenario, participants were presented with preattentive fearful or neutral facial expressions in the context of a lexical decision task (deciding whether a string of letters formed a real or nonsense word via button press—this task was included to provide a cover story for the emotional expressions). Word type was presented randomly. Affectively neutral letter strings were selected from the ANEW database of words (70). Each string of letters was preceded by either a fearful or neutral facial expression that was presented for 25 milliseconds (71) and immediately backwards masked by a 75 millisecond face scramble. Expressions were drawn from the Pictures of Facial Affect stimulus set (72). Participants completed blocks of eight facial expression sequences before each scenario. All expressions within each block were either fearful or neutral. Letter string, scenario, and question durations were determined by participant response latencies. This task structure resulted in two sets of 40 scenarios, half of which were care-eliciting and half of which were distractors, and each scenario type was further divided equally by preceding expression type. Each participant read 40 scenarios, with half of the participants completing each version, resulting in ratings for

the 80 total scenarios that were presented to fMRI participants. Presentation of the four scenario types was randomly ordered.

Sympathy ratings were analysed via repeated-measures ANOVA. There was a main effect of expression,  $F(1, 54) = 35.66, P < 0.001, \eta^2 = 0.398$ , main effect of scenario,  $F(1, 54) = 256.39, P < 0.001, \eta^2 = 0.826$ , and an expression x scenario interaction,  $F(1, 54) = 114.65, P < 0.001, \eta^2 = 0.680$ . Sympathy ratings were significantly higher for care-eliciting scenarios than for neutral scenarios, and sympathy ratings were also higher for scenarios preceded by fearful expressions than by neutral expressions (Table S5). Importantly, sympathy ratings were higher for care-eliciting scenarios preceded by fearful expressions than care-eliciting scenarios preceded by neutral expressions,  $t(54) = 11.46, P < 0.001$ .

In this validation sample, three subjects reported a diagnosis of a mood or anxiety disorder (1 generalized anxiety disorder, 1 anxiety and depression, 1 depression), two of which were on psychiatric medications (paroxetine and fluoxetine), and a fourth subject reported current use of a narcotic painkiller (oxycodone). The pattern of results remains the same after the removal of these four subjects. This task was adapted for fMRI scanning, such that four expressions were presented prior to each scenario during the fMRI task rather than eight and sympathy was rated on a 4-point scale.

**Supplemental Figure Legends:**

**Fig. S1.** Task structure of implicit facial expression portion of task.

**Fig. S2.** Sympathy difference scores are associated with greater neural activation in altruists than controls for care-eliciting scenarios preceded by fearful expressions versus neutral expressions.

Axial:  $z = -23$  to  $z = 51$ , in increments of 6mm. Sagittal:  $x = -6$ . Colour bar =  $t$  value. Clusterwise corrected threshold  $P < 0.05$ . Left = left.

Fig. S1.

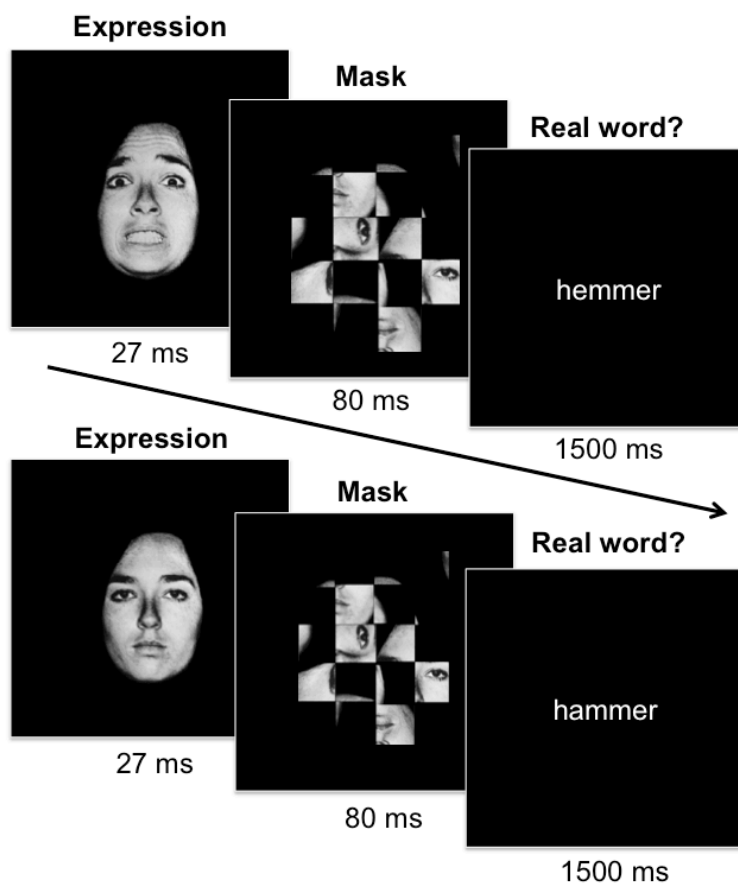
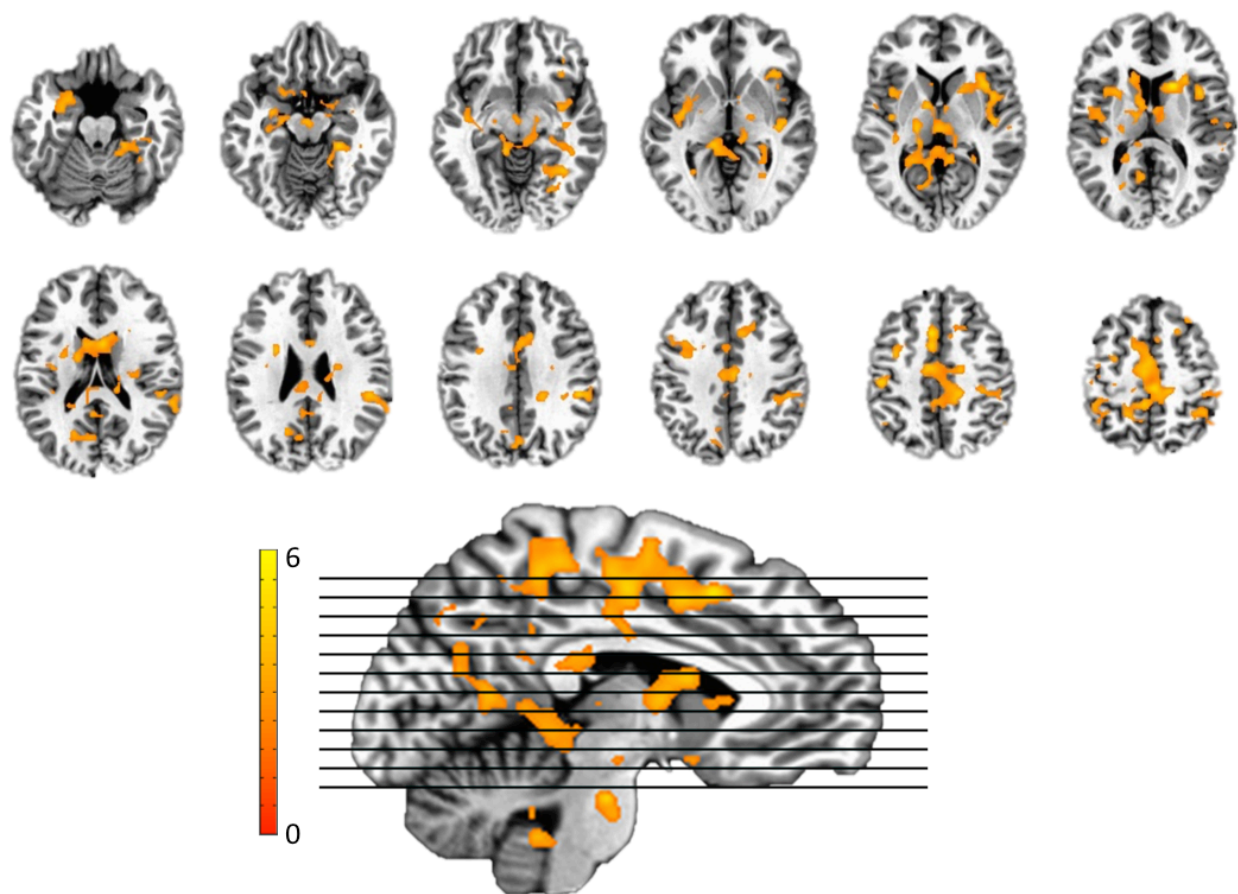


Fig. S2.



**Table S1. Participant characteristics.**

|  | <b>Altruists<br/>(<i>n</i> = 19)</b> | <b>Controls<br/>(<i>n</i> = 20)</b> | <b><i>P</i></b> |
|--|--------------------------------------|-------------------------------------|-----------------|
| Age <i>M</i> ( <i>SD</i> )               | 46.32 (8.68)                         | 44.75 (6.41)                        | 0.524           |
| IQ <i>M</i> ( <i>SD</i> )                | 115.74 (11.14)                       | 111.95 (13.06)                      | 0.338           |
| Male/Female (% Male)                     | 12/7 (63.16%)                        | 9/11 (45.00%)                       | 0.256           |
| White/Other Race<br>(% White)            | 18/1 (94.74%)                        | 17/3 (85.00%)                       | 0.316           |
| Right/Left Handed<br>(% Right)           | 18/1 (94.74%)                        | 19/1 (95.00%)                       | 0.998           |
| Household Income<br>≥ \$60,000           | 13 (68.42%)                          | 8 (40.00%)                          | 0.268           |
| Employed for Pay                         | 17 (89.47%)                          | 14 (73.68%)                         | 0.209           |
| Education<br>≥ Four-Year Degree          | 12 (63.16%)                          | 16 (80.00%)                         | 0.243           |
| Maternal Education<br>≥ Four-Year Degree | 7 (36.84%)                           | 10 (55.56%)                         | 0.254           |
| Paternal Education<br>≥ Four-Year Degree | 7 (38.89%)                           | 12 (63.16%)                         | 0.140           |

Note. Four controls did not report household income, one control did not report employment status, two controls did not report maternal education, one control and one altruist did not report paternal education.

**Table S2. Example distractor and care-eliciting scenarios.**

| Distractor Scenario  | Care-Eliciting Scenario  |
|--|--|
| Peter promised his mom that he would practice his guitar if she bought him one. She bought the guitar for Peter, but Peter never practiced because he wanted to play with his friends instead. | Karen is sitting at the school cafeteria eating her lunch. A group of girls start making fun of her weight. Karen just wanted to eat her lunch in peace, but the other girls kept making fun of her. |



**Table S3. Regions of activation associated with sympathy difference scores in altruists > controls.**

| k    | Peak x | Peak y | Peak z | Peak <i>t</i> (32) | Peak Region                         |
|------|--------|--------|--------|--------------------|-------------------------------------|
| 4418 | 2      | -32    | 62     | 5.96               | Right Paracentral Lobule and Sulcus |
| 733  | -4     | -22    | -28    | 4.57               | Left Brainstem                      |

**Table S4. Functional activation and connectivity results in altruists > controls, without subjects exceeding motion parameters\*.**

| k  | Peak x | Peak y | Peak z | Peak $t^a$ | Peak Region                         |
|--|--------|--------|--------|------------|-------------------------------------|
| <i>Left Amygdala ROI Functional Activation Results</i> |        |        |        |            |                                     |
| 11   | -20    | 7      | -23    | 3.97       | Left Amygdala                       |
| <i>Whole-Brain Functional Activation Results</i>       |        |        |        |            |                                     |
| 886  | 5      | -32    | 62     | 5.76       | Right Paracentral Lobule and Sulcus |
| 414  | 2      | -36    | -47    | 4.48       | Right Brainstem                     |
| <i>Left PAG ROI Functional Connectivity Results</i>    |        |        |        |            |                                     |
| 50 <sup>b</sup>  | -8     | -28    | -12    | 2.84       | Left PAG                            |

\*Three controls and one altruist were excluded from these analyses due to movement.

<sup>a</sup>28 degrees of freedom for functional activation results, 29 degrees of freedom for functional connectivity results.

<sup>b</sup>2mm<sup>3</sup> voxel size.

**Table S5. Sympathy ratings by scenario type in the validation task.**

| Expression Type | Scenario Type  | <i>M</i> | <i>SD</i> |
|-----------------|----------------|----------|-----------|
| All             | Care-Eliciting | 4.78     | 0.77      |
| Fear            | Care-Eliciting | 5.29     | 0.81      |
| Neutral         | Care-Eliciting | 4.27     | 0.87      |
| All             | Distractor     | 2.99     | 0.79      |
| Fear            | Distractor     | 2.89     | 0.82      |
| Neutral         | Distractor     | 3.09     | 0.90      |