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Entrepreneurial and Parental Love—Are They the Same?

Marja-Liisa Halko ^{1,2,3*}, Tom Lahti,⁴ Kaisa Hytönen,^{5,6} and Iiro P. Jääskeläinen⁷

¹HECER/Department of Political and Economic Studies, University of Helsinki, Finland

²Department of Economics, Aalto University School of Business, Finland

³AMI Centre, School of Science, Aalto University, Finland

⁴Hanken School of Economics, Finland

⁵Brain Research Unit, O.V. Lounasmaa Laboratory, Aalto University School of Science, Finland

⁶Laurea University of Applied Sciences, Finland

⁷Department of Biomedical Engineering and Computational Science, Aalto University School of Science, Finland



Abstract: Here we tested the hypothesis that entrepreneurs' emotional experience and brain responses toward their own firm resemble those of parents toward their own children. Using fMRI, we measured the brain activity while male entrepreneurs viewed pictures of their own and of a familiar firm, and while fathers viewed pictures of their own and of a familiar child. The entrepreneurs who self-rated as being very closely attached with their venture showed a similar suppression of activity in the posterior cingulate cortex, temporoparietal junction, and dorsomedial prefrontal cortex as fathers during viewing pictures of their own children versus familiar children. In addition, individual differences in the confidence trait influenced the neural encoding of both paternal and entrepreneurial processing. For underconfident fathers, a picture of one's own child was associated with stronger activation and for overconfident fathers with weaker activation in the amygdala and in caudate nucleus, a brain structure associated with processing of rewards. Similar association with activation, yet more widespread in the emotional processing network, was observed in entrepreneurs suggesting a similar neural basis for increased sensitivity to threats and potential risks concerning one's venture and child. In conclusion, both entrepreneurial and parental love seem to be supported by brain structures associated with reward and emotional processing as well as social understanding. *Hum Brain Mapp* 38:2923–2938, 2017. © 2017 The Authors Human Brain Mapping Published by Wiley Periodicals, Inc.

Key words: affect; entrepreneurship; functional magnetic resonance imaging (fMRI); behavior



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*Correspondence to: Marja-Liisa Halko; University of Helsinki, Department of Political and Economic Studies/HECER, P.O. Box 17, 00014 Helsinki, Finland. E-mail: marja-liisa.halko@helsinki.fi

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INTRODUCTION

Entrepreneurship has major economic value; it substantially contributes to employment, innovation, productivity, and economic growth [Van Praag and Versloot, 2007; Carree and Thruik, 2010]. Emotional attachment entrepreneurs create to their new ventures is integral in sustaining entrepreneurial efforts for long periods of time [Shane et al., 2003]. In addition, emotions entrepreneurs experience have an influence on new venture creation, growth, and performance [Baum and Locke, 2004; Baron, 2008]. Previous studies have examined how entrepreneurs experience emotions such as grief [e.g., Shepherd et al., 2009], fear [e.g., Foo, 2011], and passion [Cardon et al., 2009; Murnieks et al., 2014] toward their own venture. By inspiring individuals and motivating them to persist in the face of difficulties, entrepreneurial passion strongly impacts on the positive outcomes of the venture creation process [Cardon et al., 2005, Cardon and Kirk, 2015; Murnieks et al., 2014]. It also has a positive relationship with funding potential [Chen et al., 2009; Mitteness et al., 2012] and venture growth [Baum et al. 2001]. While aiming to create something remarkable, passionate entrepreneurs exert a high impact on the society [Ma and Tan, 2006].

In the postemergence stage—the time period that starts from a firm’s establishment—entrepreneur’s emotional experience toward the venture has been suggested to resemble parental love [Mirabella, 1993; Shankland, 2000; Cardon et al., 2005]. An entrepreneur’s experienced closeness to the venture increases with its formation and has been expected to be like the intimate and committed relation between a parent and a child [e.g., Shaver and Mikulincer, 2006]. Similar to parents do for their children, entrepreneurs make altruistic and sacrificing acts for their ventures and frequently put the ventures’ needs ahead of their own needs [Cardon et al., 2005]. Such a relationship of attachment is found particularly in the early stages of postemergence, as the venture’s dependence on the entrepreneur wanes at maturity as growth saturates [Cardon et al., 2005].

In the pre-emergence stage, that entails opportunity-recognition and venture-formation activities, an entrepreneur’s emotional attachment to a venture can often be described as anxious-ambivalent: passion, that reflects a drive and motivational energy, is intensified but intimacy and commitment manifest at a considerably lesser intensity [Hazan and Shaver, 1987]. Compared with earlier developmental stages, entrepreneur’s emotional experience in the postemergence stage is increasingly self-regulated [Carver and Scheier, 1998; Gross, 1999] and reflects a more balanced manifestation of intimacy, passion, and commitment—the three elements of love [Sternberg, 1986, 1997]. The triangular theory of love suggests that parental love is reflected in a balanced manifestation of the three love components, and, for entrepreneurial love to be akin to paternal love, a similar balanced manifestation should be witnessed in entrepreneurs’ evaluation of the strength of the components.

In this study, we compare the neural basis of entrepreneurial attachment with the neural basis of parental attachment. Love can be conceptualized as a “peak experience” that is an intense, beyond ordinary, emotion [Acevedo and Aron, 2009]. Schindehutte et al. [2006] found that peak experiences are particularly associated with high growth ventures, and therefore we focused on entrepreneurs that expected the annual growth of their firm to exceed 20% in the 3 years following the experiment. Focusing on entrepreneurs with growth orientation naturally limited our subject pool. There is plenty of research showing that the ventures of female entrepreneurs are less likely to grow, and that they are less likely to seek growth than their male counterparts [Autio and Pathak, 2010; Fairlie and Robb, 2009; Orser and Hogarth-Scott, 2002; Rosa et al., 1996]. Therefore, we made the decision of studying only male entrepreneurs and fathers.

Entrepreneurs’ relationship with their firm is often characterized by unrealistic expectations that often cannot be met. Similarly, parents create idealistic images of their children and put their child on an unachievable pedestal [Cardon et al., 2005]. Here we hypothesize that confidence is related with attachment relationships of entrepreneurs and ventures as well as fathers and their children. We base our hypothesis on the observations that, on the one hand, overconfidence is typical for entrepreneurs and explains entry to entrepreneurship [e.g., Cooper et al. 1988; Hyytinen et al. 2014; Cain et al., 2015], and, on the other hand, overconfidence is more characteristic of men than of women [e.g., Barber and Odean, 2001]. The entrepreneur’s optimistic view of his venture is also likely to reflect the belief that their own abilities are better than that of average entrepreneurs [e.g., Hayward et al. 2006; Hyytinen et al. 2014]. In this study, we measure overconfidence as a difference between individual’s confidence in his judgment and the accuracy of those judgments [e.g., Fischhoff et al. 1977].

Based on the literature on entrepreneurship, we hypothesize that an entrepreneur’s emotional attachments to his new venture is comparable to attachments that are formed between a parent and a child. In the fMRI experiment, entrepreneurs viewed pictures of their own firm and of a familiar firm, and fathers viewed pictures of their own child/children and pictures of a familiar child/children. Viewing pictures of one’s own child versus a familiar child has been associated with differential activation in brain regions that are linked to motivation and reward (striatum, including caudate nucleus), social cognition and mentalizing (posterior superior temporal sulcus (STS), ventromedial prefrontal cortex, temporal poles, anterior cingulate cortex, insula, inferior parietal lobule, dorsomedial prefrontal cortex, and inferior frontal gyrus), and emotion processing (amygdala, ventral anterior cingulate cortex, insula) [Abraham et al., 2014; Atzil et al., 2012; Bartels and Zeki, 2004; Leibenluft et al., 2004]. Although the majority of these studies have been conducted with mothers as

subjects, recent studies comparing mothering and fathering have in general found similar neural basis and synchronous brain activation for both groups. In particular, high activation of STS and amygdala has been associated with parenting, both with mothers and fathers, and high STS activation especially with fathers [Abraham et al., 2014]. Two other areas in the emotional processing network, namely the middle insula and the ventral anterior cingulate cortex (vACC), are also relevant for parental love and caregiving [Abraham et al., 2014; Bartels and Zeki, 2004]. In addition, fathers' faces elicited activity in the caudate nucleus in a study of adult children viewing pictures of their parents [Arsalidou et al., 2010].

Based on the literature on the neural basis of paternal love, we hypothesize that the neuronal activations relating especially to reward, motivation and affective experiences are salient and similar between the two groups. As a parent-child relationship is to a large extent social by nature and an entrepreneur-firm relationship is more unidirectional, we expected to find differential activation patterns in brain regions related to social cognition.

MATERIALS AND METHODS

Participants

Altogether, 42 healthy subjects participated in the fMRI study: 21 entrepreneurs (all male, mean age 33 years, range 24–45) and 21 fathers (mean age 35 years, range 27–43). The average “age” of the entrepreneurs' companies was 4.5 years (range 0–11), and the average age of the fathers' first child was 5.6 years (range 1–10). The entrepreneurs thus had slightly shorter experience in entrepreneurship than the fathers in parenthood, but the difference is not statistically significant (two-sided *t* test, $P = 0.20$). On average, participants had completed 15 years of education ($SD = 2.45$), and there were no significant differences between the groups.

Participants were recruited by spreading ads through entrepreneurial organizations (entrepreneurs) and through the day-care centers of the city of Helsinki (fathers). Interested individuals signed up through a web site, after which the subjects who fulfilled the eligibility criteria (entrepreneurs: growth orientation, not serial entrepreneur; fathers: no entrepreneurial background) were screened by phone for fMRI contraindications. All subjects were compensated for their travel cost and they signed informed consent forms. The Ethics Committee of the Aalto University approved the study protocol, and the study was conducted in accordance with the Helsinki Declaration.

Behavioral Measures and Task

The experiment consisted of two separate sessions. Before the first session, subjects were asked to select and send us 2–4 pictures of their own firm/child and of another firm/child familiar to them (the pictures of the firms depicted

business idea, logo, product or key personnel). To avoid possible antagonistic reactions to a familiar firm, the entrepreneurs were asked not to select pictures of their direct competitors. The subjects filled out questionnaires on affect intensity [the 40 items Affect Intensity Measure, AIM, questionnaire, Larsen, 1984], sense of closeness of the relationship between the father and his child and between the entrepreneur and his venture (the Inclusion of Other in the Self, IOS, scale, Aron et al. [1992]), optimism (the 10 items LOT-R questionnaire [Scheier et al., 1994]), confidence [e.g., Fischhoff et al., 1977], and socioeconomic and entrepreneurship/parenthood background.¹

The 40 items of the AIM describe emotional reactions to typical situations in life, like “When I am excited over something I want to share my feelings with everyone,” or “When I do something wrong, I have strong feelings of shame and guilt.” Subjects rated whether they react to those situations as described, and the scale was from 1 to 6, 1 = never, 3 = sometimes, 6 = always. The IOS scale is a graphical measure that consists of seven pairs of differentially overlapping circles, and the participants were asked to select the pair that best describes their relationship with their firm/child (see Supporting Information). The 10-item LOT-R is a measure of optimism versus pessimism and consists of statements like “I rarely count on good things happening to me.” Subjects rated each item on a scale from 1 to 5: 1 = strongly disagree, 3 = neutral, and 5 = strongly agree. We measured participants' confidence with a judgment task in which subjects were presented seven general knowledge related statements and they had to choose between two mutually exclusive answers. In addition, subjects had to evaluate their confidence that the answer is correct on a scale from 50% to 100%, where 50% stands for “I am not at all sure” and 100% stands for “I am completely sure” (see Supporting Information). The final confidence score was defined as a difference between the mean confidence score and the mean proportion of correct answers.

Sternberg's [1986] triangular theory of love suggests that love can be understood by three components: intimacy, passion, and commitment. These components have also been used in other theories of love [Aron and Westbay, 1996] and they reflect the different aspects of love [Sternberg, 1997]. We did not use Sternberg's Love Scale directly, as its individual items could not be applied to the relationship between an entrepreneur and the venture. Here, subjects were asked to directly evaluate how strongly the three components—intimacy, passion and commitment—characterize their relationship with their venture/child. This was measured on a scale from 1 to 5, 1 = not at all, 3 = moderately strongly, 5 = very strongly. To ensure that the subjects understood the meaning of the components, a clarifying text was added in the brackets: intimacy (reflects a feeling of connection/emotional bond), passion (reflects a drive and

¹The questionnaire included also questions that are of less relevance for the current report (for ex. risk attitude).



Figure 1.

Trial structure. Upper panels, the task of the fathers. The photos of own child/children and a familiar child/children were presented in an alternating order for 30 s each. Note that the photos in the figure are just example photos; the children in the photos are not related to the study. Lower panels, the task of the entrepreneurs. The pictures of subject’s own firm and a familiar firm were presented in an alternating order for 30 s each. The pictures of the firms depicted business idea, logo, product, or key personnel, and the pictures related with one’s own firm and with the familiar firm

were chosen for each subject from the same categories. Subjects were instructed to think about things and events related to the picture on the screen. Each picture was followed by a count-back distraction task. Subjects saw a number on the screen and their task was to count back from the number in increments of seven as long as the number was on the screen. The total duration of the task was ~13 min. [Color figure can be viewed at wileyonlinelibrary.com]

motivational energy), and commitment (reflects a decision to maintain in the relationship).

Furthermore, we asked subjects to evaluate the chances of success of their company/child, compared to other companies in the same industry/children of the same age (scale from 1 = significantly worse to 5 = significantly better) and how often they set the needs of their company/child before their own needs (scale from 1 = very seldom to 5 = very often). Finally, the date and the time of the second session were scheduled. As a reward, subjects received one movie ticket, the value of which is about 10 Euros.

Among each individual’s pictures, we selected two pictures that depicted their own firm/child and two pictures that depicted a firm/child (children) the subject was familiar with. The two pictures of own and “known” firm were selected from the same subject category (e.g., logos of own and known firm). All possible extra factors were cropped and pictures were cut the same size (1024 × 768 pixels).

During fMRI, the two pictures of the own firm/child and the known/child were presented in an alternating order (starting condition counterbalanced) on a dark background

(Fig. 1). The pictures were presented for 30 s at a time and each picture was repeated six times. Subjects were instructed to focus on the picture viewing and to think about things and events related to the presented picture. To reduce any carry-over effects, subjects performed a count-back task for 30 s between the pictures [Aron et al., 2005; Acevedo et al., 2012]. Subjects saw a four-digit number, such as 8421 (the number varied), on the screen and their task was to count back from the number in increments of seven as long as the number was on the screen.

After the fMRI, subjects rated the emotional intensity elicited by each picture. They rated how strongly different emotions (joy, satisfaction, pride, love, passion, disappointment, fear, sadness) related to each picture (the scale from 1 to 5: 1 = not at all, 3 = moderately, 5 = very strongly).

MRI Data Acquisition

Magnetic resonance imaging (MRI) was performed with Siemens MAGNETOM Skyra 3-tesla MRI scanner at the Advanced Magnetic Imaging Centre (AaltoNeuroImaging,

TABLE I. Predicted regions of change

Brain region	MNI coordinates	
	Left	Right
Amygdala	-24 -2 -29	26 -2 -29
STS	-61 -6 -11	63 -6 -9
Middle insula	-44 12 -9	49 16 -13
Ventral ACC	-8 49 -6	11 44 -6

Aalto University). Whole-brain data were acquired with T2*-weighted echo-planar imaging (EPI), sensitive to blood-oxygen-level-dependent (BOLD) signal contrast with the following parameters: 36 axial slices, 3 mm slice thickness, TR = 2170 ms, TE = 30 ms, flip angle = 70°, FOV = 192 mm, voxel size 3 × 3 × 3 mm³. A total of 345 volumes were acquired, preceded by 4 dummy volumes to allow for equilibration effects. T1-weighted structural images were acquired at a resolution of 1 × 1 × 1 mm³. All images were acquired using a 32-channel head coil.

Stimulus delivery was controlled using Presentation software (Neurobehavioral Systems Inc., Albany, California, USA). Visual stimuli were back-projected on a semi-transparent screen, and from there via a mirror to the subject. Data were preprocessed and analyzed using SPM8 (Wellcome Department of Imaging Neuroscience, London, UK [Friston et al., 1995]). The functional data were motion and slice time corrected and indirectly normalized to MNI template by applying co-registration and segmentation procedures prior to the normalization. Finally, the data were spatially smoothed using a kernel with 7 × 7 × 7 mm full-width-at-half-maximum, that is, twice the original voxel size in each dimension. A standard high-pass cutoff of 0.008 Hz was used.

Data Analysis

At a single-subject level, the two types of image blocks (Fig. 1) were modeled using boxcar functions, convolved with canonical hemodynamic response function. The model also included six motion parameters as nuisance regressors. Subject-level contrasts, one contrast per subject (own vs known child/firm), were entered into a second-level analysis. The second-level analysis studied activation for each group separately (one-sample *t*-test) and group differences in activation (two-sample *t*-test), and modeled also an individual level covariate (Affect Intensity Measure score) to account for the potentially confounding effect of group differences in affect intensity. Here, the statistical maps were created using thresholds $P < 0.001$ (uncorrected) at voxel level and $P < 0.05$ (with familywise error correction) at cluster level unless otherwise stated. Locations of supra-threshold clusters are reported in MNI coordinates.

The fMRI data analysis involved three approaches. First, we analyzed fathers' and entrepreneurs' data separately

using the whole-brain search volume. This analysis identified brain regions where activity differs between the two conditions: viewing a picture of own versus a familiar child/firm. In the second approach, we performed the region of interest (ROI) analysis to compare our results with other studies about paternal attachment and to test differences between the two groups, fathers and entrepreneurs, for the contrast own child/firm versus familiar child/firm. We identified the ROIs either based on previous research on paternal love (caudate nucleus, amygdala, STS, middle insula, vACC) or based on our first analysis approach. That is, ROIs were either defined a priori or identified with one data set and used in the other data set. The coordinates for bilateral amygdala and STS ROIs were obtained from Abraham et al. [2014] who also reported parental love-related activations in the left middle insula and the left vACC. As Abraham et al. [2014] did not, however, report right-hemisphere activations in these structures, we obtained bilateral insula and vACC coordinates from Bartels and Zeki [2004]. For the caudate nucleus, we used an anatomically defined ROI (bilateral).

ROIs were defined using the WFU Pick Atlas Tool [Wake Forest University School of Medicine, Maldjian et al., 2003, 2004] and the MarsBaR software package [Brett et al. 2002; <http://marsbar.sourceforge.net>]. For bilateral amygdala, STS, middle insula, and vACC, we located a sphere-shaped volume (two voxel radius) around the pre-defined locations (Table I). Mean parameter values across voxels in the ROIs were calculated for each participant and each ROI using the MarsBaR software package. Last, we assessed associations (Pearson correlation) between ROI activation and subjects' behavioral data.

As individual love and IOS scores most closely relate with the affect relationship under study, in the last approach, we also analyzed models where we used the IOS scores as an additional individual level covariate in the second-level analysis. The love score is strongly correlated with the IOS score (Supporting Information, Tables S1–S3), especially in fathers, and therefore, it was not included in the model.

RESULTS

Behavioral Results

Both entrepreneurs and fathers were slightly overconfident about the chances of success of their company/child. Entrepreneurs rated their company and fathers rated their child significantly better than average on the chances of success, and there were no statistically significant difference between the groups (4.35 vs 4.10, two-sided *t*-test, $P = 0.26$). Both entrepreneurs and fathers were also slightly overconfident in their judgments (8.30 vs 15.72, two-sided *t*-test, $P = 0.19$), and both entrepreneurs and fathers reported that they set the needs of their company/child before their own needs more frequently than “often” (3.95 vs 4.19, two-sided *t*-test, $P = 0.26$).

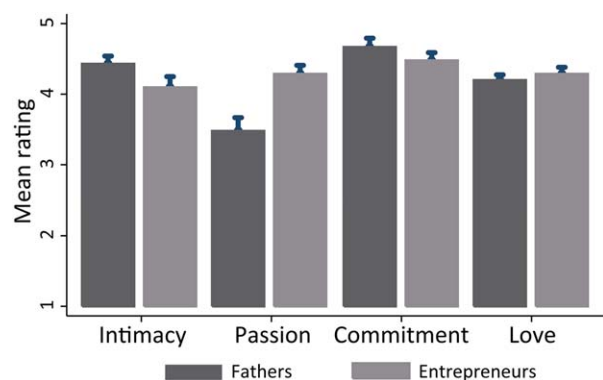


Figure 2.

Love components. Subjects rated how strongly the following three components relate to their relationship with their venture/child: intimacy (reflects a feeling of connection/emotional bond), passion (reflects a drive and motivational energy), and commitment (reflects a decision of maintaining the relationship). The scale was from 1 to 5, 1 = not at all, 3 = moderately, 5 = very strongly. The bars represent mean ratings for the three components and their average (love). Error bars indicate the standard error of the mean. [Color figure can be viewed at wileyonlinelibrary.com]

Entrepreneurs scored slightly higher than fathers in the amount of *love*, the average measure formed from the values for the three love components (Fig. 2), but the difference between the groups was not statistically significant (4.29 vs 4.19, two-sided *t*-test, $P = 0.45$). In addition, entrepreneurs rated their relationship with their company slightly closer, or more interconnected, than fathers their relationship with their child/children but the difference was not statistically significant (IOS-test, scale 1–7, a higher number indicates higher closeness, 5.29 vs 4.81, two-sided *t*-test, $P = 0.13$).

Even though the overall measures of love and closeness did not differ between the two groups, we did however find some differences between the groups in respect to some of the three love components (Fig. 2). In entrepreneurs, a repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean ratings did not differ statistically significantly between the different components ($F(1.59, 36.94) = 1.59, P = 0.22$). In fathers, the ratings differed statistically significantly between the components ($F(1.64, 32.70) = 22.73, P < 0.0005$). The fathers in our study, as in Sternberg [1997], rated the passion component somewhat lower than the other two components. Post hoc tests using the Bonferroni correction revealed that fathers rated the commitment component (mean = 4.67) slightly higher than the intimacy component (mean = 4.43) but the difference was not statistically significant ($P = 0.23$), whereas fathers' rating for the passion component (mean = 3.48) was statistically different to the intimacy ($P = 0.001$) and commitment ($P < 0.0005$) components.

Individual differences in love and the sense of closeness were associated with each other: subjects with high IOS

scores had also high scores in love (Supporting Information, Table S1, pairwise correlation $r = 0.57, P < 0.01$). In addition, individuals who had higher success beliefs were also more optimistic and more overconfident in their judgment (Supporting Information, Table S1, pairwise correlations: $r = 0.39, P = 0.01$ and $0.32, P = 0.04$). A more detailed analysis showed that, in fathers, the sense of closeness was strongly associated with love (Supporting Information, Table S2, pairwise correlation $r = 0.76, P < 0.01$) whereas, in entrepreneurs, the correlation was also positive but not significant (Supporting Information, Table S3, pairwise correlation $r = 0.32, P = 0.16$).

Affect Intensity

Entrepreneurs scored higher than fathers on the Affect Intensity Measure (AIM) (Supporting Information, Fig. S2, 3.83 vs 3.46, two-sided *t*-test, $P = 0.01$). Instead of being a unidimensional construct that measures the intensity with which people experience both positive and negative emotions [Larsen and Diener 1987], several studies have suggested that the AIM comprised several weakly correlated factors [e.g., Williams et al., 1989; Weinfurt et al. 1994; Rubin et al., 2008; Rubin et al., 2012]. When we applied the four factor structure suggested by Williams et al. [1989] and Weinfurt et al. [1994], we found that entrepreneurs scored higher than fathers especially in factors related with positive emotions (Supporting Information, Fig. S2, positive intensity: 3.88 vs 3.27, two-sided *t*-test, $P = 0.02$; positive affectivity: 4.33 vs 3.86, two-sided *t*-test, $P = 0.007$). In factors measuring the strength with which people experience negative emotions, there were no statistically significant differences between entrepreneurs and fathers (Supporting Information, Fig. S2, negative intensity: 2.87 vs 2.74, two-sided *t*-test, $P = 0.47$; negative reactivity: 3.77 vs 3.59, two-sided *t*-test, $P = 0.44$). The AIM score was not significantly associated with the other behavioral measures (Supporting Information, Tables S1–S3).

Positive Versus Negative Emotions, Own Versus Known

Both entrepreneurs and fathers rated the intensity of positive emotions (joy, satisfaction, pride, love, passion) associated with their company/child significantly stronger than the intensity of positive emotions associated with the company/child they know (Supporting Information, Fig. S3 and S4). The strongest positive feeling the images elicited in entrepreneurs was pride and in fathers love. Subjects rated the intensity of negative emotions (disappointment, fear, sadness) very low in general and there were no significant difference between negative emotions associated with their own company/child and negative emotions associated with a familiar company/child. The only exception was fathers and fear; the intensity of fear associated with own child was not strong but significantly stronger than the intensity of fear associated with a familiar child.

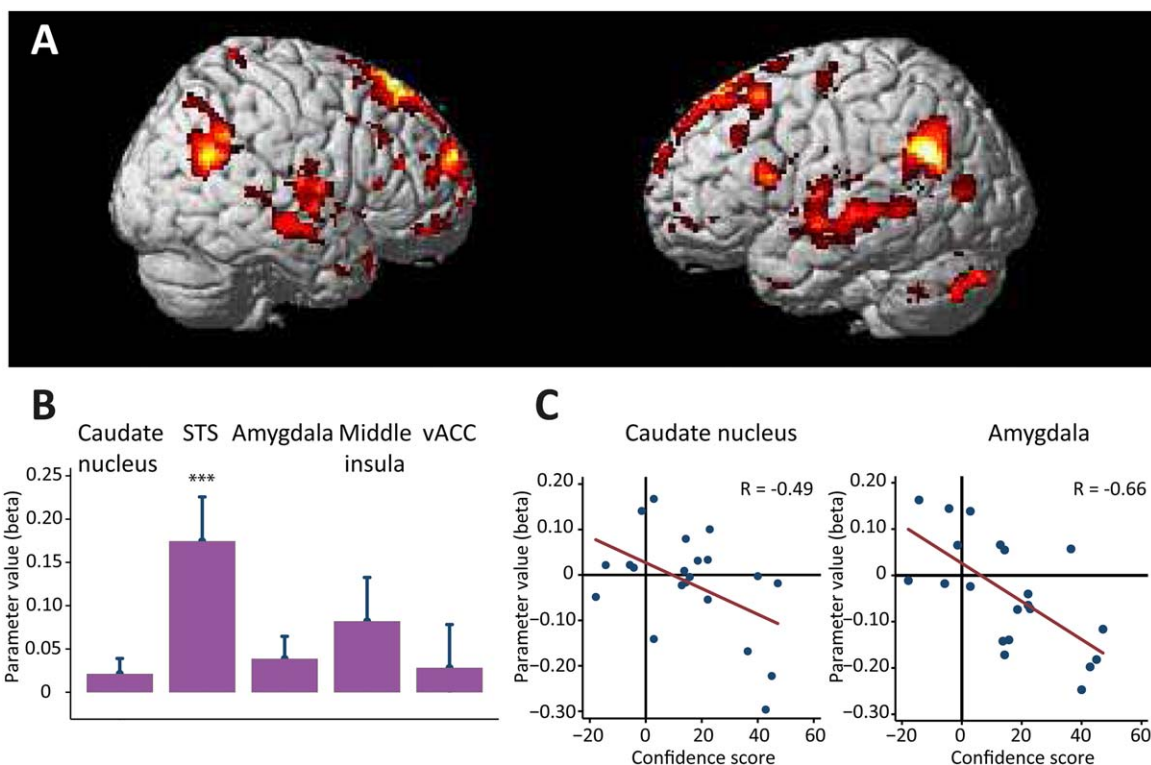


Figure 3.

Paternal love. Panel A. Activations revealed when fathers viewed pictures of familiar children versus pictures of their own children. For illustration, voxel-level threshold of $P < 0.005$, minimal cluster size 20 voxels of $2 \times 2 \times 2 \text{ mm}^3$. Panel B. Average betas from bilateral caudate nucleus (anatomically defined), STS, amygdala, middle insula and vACC (known – own contrast results). Betas calculated from a 6-mm-radius spheres, center at $-61 -6 -11$ and $63 -6 -9$ (STS), $-24 -2 -29$ and $26 -2 -29$ (amygdala), $-44 12 -9$ and $49 16 -13$ (middle insula),

$-8 49 -6$ and $11 49 -6$ (vACC). Error bars indicate the standard error of mean (SEM). Two-sided t tests, $*P < 0.10$, $**P < 0.05$, $***P < 0.01$. Panel C. Average betas from bilateral caudate nucleus and amygdala (own – known contrast results) and fathers individual confidence scores. Individuals with confidence score > 0 are overconfident. The scatterplots include regression lines for visualization only. [Color figure can be viewed at wileyonlinelibrary.com]

We combined the intensity ratings related with positive emotions (joy, satisfaction, pride, love, passion) and ratings related with negative emotions (disappointment, fear, sadness) and calculated average difference between the ratings associated with own company/child and with a familiar company/child. Entrepreneurs rated the intensity of negative emotions associated with their own company equally strong, or weak, as the intensity of negative emotions associated with a familiar company (1.24 vs 1.33, paired t -test, $P > 0.10$). Fathers, on the other hand, rated the intensity of negative emotions associated with their own child slightly stronger than the intensity of negative emotions associated with a familiar child (1.53 vs 1.25, paired t -test, $P = 0.04$). In positive emotions, differences in the intensities were clear; the intensity of positive emotions associated with own company/child was much stronger than the intensity associated with a familiar company/child (entrepreneurs: 3.57 vs 2.30, paired t -test, $P < 0.01$; fathers: 4.06 vs 2.31, paired t -test,

$P < 0.01$). In addition, fathers' estimate of positive emotions associated with their own child was significantly higher than entrepreneurs' estimate of positive emotions associated with their own company (4.06 vs 3.57, two-sided t -test, $P = 0.01$).

Regional Effects in fMRI

Paternal love

We first identified brain regions involved in fathers viewing images of their own versus familiar child. The contrast own versus known child revealed no regions that were significantly more activated in the own-child than in the familiar-child condition. The opposite contrast, known versus own child, revealed activations in left posterior cingulate cortex (PCC, BA23), bilateral temporoparietal junction (TPJ, BA39), and right and left dorsomedial prefrontal

TABLE II. Brain regions with significant differences own versus known or known versus own contrasts

Activated region	BA	Coordinates	Cluster size	Z _{max}
(1) Fathers				
<i>Known vs own</i>				
Posterior cingulate cortex	23	12 -44 32	536	4.68
Temporoparietal junction	39	48 -58 24	197	4.59
Temporoparietal junction	39	-48 -64 24	397	4.36
Dorsomedial prefrontal cortex	8	8 36 56	470	3.90
Dorsolateral prefrontal cortex†	9	12 40 26	1856	4.16
Dorsomedial prefrontal cortex†	8	-30 18 56	325	4.05
Superior temporal gyrus, extending to insula†	22	-46 -8 -4	763	3.72
Superior temporal gyrus†	22	52 -10 10	368	3.71
(2) Entrepreneurs				
<i>Own vs known</i>				
Caudate†	48	20 2 22	532	3.99
<i>Known vs own</i>				
Superior temporal gyrus, extending to insula †	13	42 6 -16	324	3.67

Voxel-level threshold of $P < 0.001$, cluster-level threshold of $P < 0.05$, familywise error correction, whole-brain, cluster size in voxels of $2 \times 2 \times 2 \text{ mm}^3$ († voxel-level threshold of $P < 0.005$). Locations of suprathreshold clusters are reported in MNI coordinates.

cortex (DMPFC, BA8), and two clusters in temporal cortex (BA22; Fig. 3A and Table II).

Next we compared responses to the pictures of own child versus familiar child with those found in previous studies on paternal attachment. Therefore, we performed a ROI analysis on bilateral STS, amygdala, middle insula, and vACC (Table I) and on anatomically defined caudate nucleus. The ROI analysis in the STS showed significant differences with the contrast known – own child but not the ROIs in the caudate nucleus, amygdala, middle insula, and vACC (Fig. 3B, two-sided *t*-tests, caudate nucleus $P = 0.48$, STS $P = 0.003$, amygdala $P = 0.15$, middle insula $P = 0.12$, and vACC $P = 0.58$). The activation in the caudate nucleus or in the emotional processing network did not significantly differ between own and familiar child trials, but the further analysis revealed that the activation in the caudate nucleus and amygdala was associated with fathers’ individual confidence scores. There was a significant negative correlation between confidence of fathers and caudate nucleus and amygdala response to own versus familiar child (Fig. 3C, pairwise correlation, caudate nucleus $r = -0.49$, $P = 0.024$; amygdala $r = -0.66$, $P = 0.001$). For fathers who were slightly underconfident in their judgments, an image of an own child tended to elicit higher caudate nucleus and amygdala activation than an image of a familiar child, whereas for most of the overconfident fathers, and image of own child elicited lower activation on the caudate nucleus and amygdala than an image of a familiar child.

When responses to the own versus known child were modeled with subjectwise IOS scores (random effects group analysis with individual IOS scores as an additional covariate), a significant positive correlation was observed in the left superior frontal gyrus (BA8; Supporting Information,

Table S4; pairwise correlation coefficient $r = 0.66$, $P < 0.01$; Supporting Information, Fig. S5), and in two smaller clusters in the right prefrontal cortex (sup. front. gyrus, BA8; med. sup. front. gyrus, BA9; Supporting Information, Table S4).² As father’s individual IOS scores are highly correlated with their individual love scores (Supporting Information, Table S2), activation in left superior frontal gyrus was also associated with fathers’ individual love scores (pairwise correlation coefficient $r = 0.55$). For the subjects with a high IOS or love score, an image of own child tended to elicit higher activation on these areas than an image of a familiar child, whereas for the subjects with a low IOS or love score, an image of own child elicited lower frontal activation than an image of a familiar child. No negative associations were observed between responses to own versus known child and IOS or love score.

Entrepreneurial love

Next we identified brain regions involved in viewing images of own versus familiar company. The contrast own versus known firm revealed one region in right caudate nucleus that was significantly more activated in the own-company than in the familiar-company condition, and the opposite contrast revealed one region in right insula that was significantly more activated in the known-company than in the own-company condition (Fig. 4A,B and Table II).

²In the group of fathers, there is no significant correlation between the two covariates, the AIM score and the IOS score (Table S2). In addition, we did not find significant correlation between the IOS scores and the caudate, amygdala, STS, middle insula, vACC activation.

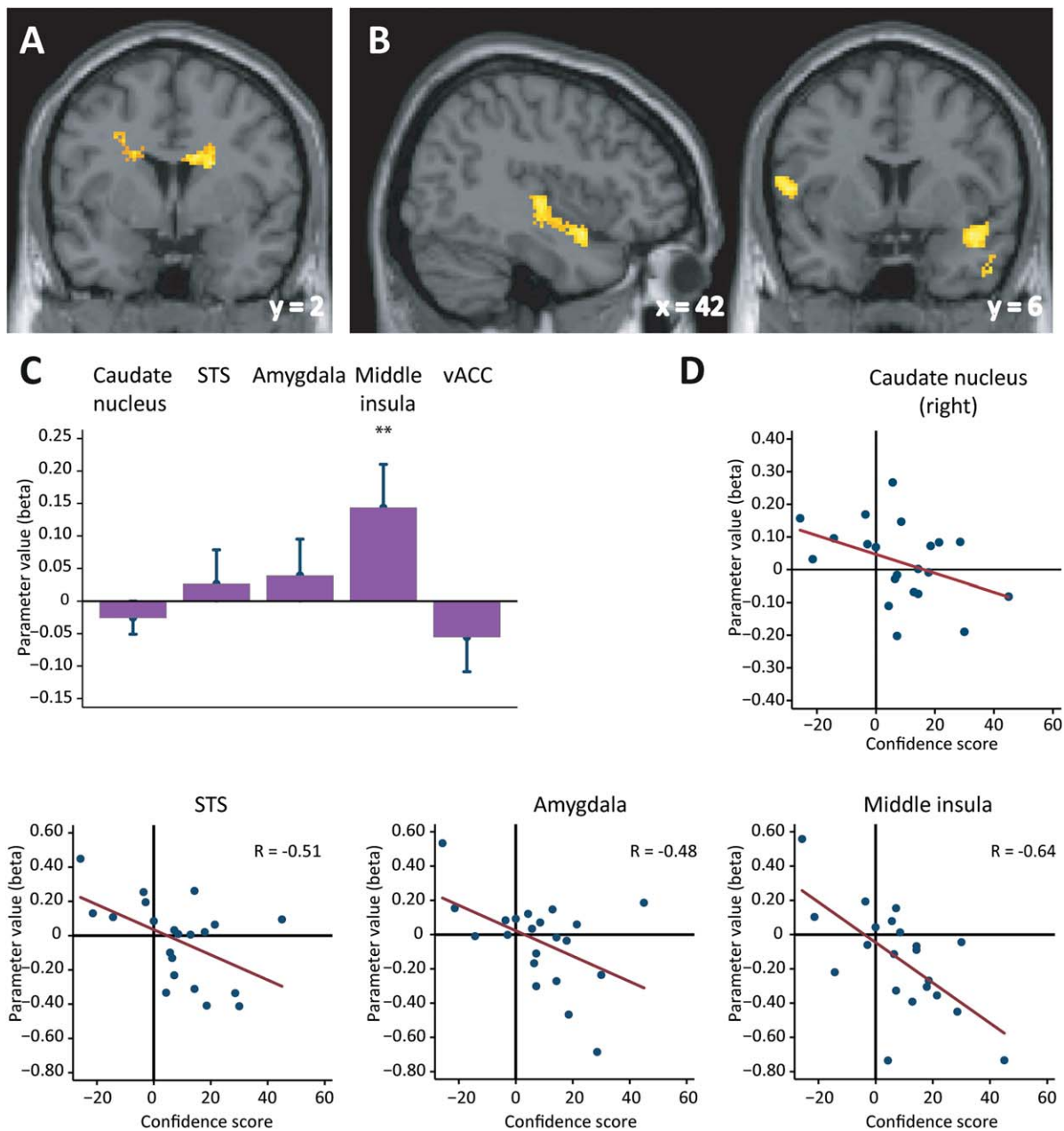


Figure 4.

Entrepreneurial love. Panel A. Activations revealed when entrepreneurs viewed pictures of their own firm versus pictures of a familiar firm. For illustration, voxel-level threshold of $P < 0.005$, minimal cluster size 20 voxels of $2 \times 2 \times 2 \text{ mm}^3$. Panel B. Activations revealed when entrepreneurs viewed pictures of familiar firms versus pictures of their own firm. For illustration, voxel-level threshold of $P < 0.005$, minimal cluster size 20 voxels of $2 \times 2 \times 2 \text{ mm}^3$. Panel C. Average betas from bilateral caudate nucleus (anatomically defined), STS, amygdala, middle insula and vACC (known – own contrast results). Betas calculated from a 6 mm radius spheres, center at $-61 \ -6 \ -11$ and $63 \ -6 \ -9$

(STS), $-24 \ -2 \ -29$ and $26 \ -2 \ -29$ (amygdala), $-44 \ 12 \ -9$ and $49 \ 16 \ -13$ (middle insula), $-8 \ 49 \ -6$ and $11 \ 49 \ -6$ (vACC). Error bars indicate the standard error of mean (SEM). Two-sided t-tests, * $P < 0.10$, ** $P < 0.05$, *** $P < 0.01$. Panel D. Average betas from right caudate nucleus and bilateral STS, amygdala and middle insula (own – known contrast results) and entrepreneurs individual confidence scores. Individuals with confidence score > 0 are overconfident. The scatterplots include regression lines for visualization only. [Color figure can be viewed at wileyonlinelibrary.com]

With entrepreneurs, we also compared responses to the pictures of own firm versus familiar firm with those found in previous studies on paternal attachment. Therefore, like with fathers, we next performed a ROI analysis on bilateral STS, amygdala, middle insula and vACC (Table I) and on anatomically defined bilateral caudate nucleus. Unlike with fathers, the ROI analysis in the bilateral middle insula showed significant differences with the contrast known – own firm but not the ROIs in the caudate nucleus, amygdala, STS, and vACC (Fig. 4C, two-sided *t*-tests, caudate nucleus $P = 0.45$, STS $P = 0.62$, amygdala $P = 0.50$, middle insula $P = 0.04$, vACC $P = 0.31$).

For fathers, the average parameter values in the reward and emotional processing network—caudate nucleus, amygdala, middle insula, and vACC—did not significantly differ from zero. For entrepreneurs, a picture of a familiar firm elicited significantly lower activation in the middle insula than a picture of own company (Table II). Further analysis showed that the activation in STS and in all three areas of the emotional processing network was associated with entrepreneurs' individual confidence scores; there was a significant correlation between confidence of entrepreneurs and STS, amygdala, middle insula and vACC response to own vs. familiar firm (Fig. 4D, pairwise correlations: STS, $r = -0.51$, $P = 0.02$; amygdala, $r = -0.48$, $P = 0.03$; middle insula, $r = -0.64$, $P = 0.002$; vACC, $r = -0.39$, $P = 0.08$). In bilateral caudate nucleus, the association was also negative but not statistically significant ($r = -0.34$, $P = 0.13$). When we studied the left and right caudate nucleus separately, we found a significant negative association between the activation in the right caudate nucleus and entrepreneurs' individual confidence scores (Fig. 4D, pairwise correlation: $r = -0.41$, $P = 0.07$). Like for underconfident fathers also for under-confident entrepreneurs', an image of own firm tended to elicit stronger activation on the bilateral amygdala, middle insula and vACC, and in the right caudate nucleus than an image of a familiar firm, whereas for overconfident entrepreneurs, the activation pattern in those areas was reversed.

When responses to the own versus known company were modeled with subjectwise IOS scores (random effects group analysis with individual IOS scores as an additional covariate), a significant negative correlation was observed in the right posterior cingulate cortex (BA31; Supporting Information, Fig. S6A; pairwise correlation $r = -0.71$, $P < 0.01$).³ Activation in the region was also negatively but not significantly associated with entrepreneurs' individual love scores (Supporting Information, Fig. S6B, pairwise correlation $r = -0.17$, $P = 0.47$). For the subjects with high

IOS score, an image of own company tended to elicit lower activation on this area than an image of a familiar company, whereas for the subjects with low IOS score, an image of own company elicited higher PCC activation than an image of a familiar company. No positive associations were observed between responses to own versus known company and IOS score.

Paternal versus entrepreneurial love

Next we compared responses to the pictures of own child/firm versus familiar child/firm between the two groups, fathers and entrepreneurs. Two-sample *t*-tests examining for group differences in the own – known contrast at the whole-brain level revealed four clusters of increased neural activity in the entrepreneurs' group (Fig. 5A and Supporting Information, Table S5): two clusters in the posterior cingulate cortex (BA23, BA31), in the left temporo parietal junction (BA39), and in the dorsomedial prefrontal cortex (BA8). The areas where the group difference, entrepreneurs – fathers, was the largest overlapped to a great extent with the areas activated when fathers viewed pictures of children familiar to them (vs. pictures of their own children). No significant clusters were found in the fathers' versus entrepreneurs' group contrast.

As the group differences were found in the areas that, in fathers, triggered deactivation while watching pictures of one's own child (PCC, TPJs, and DMPFC), we next used the four clusters identified by the fathers' known – own child contrast to define ROIs. For each cluster, we first located a sphere-shaped volume (6 mm radius) around the peak activation, and extracted BOLD signal values from each of the regions. For entrepreneurs, average betas on those areas did not significantly differ from zero, but interestingly, activation in DMPFC was negatively associated with entrepreneurs' IOS scores. Thus, there was a significant correlation between the feeling of closeness of entrepreneurs and their DMPFC response to own versus familiar firm (Fig. 5B, pairwise correlation $r = -0.40$, $P = 0.07$). In PCC and TPJs, the association was also negative but not significant.

To study this negative association further and more broadly in the PCC and TPJ clusters, we next modeled entrepreneurs' responses to the own versus known company with subjectwise IOS scores as an additional covariate, and used the PCC and TPJ clusters as ROIs. In this more comprehensive analysis, we found a significant negative correlations also within the clusters (Fig. 5C; PCC pairwise correlation $r = -0.57$, $P < 0.01$; left TPJ pairwise correlation $r = -0.65$, $P < 0.01$; right TPJ pairwise correlation $r = -0.49$, $P = 0.02$).

Activation in the four regions (PCC, left and right TPJ, and DMPFC) was also negatively associated with the intensity of positive emotions entrepreneurs related with their own company vs. with a familiar company (Supporting Information, Fig. S3, pairwise correlations DMPFC, $r = -0.47$; PCC, $r = -0.41$; left TPJ, $r = -0.36$; right TPJ, $r = -0.51$). For the entrepreneurs with a high IOS score or

³In the group of entrepreneurs, there is no significant correlation between the two covariates, the AIM score and the IOS score (Supporting Information, Table S3). In addition, we did not find significant correlation between the IOS scores and the caudate, amygdala, STS, middle insula, vACC activation.

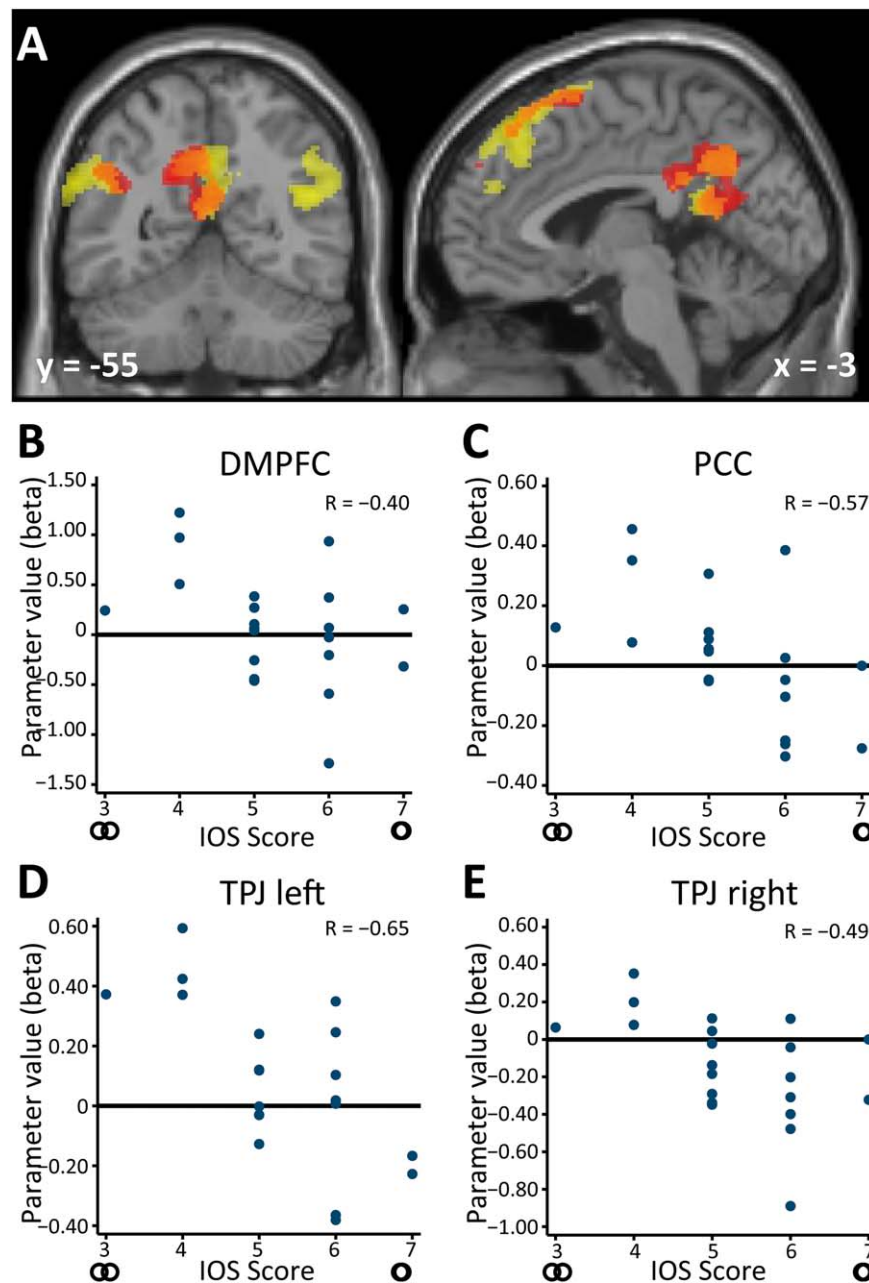


Figure 5.

Parental versus entrepreneurial love. Panel A. Activations revealed when fathers viewed pictures of familiar children versus pictures of their own children (yellow blobs), and activations revealed by the contrast testing the group differences (entrepreneurs – fathers) in the own – known contrast (red blobs). Overlapping areas in orange. Panel B. Correlation between DMPFC activation and entrepreneur – firm closeness scores; average betas from DMPFC cluster and individual IOS scores (betas

calculated from a 6-mm-radius sphere, center at 8 36 56). Panels C–E. Correlation between PCC and TPJ activation and entrepreneur – firm closeness scores; average betas from PCC, left TPJ and right TPJ cluster and individual IOS scores (betas calculated from a 6-mm-radius sphere, center at 8 –50 24 (PCC), –46 –50 34 (TPJ left), and 50 –48 24 (TPJ right)). [Color figure can be viewed at wileyonlinelibrary.com]

a large difference in the intensities, an image of own company tended to elicit lower activation on these areas than an image of a familiar company, just like for fathers, an image of own child elicited lower activation than an image of a familiar child. No positive associations were observed between responses to own versus known company and the IOS score or with the intensity of positive emotions related with own versus familiar company.

Affect Intensity and Brain Activation

The basic second-level analysis was carried out using the Affect Intensity Measure (AIM) score as an individual level covariate. Excluding the covariate from the analysis has only minor effects on the basic contrast results (Supporting Information, Table S6). However, for fathers, a significant positive correlation was observed in the right superior temporal gyrus (BA22; peak at 68 -46 8, cluster size = 137, $Z_{\max} = 4.03$). For the fathers with strong emotional reactions, an image of own child elicited higher activation on the right superior temporal gyrus than an image of a familiar child, whereas for the fathers with mild emotional reactions, an image of own child elicited lower temporal activation than an image of a familiar child (Supporting Information, Fig. S7; pairwise correlation $r = 0.68$, $P = 0.0007$). For fathers, no negative associations, and for entrepreneurs, no associations, positive or negative, were observed between responses to own versus known child/firm and the AIM score.

DISCUSSION

This is the first fMRI study to examine the brain basis of entrepreneurs' attachment to their own firms. We started with the hypotheses that an entrepreneur's emotional experience toward his firm resembles parents' feelings toward their children [e.g., Cardon et al., 2005]. According to the behavioral results, entrepreneurial love is strikingly similar to paternal love. In particular, entrepreneurs and fathers scored equally high in the amount of love [the triangular theory of love, Sternberg, 1986] and had a similar sense of closeness with their company/children [the IOS scale, Aron et al., 1992]. At the neural level, we confirm the earlier finding that parental love deactivates the areas associated with the social assessment of other people [Bartels and Zeki, 2004]. Entrepreneurs who rated their relationship with their enterprise very close, or interconnected, or who associated especially intense positive emotions with their company, showed a similar suppression of activity in the areas mediating social assessment. Although an entrepreneur-firm relationship is by nature only indirectly social and more abstract than a parent-child relationship, they both appear to be supported by neural networks associated with social understanding.

In addition, individual differences in confidence also influenced neural encoding of both paternal and

entrepreneurial love. For underconfident fathers, a picture of one's own child was associated with stronger activation and for overconfident fathers with weaker activation in the caudate nucleus and amygdala. For entrepreneurs, a similar pattern of activation was more widespread in the reward and emotional processing network (right caudate nucleus, amygdala, middle insula, vACC), suggesting similar neural mechanisms underlie sensitivity for potential threats concerning one's child and venture in both parents and entrepreneurs.

Love is Rewarding

Both paternal and entrepreneurial love activate the brain areas which fall within the reward network of the brain. Previous studies about maternal and romantic love have shown that the activation pattern in the striatum (nucleus accumbens, caudate nucleus and putamen) is associated with the two types of love [Bartels and Zeki, 2004; Aron et al., 2005; Zeki, 2007; Acevedo et al., 2012]. The striatum is a crucial part of the reward system of the human brain and a major projection site of midbrain dopamine cells, and it is activated by a variety of reward: primary reinforcers like food and drink [e.g., Kelley, 2004], secondary reinforcers like money [e.g., Knutson et al., 2001], reward prediction [e.g., Onoda et al., 2011], and is also central to social decision-making [e.g., King-Casas et al., 2005].

In Bartels and Zeki [2004], the activation in the caudate nucleus was associated both with maternal and romantic love. In our study, especially a picture of one's own firm elicited stronger activation in the right caudate nucleus than a picture of a familiar firm. Like parenting or romantic love, entrepreneurship may be a rewarding experience. To explain the motivational tendencies of entrepreneurs, we can apply, for example, the regulatory focus theory [Higgins, 1998]. The theory suggests that individuals with a promotion focus direct effort toward tasks that will bring about the achievement of goals and aspirations [Trevelyan, 2008] and consequently establish ventures to seek rewards and pleasure. It represents an opportunity for advancement and growth that bring them into alignment with their ideal selves [Brockner et al., 2004].

Social Representation and Self-Identification

Watching pictures of one's own child triggered deactivation in brain regions that are associated with social understanding (mentalization) and social processing. Previous research has indicated that both maternal and romantic love are related with deactivation in the areas of social judgement [Bartels and Zeki, 2004]. In fathers, the deactivation pattern was remarkably similar to that of mothers and romantically in love: a picture of one's own child evoked weaker activation in the PCC, left and right TPJ, DMPFC and in the superior temporal gyrus than a picture of a familiar child. The prefrontal cortex and the

temporoparietal junctions belong to the brain areas active in tasks that require understanding of other people's intentions and emotions. In parents, both in mothers and in fathers, the deactivation in those areas may be an indication of a suspension of critical assessment related with one's own child [Bartels and Zeki, 2004]. Or, mothers and fathers do not engage in social processing when watching their own child as the child represents an extension of their self.

In entrepreneurs, individual differences in closeness between an entrepreneur and his firm influenced the activation pattern in the PCC, TPJ and DMPFC. To assess the closeness of the relationship between an entrepreneur (a father) and his venture (child), we used the IOS scale [Aron et al., 1992]. The IOS scale has become a widely used index of the sense of closeness, and it has been used to measure self-expansion and the inclusion of others in the self [e.g., Aron and McLaughlin-Volpe, 2001; Ashforth et al., 2016]. Studies on social identities have indicated that the self can be composed of many things including one's family, social relationships, and family possessions [e.g., Trump and Bucks, 2012]. For example, individuals may identify non-human phenomena such as loved brands with themselves and include them in one's self [e.g., Escalas and Bettman 2005; Trump and Bucks, 2012; Batra et al. 2012]. For entrepreneurs, the own venture may represent an extension of their self: an entrepreneur identifies with the values, attitudes and attributes of the venture which define who he is [e.g., Ashforth et al. 2016]. Therefore, for entrepreneurs who felt very close and interconnected with their firm, a picture of their own firm was associated with weaker activation, and for entrepreneurs not so close and interconnected with their firm, with stronger activation in the PCC, TPJ, and DMPFC.

Overconfidence and Emotional Processing Network

In fathers, individual differences in confidence affected the activation pattern in the emotional processing network. In under-confident fathers, a picture of one's own child elicited greater activation in the amygdala than a picture of a familiar child. Previous research has linked the amygdala activation particularly with primary-caregiving mothers [Abraham et al., 2014], and, on the other hand, underconfidence is more typical for women than for men [e.g., Barber and Odean, 2001]. The results can indicate that underconfident fathers, like mothers, are more sensitive to the risks and threats related with parenthood. In overconfident fathers, a picture of one's own child elicited weaker activation in the amygdala than a picture of a familiar child. In overconfident entrepreneurs, the suppression of activity was even more pronounced and covered the three areas of the emotional processing network (amygdala, middle insula, and vACC). Our results suggest that overconfidence and the suspension of negative emotions may also

underlie the entrepreneurs' overestimation of success probability and optimistic beliefs.

Entrepreneurial Love Can be Blind

At the neural level, our results suggest that activation in the brain regions related with critical social assessment and negative emotions are suppressed when watching a picture of one's own child/firm versus a picture of a familiar child/firm. Bartels and Zeki [2004] made a similar observation with mothers and with individuals romantically in love, and makes the tentative conclusions that this result brings us closer to explaining in neurological terms why "love is blind." The "love is blind" thesis claims that love generates an overly sanguine view of the close other [Fletcher and Kerr, 2010]. It represents a cognitive bias that makes individuals less inclined to accurately evaluate their close ones. This positive illusion, that is particularly typical in romantic relationships, is associated with individual's tendency to write off faults and negative behavior and rely on pre-existent beliefs rather than objective data [Swami et al., 2009; Fletcher and Kerr, 2010]. It also reflects social trustworthiness [Winston et al., 2002; Critchley et al., 2000], which means that the need to assess the social validity of the other is reduced [Bartels and Zeki, 2004]. At the same time, the cognitive bias has a positive effect in that it cultivates happiness and creates a strong bond and commitment by enhancing individual's sense of security in a relationship [Swami et al., 2009].

Entrepreneurs "in love" rely on their subjective beliefs represented in "an inside view" which perceives the details of one's own firm as unique and ignore or underweight objective information that may undermine these beliefs [Camerer and Lovallo, 1999]. As in interpersonal relationships, the perceived need to rely on external data to validate the qualities of one's own venture is reduced. Accordingly, entrepreneurs tend to underestimate the competitor's abilities [Hayward et al. 2006], which would explain their critical assessment of the familiar company within the same industry. In addition, in close relationships, the identity of the close other is internalized meaning that the entrepreneur's optimistic view of his venture is also likely to reflect the belief that their own abilities are better than that of average entrepreneurs [e.g., Hayward et al. 2006; Hyytinen et al. 2014]. While cognitive illusions, that appear to be shared in entrepreneurship and fatherhood, explain entry into entrepreneurship and persistence of entrepreneurs when they face uncertainties and difficulties, illusions are also often responsible for many flops and nonoptimal decisions that are made in the entrepreneurial process.

Differences in Affect Intensity

Entrepreneurs scored higher than fathers in the AIM factors that measure the intensity of positive emotions. Entrepreneurship research highlights the importance of

affect in entrepreneurship [Baron, 2008, Baron and Tang, 2011]. In relation to their work, entrepreneurs may experience more intense emotions than the other people because of their high passion and commitment to their business ideas [Baron, 1998]. In addition, positive affect has been related with entrepreneurs' creativity, and creativity in turn has a positive association with firm-level innovation [Baron and Tang, 2011]. In entrepreneurship, emotions may also influence opportunity evaluation; for example, happier entrepreneurs make riskier investment choices [Foo et al., 2009]. In our study, the emotional attachment an entrepreneur creates to his venture, or a father to his child, was studied taking into account the individual differences in affect intensity.

Future Directions and Limitations

In this study, we specifically examined entrepreneurs with growth orientation. Because entrepreneurs have varying motives and strategies for their business, future research could compare the emotional responses of varying segments of the entrepreneur population, including, for instance, entrepreneurs in family businesses, growth driven entrepreneurs (represented in the current study), and necessity-based entrepreneurs. For example, entrepreneurs in family businesses, the emotional attachment to their venture might be stronger than for the other groups as typically the values and the traditions of their venture are congruent with and salient to their self-identity. Another limitation of our study is that all participants were male, mainly due to difficulties in finding female entrepreneurs who would fulfill the selection criteria. Future research on entrepreneurs' emotional attachment to their venture could perform an assessment and comparison of neural activations of female and male entrepreneurs.

CONCLUSION

Our results are among the first to address the brain basis of entrepreneurship and they show that the strong attachment entrepreneurs can have to their venture is reflected in the same brain areas as the attachment between a parent and a child. We conclude that both entrepreneurial and parental love is reflected in reward processing in the caudate nucleus and supported by neural networks associated with emotional processing and social understanding.

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