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FOUNDER GENDER AND INVESTOR PITCH ASSESSMENTS: AN fMRI MULTIVARIATE PATTERN ANALYSIS INVESTIGATION

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We extend recent conversations on gender differences in entrepreneurship by examining investors' neural responses to pitches made by male versus female founders. We conduct an experiment that assigns a series of male and female entrepreneur pitches to prospective investors, while undergoing functional magnetic resonance imaging (fMRI) scanning to investigate differential neural activations. We find that investor's neural activity in the left posterior temporal fusiform cortex is significantly enhanced when presented with pitches from male versus female entrepreneurs. Moreover, using machine learning methods we can reliably decode the gender of the entrepreneur from both multivariate neural activation patterns of investors (71% accuracy) and investing interest (86% accuracy), thereby exposing a possible association between neural mechanisms and behavioral attitudes towards male entrepreneurs. Collectively, this paper is one of the first-known investigations that experimentally advances the neuroscience research agenda in entrepreneurship, uses multivariate pattern analysis as methodology, and sheds new light on the neural-based underpinnings of differential gender evaluations in entrepreneurship.

Keywords: fMRI; Gender; Machine Learning; Multivariate Pattern Analysis; Organizational Neuroscience.

INTRODUCTION

The role of gender in entrepreneurship has long been the center of research attention (e.g., Fischer et al., 1993; Minniti, 2009; Simmons et al., 2019; Stephan and El-Ganainy, 2007; Yang and Aldrich, 2014). For instance, researchers continue to explore why more males become entrepreneurs or why key stakeholders may hold gender-related biases. Indeed, a recent wave of research attention in general entrepreneurship, and in entrepreneurial finance in particular, has focused on gender bias (Kanze et al., 2017; Kanze et al., 2018; Lee and Huang, 2018; Mohammadi and Shafi, 2018). These works have been largely ignited by the availability of data that illustrates the disproportionate amount of early stage capital that goes to males, versus females—well over 90% by most accounts (Brush et al., 2014; Field, 2018).

While there is considerable evidence documenting the fact that most investments go to male entrepreneurs, there remains a lack of understanding of the drivers of this phenomenon. Several authors have suggested that acknowledged cognitive biases, such as similarity (e.g., Franke et al., 2006) and gender bias (e.g., Lee and Huang, 2018), may profoundly influence investors' behaviors and the allocation of venture funding. While such approaches are indeed useful given explanations are multifaceted, they have overlooked an examination of what the cognitive substrates and related mechanisms may be. A neuroscience-based investigation of such cognitive drivers can offer a non-incremental advance to tackle this research gap.

A recent vibrant movement within the broader management scholarly community, termed "organizational neuroscience," is shedding new light on decision making, cognition, and psychological biases through tools of neuroscience. Neuro-entrepreneurship has been shown to explain key drivers of the entrepreneurial process. Studies of investors, founders, the creative process, and the dynamics of entrepreneurs throughout the workflow of production have elucidated some key mechanisms of the biological underpinning of the execution of an endeavor. Specifically, in the context

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of this work, Bonte and colleagues (2016) have shown that differences in pre-natal testosterone—a hormone with strong influence on neurotransmitters and correlated behaviors—can explain why certain people are more likely to start their own business. Similarly, Ortiz-Terán et al. (2013) reveal that the neural activity of entrepreneurs differs from non-entrepreneurs while engaging in decision tasks.

Thus, the use of neuroscience techniques and evidence is increasingly offering a lens that can advance entrepreneurship understandings in multiple ways. The main purpose of this study is to leverage this potential to explore the role of gender in entrepreneurial finance, investigating whether neural differences emerge when investors assess male versus female pitches and why and how these may be connected to a certain preference for investing in male entrepreneurs.

The use of functional neuroimaging approach is particularly useful as it well-suited for questions of gender and bias, where explanations may be obscure or not accurately revealed via self-reports (Morwitz and Fitzsimons, 2004; Phelps et al., 2000). As such, to explore differential neural activity that relates to gender, we conducted an experiment that assigns prospective investors a set of entrepreneur pitch videos to assess while undergoing functional magnetic resonance imaging (fMRI) brain-scanning. Specifically, we used a controlled design, where the treatment is gender (male/female). This approach allows us to explore whether investors' neural activity is different when faced with a female versus male entrepreneur.

Given the limited evidence related to brain activations in gender recognition and investment decisions in general, we pursued this exploratory study by way of guiding research questions. As such, we ask: Are there differential patterns of neural activations when investors view male- versus female-led pitches? Can entrepreneurs' gender be reliably decoded based on investors' brain network activation, as well as on their interest to invest? If so, is there any relationship between neural and behavioral evidence?

Our investigation of these questions leads to several contributions. First, we find that the patterns of neural activity of investors varies when the investors are facing random assignment of a male versus female entrepreneur. Specifically, we observe that the left posterior fusiform cortex is significantly more active when investors view males versus female entrepreneurs. Moreover, this evidence persists regardless of the investors' own gender. Second, using a similarity-based multivariate pattern decoder (e.g., Chen et al., 2016), we decoded the gender of the entrepreneur using neural activation. Using a multivariate neural activation pattern, gender of the pitching entrepreneur can be correctly classified at 71%; that is, by observing neural activity, we can determine with considerable accuracy whether the founder is a male or female. In a related vein, we can also reliably decode whether the entrepreneur is male or female by examining the investor's behavioral response, i.e. their interests in the pitch (86% accuracy. Finally, we observe a non-zero association between decoding of the neural activity and behavioral responses (i.e., investor interest). This evidence allows us to infer that the decoding analyses reflect an indirect relationship between investors' patterns of neural activity and their behavioral interest towards male entrepreneurs relative to females. Together, our contribution has a number of implications, which we will unpack in the remainder of this paper.

NEUROSCIENCE EXPLORATION OF GENDER DIFFERENCE IN ENTREPRENEUR PITCHES

The study of gender in entrepreneurial finance has attracted considerable research attention in the past few years (e.g., Fischer et al., 1993; Minniti, 2009; Simmons et al., 2019; Stephan and El-Ganainy, 2007; Yang and Aldrich, 2014). As of recently, this topic has become of particular interest within entrepreneurial finance given the growing funding gap between males and females. For instance, it is well-documented that males receive the lion's share of venture funding—over 90% (Field, 2018).

Researchers continue to delineate the emergence of the funding patterns across gender, as well as explanations for it. Male and female founders, for instance, are asked different questions following pitches; these differences may ultimately penalize female founders given the types of questions that are asked (Kanze et al., 2017). Moreover, it has also been suggested that females are treated differently due to role incongruity or stereotypes, but can offset this by enacting certain behaviors (e.g., social impact framing) (Lee and Huang, 2018).

In parallel, functional neuroimaging research has rapidly advanced the understanding of the human brain activities and associations to behavior (e.g., Adolphs, 2003; Bear et al., 2007; Deary et al., 2010), including explanations of gender biases. Thus, it is intuitive that neuroscience holds considerable potential within the field of entrepreneurship. For instance, Lahti et al. (2019) found that entrepreneurs exhibit bonds with their ventures in a similar way that parents bond with their children (i.e., via similarities in the brain's reward system), which offers implications for understanding important questions such as why founders persist with poorly performing ventures. Other work has sought to address the long unaswered question of whether entrepreneurs think differently from non-entrepreneurs. Deploying EEG, Ortiz-Terán et al. (2013) found that entrepreneurs respond differently than non-entrepreneurs while engaging in decision tasks (Ortiz-Terán et al., 2013). In a similar vein, using EEG, Zaro et al. (2016) revealed that entrepreneurs brains appear to function differently than non-entrepreneurs while assessing business opportunities. Despite such evidence and growing calls for the incorporation of neuroscientific explanations for many aspects of entrepreneurship (Day et al., 2017; de Holan, 2014; de Holan and Couffe, 2017; Krueger et al., 2010; McMullen et al., 2014; Smidts et al., 2014; Ward et al., 2017), to the best of our knowledge, no research examining differential gender evaluations in entrepreneurial finance has been conducted thus far.

We address this gap by positing that investors brain activities can differentially recognize males and females presenting an entrepreneurial pitch and this may be correlated to their investment preferences for male entrepreneurs. If this is the case, it might assist in better understanding, at least in part, why male and female entrepreneurs are viewed differently. If different neural patterns are engaged when viewing male versus female founders, we may be able to add new explanations of why males and females are treated differently in the startup funding context. Because this is a first foray into the neural underpinning of gender-related issues in entrepreneurship, we examine this possibility through our first exploratory research question.

Research Question #1: Are there differential patterns of neural activations when investors view male- versus female-led pitches?

If such differences in neural activation occur when viewing male versus female pitches, we may be able to decode these activations. In this way, it would then be possible to reliably decode the founder's gender based on the investor's brain network activation. Put more simply, we seek to identify if we can determine whether a founder is male or female by examining investors' neural activity patterns. We explore this by investigating the following research question:

Research Question #2: Can entrepreneurs' gender be reliably decoded based on investors' brain network activation?

Similarly, we believe that gender of the founder could also be decoded by investor interest. That is, if there are differences in the way investors assess founders, and part of this difference is attributed to gender, then such differences should emerge in their behavioral ratings, or interest in investing. Thus, we expect that we can reliably decode founder gender by ratings of investor interest. We explore this possibility by way of the following question:

Research Question #3: Can entrepreneurs' gender be reliably decoded based on investors' interest?

It follows, that if we can reliably decode gender by both neural activity and by behavioral ratings, we could also expect some association between them. Finding such an association would reflect a relationship between investors' patterns of neural activity and their behavioral interest towards male entrepreneurs relatively to female ones. As such, we investigate the following guiding research question:

Research Question #4: Is there a relationship between neural activity and behavioral decodings?

METHODOLOGY

Participants. Fifteen healthy normal subjects, comprising both university members (i.e., faculty and students) and the public, were recruited and participated to this study. Participants were all right-handed, fluent in English, and had normal or corrected-to-normal vision. Participants were compensated for their participation in line with hourly national wages.

One participant was excluded from subsequent analysis due to scanner recording errors. The final sample size analyzed was of 14 participants (male =10, mean age = 29; female = 4, mean age = 25 years). This sample size aligns with current criteria in entrepreneurship research using fMRI (Drover, Massaro, Cerf, & Busenitz, 2017; Ward, Reeck, & Becker 2017) and, given the nature and purpose of the analyses conducted in this study, in closely related neuroimaging studies (e.g., Brosch, Bar-David, & Phelps, 2013; Chen, Leong, Honey, Yong, Norman, & Hasson, 2016). Additionally, with respect to sample size, it is worth noting that Brookes et al. (2014, p. 4427) suggest that in investigating gender biases in entrepreneurship "available sample sizes are small […and…is] difficult for researchers to make gender comparisons."

Procedure and Stimulus Material. After participants arrived at the MRI scanner site they were debriefed on the general nature of the study. Participants were asked to recline in the scanner. They were asked to wear noise cancelling headphones (Universal Medical, Walpole, MA) to assure optimal auditory experience and received audio input to each ear. To minimize movements, participants' heads were stabilized with a head-support.

Experimental task. Participants were assigned the active role of informal investors (hereafter, investors) and asked to view several videos while undergoing MRI scanning. Each video lasted about one minute each. Following each video, participants responded to a brief set of questions related to each video. The whole set of stimuli was administered through the Presentation software (Neurobehavioral Systems, Berkeley, CA). Participants watched the stimuli through a mirror-monitor system; the viewing was optimized to minimize both head and eye movements.

Behavioral responses were captured within the MRI scanner by means of a hand-held controller with two selection buttons (i.e., plus and minus) and a third one to confirm the choice. Investors responded to questions in about four seconds on average. At the end of each evaluation, participants were debriefed on their experience, to assess potential cognitive load, attentive decline, or appreciate any other issue potentially affecting the study's outcome. No such issues were reported.

The videos represented our experimental stimuli and constituted of entrepreneurial pitches. Specifically, we recruited ten different actors (five males and five females) who were commissioned to act as entrepreneurs and deliver unique pitches while being video-recorded. The pitches were simulated on the basis of existing early-stage pitches taken from real pitches (e.g., Calic & Mosakowski, 2016). These spanned several topics, from medical innovations to 3D-printing and environmentally sustainable solutions, among others. To provide investment options that were close-to-reality, the pitches were characterized by different features, such as different financial or social purpose, and covered a number of sectors.

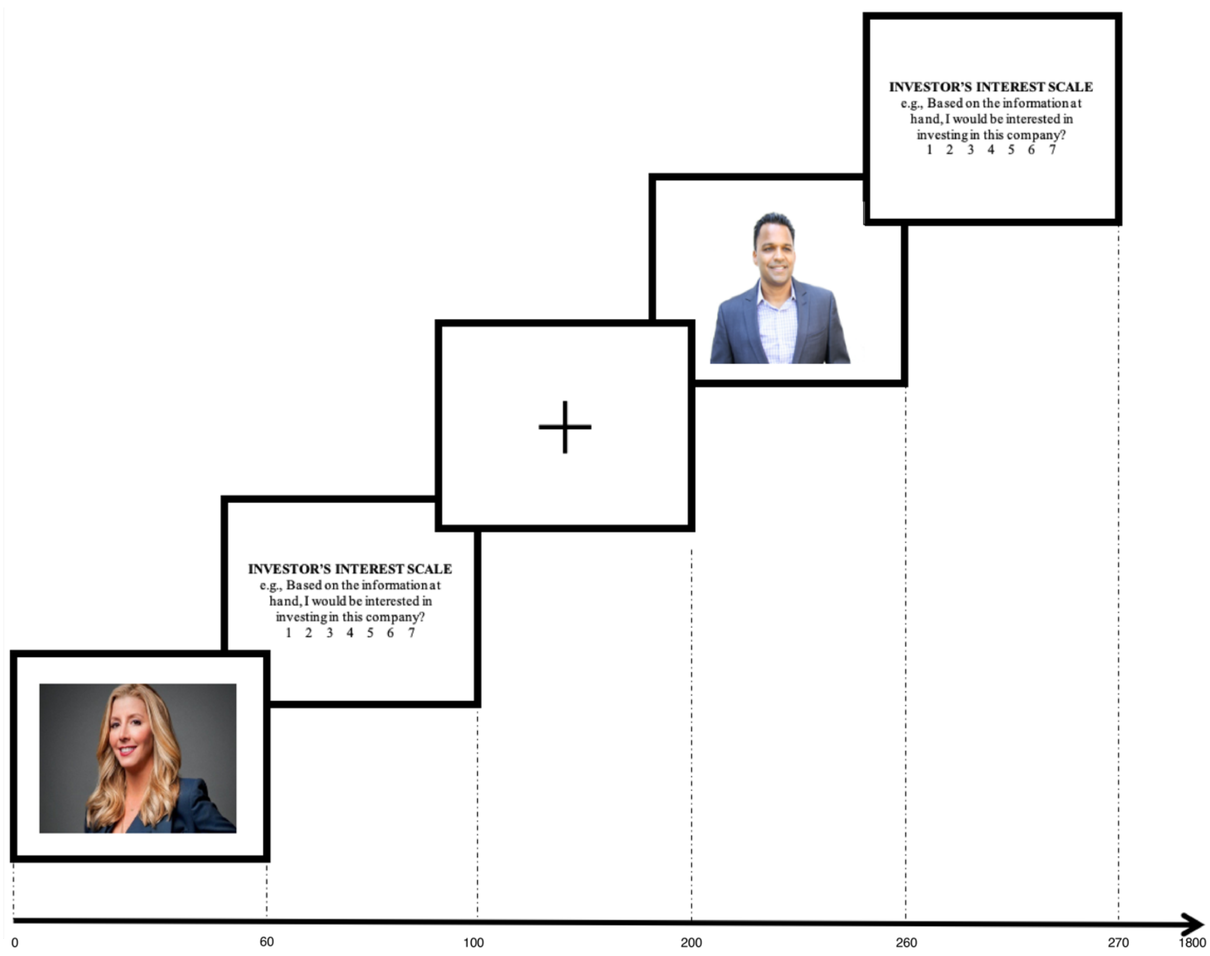

Figure 1. Schematic representation of the study research design. Time is not on scale and includes debriefing.

In order to match the real pitches, actors were trained to ensure consistency in their voices, movements, and expressions. Moreover, to ensure reproducible experimental conditions and minimize possible confounding factors, each performer (hereafter, entrepreneur) occupied the same visual angle on the screen, under the same background and having the same distinctive features (e.g., clothes' colors, posture). The clips are available online per request.

As concerns this study's research design, we adopted a single-blind design focusing on differential gender recognition. Simply put, our experimental conditions were whether a pitch was delivered by a male or a female entrepreneur.

In the scanning sessions, we assigned to each investor a pool of ten randomly selected pitches, presented in random order, for a total of 140 assessments. Each investor viewed any given entrepreneur only once. Participants watched the videos through a mirror-monitor system; the viewing was optimized to minimize both head and eye movements.

Investors' interest. After viewing each video, investors were prompted to respond to the "Investor's Interest Scale" validated by Shane et al. (2020) (Figure 1). This six-items scale includes questions on a pitch's content, scored on a low to high seven-points Likert scale, such as: "Based on the information at hand, I would be interested in investing in this company." Items were averaged to generate a measurement variable for an investor's interest. The scale's internal consistency was high (α=.91).

These behavioral responses were captured within the MRI scanner by means of a hand-held controller with two selection buttons (i.e., plus and minus) and a third one to confirm the choice. Investors responded to each question in about four seconds on average. At the end of each evaluation, participants were debriefed on their experience, to assess potential cognitive load, attentive decline, or appreciate any other issue potentially affecting the study's outcome. No such issues were reported.

Data Acquisition and Pre-processing. fMRI data were acquired using a 3T MRI scanner (Magnetom Skyra, Siemens, Erlangen, Germany) with a 12-channel head coil. Functional scans were acquired using a T2*-weighted echo planer imaging (EPI) pulse sequence [repetition time (TR), 1500 ms; echo time (TE), 28 ms; flip angle 64o], each volume comprised of 27 interleaved slices (4 mm thickness; 0 mm gap); in-plane resolution was 3x3 mm2 [Field of View (FOV), 192x192 mm2]. Anatomical images were acquired using a T1-weighted magnetization-prepared rapid-acquisition gradient echo (MPRAGE) pulse sequence (TR, 2300 ms; TE, 3.08 ms; flip angle 9o; .89 mm3 resolution; FOV, 256 mm2).

Analyses were performed in Python 3.7.3 (anaconda.org/anaconda/python). As pre-processing steps, data were corrected for motion and slice scan-time, followed by a linear trend removal and high-pass filtering; spatial smoothing was also applied using a Gaussian filter of 6 mm full-width at half-maximum value.

To evaluate functional activation, we assessed the subjects' brains across 111 Regions of Interest (ROIs). These were based on the Harvard-Oxford atlas distributed via FSL (fmrib.ox.ac.uk/fsl). Here, each ROI is comprised of a number of voxels (i.e., 3D imaging arrays) associated to defined brain areas. Voxels were pooled into the designated ROIs and averaged to produce an activation single time-series at each ROI location; data was normalized into unit intervals over the acquisition period recorded.

Prior to performing the general linear model (GLM), we regressed the global signal on the parcellated time series data to remove further artifacts associated with motion, respiration, and/or cardiac activity (Power, Plitt, Laumann, & Martin, 2017). In order to remove outliers, we then filtered the points in which the blood-oxygen-level dependent (BOLD) signal deviated more than four standard deviations from the median, and substituted the activity in that point with the median BOLD activity for that brain area.

Univariate analysis. To extract the ROIs' neural activation associated with our experimental stimuli, we performed a standard GLM. Each regressor in the GLM consists of an ideal hemodynamic response function (HRF) for the event category (i.e., gender), obtained by convolving the event time records with a γ-variate function (Lindquist, Loh, Atlas, & Wager, 2009). Specifically, we used a boxcar function—which assumes that neural activation equals 1 when the stimulus is present, and 0 otherwise—to represent each experimental condition, and convolved it using the canonical HRF to account for the time-lag associated with the BOLD signal (Friston, Holmes, Worsley, Poline, Frith, & Frackowiak, 1994). We considered a five seconds post-stimulus onset throughout (van Zijl, Hua, & Lu, 2012).

In practice, we were interested in estimating the activation coefficients "male entrepreneur" (β_m) and "female entrepreneur" (β_f) from the following general equation model:

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$$y = \beta_0 + \beta_f x_f + \beta_m x_m + \varepsilon \text{ (Eq. 1)}$$

where y indicates the time series of an ROI, β_0 is the estimated mean activity of y, x_m is the HRF convolved regressor associated with the time points related to a male entrepreneur, and x_f is the HRF convolved regressor associated with time points related to a female entrepreneur, and ε indicates the error associated with the model fit (i.e., residual time series).

To assess whether the investors' ROIs were differentially activated when viewing pitches presented by male versus female entrepreneurs, we performed a cross-subject univariate t-test contrasting gender. Based on the existing neuroscience literature, we performed such analysis on 12 selected ROIs (i.e., six bilateral regions) within the Harvard-Oxford atlas (see Table 1). We corrected for multiple comparisons using the False Discovery Rate (FDR; Genovese & Wasserman, 2002); statistical significance was assessed using an FDR-corrected threshold at $p < 0.05$ (Genovese, Lazar, & Nichols, 2002).

N	ROIs	References
1	Nuclei accumbens	Kranz & Ishai (2006)
2	Amygdalae	Knutson, Mah, Manly, & Grafman (2007)
3	Temporal occipital fusiform cortices	Grill-Spector, Knouf, & Kanwisher (2004)
4	Temporal fusiform cortices (anterior division)	Gozzi, Raymont, Solomon, Koenigs, & Grafman (2009)
5	Temporal fusiform cortices (posterior division)	Podrebarac, Goodale, van der Zwan, & Snow (2013)
6	Frontal orbital cortices	O'Doherty, Winston, Critchley, Perrett, Burt, & Dolan (2003)

Table 1. Regions of Interest (ROIs) likely to be involved in face-driven gender-evaluation biases.

Multivariate pattern analysis. We used a similarity-based multivariate pattern decoder (MVP; e.g., Chen, Leong, Honey, Yong, Norman, & Hasson, 2016; Haxby, Connolly, & Guntupalli, 2014, see also for review) to detect the gender of the entrepreneurs departing from the investors' neural activation patterns. MVP classification leverages machine learning algorithms to associate neural activations with given experimental conditions. In practice, it requires splitting data into training and testing sets [or subject(s)] and then testing a classifier, which is run to define portions of the vector space linked to the indicator (e.g., gender) provided for the samples in the training set (Haxby et al., 2014). The testing sample, or subject as in our case, is then classified as belonging to the class (e.g., male or female) associated with the space in which they are located. Finally, the accuracy of the decoding procedure is computed as the ratio of predictions that "hit" the actual target for each testing item.

Specifically, we performed the MVP decoding using a *n-1* subject cross-validation on the ROIs of interest (Mur, Bandettini, & Kriegeskorte, 2009). For each cross-validation fold, we constructed the prototypical activation patterns for assessing male and female entrepreneurs using the training dataset (*n-1*), yet averaging the activation patterns for each gender separately across investors. To decode the activation patterns of the target investor, we computed the spatial similarity of the investor's neural activation patterns with the prototypical activation patterns for both genders by means of a Pearson's correlation.

If the target investor's neural activation pattern for female was more similar to the training set's prototypical activation pattern for female than the prototypical activation pattern for male, we assigned a correct decoding value (i.e., 1). If not, we assigned an incorrect decoding value (i.e., 0). This procedure was repeated for the target investor's neural activation pattern for the videos showing male entrepreneurs. Finally, this process was reiterated for every investor in our sample, which allowed us to generate a set of decoding binary values. We then performed a binomial test to assess statistical significance; performance was tested against chance (i.e., 50%).

In addition to using neural activity, we also sought to decode entrepreneurs' gender by using the investor interest score relatively to male and female entrepreneurs. Here, the decoding scheme matched the one described above. The only difference is that we trained the algorithm on the behavioral responses rather than on the investors' neural activity.

Canonical correlation analysis. To correlate the multivariate activation patterns and behavioral responses associated with gender we used a canonical correlation analysis (CCA). This is a procedure that seeks maximal correlations between combinations of variables in both sets (Hardoon, Szedmak, & Shawe-Taylor, 2004). This analysis correlates two sets of multivariate observations, say **X** and **Y**, by estimating their linear combinations having maximal intercorrelations. In other words, CCA seeks to reduce the dimensionality of **X** and **Y** into a univariate distribution, so that the univariate equivalents of **X** and **Y**, **X'** and **Y'**, will have maximal correlation. Moreover, because in absence of cross-validation, CCA tends to overfit (given that it isolates the linear combination of **X** and **Y** maximizing the correlation), we used a *n-1* subject cross-validation scheme.

We estimated the linear combination of the neural activation patterns (**X**) and behavioral responses (**Y**) using all training subjects. We then applied the linear combination estimated from the training set on the target investor. This procedure was performed in a cross-validated fashion for each investor, until two univariate distributions (**X'** and **Y'**) were obtained for both sets of variables. We then correlated **X'** and **Y'** to estimate the relationship between **X** and **Y**.

RESULTS

In our first guiding research question, we assessed whether investors responded differently in certain brain areas in response to presentation of entrepreneurial pitches by either male or female entrepreneurs. We performed a univariate t-test on fMRI data contrasting periods of activity when investors were presented with male and female entrepreneurs. After correcting for multiple comparisons, we found that the investors' activity in the left posterior fusiform cortex (Table 2; Figure 2) was significantly more active when they were viewing males versus female entrepreneurs [$t(13) = 4.29$, $p = 0.01$; FDR-corrected]. Importantly, when controlling for the investors' gender, the results were not statistically significant, thereby ruling out possible homophilic explanations (cf., Greenberg & Mollick, 2017). We found that regardless of their own gender, investors were presenting more activation in the fusiform area when seeing male entrepreneurs relatively to female entrepreneurs.

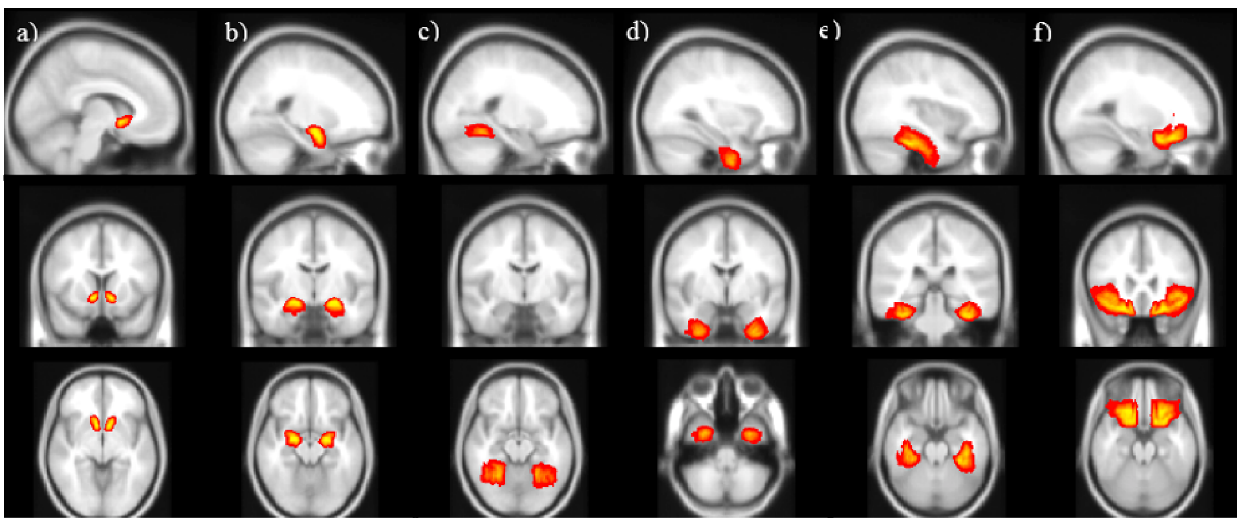

Figure 2. Sagittal, coronal, and axial sections (from top to bottom) of the brain showing FDR-corrected ($p < 0.05$) activations of bilateral: **a)** nucleus accumbens, **b)** amygdala, **c)** temporal occipital fusiform cortex, **d)** temporal fusiform cortex (anterior division), **e)** temporal fusiform cortex (posterior division), and **f)** orbito-frontal cortex.

N	ROIs	L/R	β_m	β_f	t-value	p-value	p-value (*Corrected*)
1	Nucleus accumbens	L	2.549	1.245	0.35	0.732	0.745
2	Nucleus accumbens	R	-0.332	3.106	-0.889	0.39	0.568
3	Amygdala	L	3.756	-1.494	0.941	0.364	0.568
4	Amygdala	R	-4.899	4.68	-0.948	0.36	0.568
5	Frontal orbital cortex	L	4.098	-3.369	0.762	0.46	0.585
6	Frontal orbital cortex	R	-3.752	6.802	-1.275	0.225	0.568
7	Temporal occipital fusiform cortex	L	2.606	-12.011	1.548	0.145	0.568
8	Temporal occipital fusiform cortex	R	0.421	-3.381	1.111	0.287	0.568

9	Temporal Fusiform Cortex (anterior div.)	L	2.729	-1.201	0.653	0.525	0.613
10	Temporal Fusiform Cortex (anterior div.)	R	-1.846	-0.291	-0.332	0.745	0.745
11	Temporal Fusiform Cortex (posterior div.)	L	6.928	-5.553	4.287	0.001	0.012
12	Temporal Fusiform Cortex (posterior div.)	R	2.137	-5.022	2.282	0.04	0.28

Table 2. ROIs activation (*Univariate Analysis*).

To strengthen this inference, we evaluated whether the gender of the entrepreneur could be decoded using the investors' wider neural activation pattern. Using a similarity-based multivariate pattern decoder (e.g., Chen et al., 2016), we found that across investors the gender of the entrepreneur could be reliably decoded from their multivariate neural activation patterns. Specifically, we retrieved a decoding accuracy of over 70% (71.43%, $p = 0.018$). In other words, this result shows that we were able to reliably decode the gender of the entrepreneur from neuroimaging data: Across investors their neural patterns of activity were consistently distinct when appreciating pitches delivered by male versus female entrepreneurs.

To further appreciate whether this decodability was due to an intrinsic bias, we investigated if we could comparatively decode the gender of the entrepreneurs by using the investors' behavioral responses to the stimuli. Here, by using the scoring on investor's interest scale, we found that it was indeed possible to significantly decode entrepreneurs' gender above chance too (decoding accuracy = 85.71%, $p < 0.001$). That is, we could detect whether an investor was evaluating a male or female entrepreneur based on their scores on the investor's interest scale. This evidence supports the intuition that an investor's evaluation can reveal the gender of entrepreneurs.

Altogether, these findings suggest that both neural activity patterns and behavioral responses of investors can reliably decipher the gender of entrepreneurs delivering their pitches. Thus, we tested for association between behavioral responses and neural activity patterns. Given the multivariate nature of both sets of variables a straightforward correlation was not possible, we used a CCA with a *n-1* cross-validation mapping both sets of variables into a one-dimensional scalar (see also Smith et al., 2015). We found an association between neural activation patterns and behavioral responses of -0.27 (p=0.17), which allows us to conclude that the decoding analyses reflect an indirect relationship between investors' patterns of neural activity and their behavioral interest towards male entrepreneurs relatively to female ones.

DISCUSSION AND CONCLUSION

Both practitioners and researchers are increasingly concerned about the role of gender in investor assessments of entrepreneurial pitches. Recent research, for instance, has shown that investors treat females differently than males, and that there is a preference from investors to positively evaluate male over female entrepreneurs (eg., Kanze et al., 2017; Kanze et al., 2018; Lee and Huang, 2018; Mohammadi and Shafi, 2018). In this study, we used fMRI and machine learning methods to investigate whether neuroscience evidence can shed new light on the role of founder gender within entrepreneurial finance. Indeed, the neuroscience literature has suggested that gender-based evaluations may have strong neural underpinnings (see Table 1).

Our exploratory study shows that investors' neural activities in the left posterior fusiform cortex are significantly enhanced when presented with pitches from male versus female entrepreneurs. We also explore whether neural activation patterns of informal investors assessing entrepreneurial pitches could accurately detect entrepreneurs' gender. Using advanced machine learning methods, we reliably decode the gender of the entrepreneur from both multivariate neural activation patterns of investors (71% accuracy) and investing interest (86% accuracy). This, in turn, reveals a possible association between neural mechanisms and behavioral attitudes towards male entrepreneurs.

Our study opens the door to a new approach for entrepreneurship scholars to better understand the important role of gender within entrepreneurship. Researchers might continue to build on our findings by formulating new research questions and hypotheses that expand upon our results. For instance, Lee and Huang (2018) find that certain actions tend to decrease the penalty for female entrepreneurs in the pitch setting. Introducing manipulations, and capturing neural responses might further inform why and when such interventions are effective. Future researchers might also capture neural data as it pertains to gender in settings beyond the funding pitch, such as neural-based explanations for why more men tend to become entrepreneurs, why risk taking proclivities differ by gender, and differences in how women and men entrepreneurs seek and process critical feedback in their entrepreneurial pursuits. Neural methods, such as fMRI and wireless EEG headsets offer a powerful set of tools to better understand the role of gender in entrepreneurship.

Next, while homophily may be a factor in investor assessments (e.g., males favoring male founders, females favoring female founders, etc.), data from the field indicate that while the number of female VCs more than doubled from 2014 to 2017, the gender gap of founders receiving funding became worse (Kanze et al., 2017). This raises the possibility that both male and female investors exhibit bias toward male founders – possibly due to the so-called “masculine gender-role stereotype” (e.g., Gupta, Turban, Wasti, & Sikda, 2009). An interesting addition to this conversation is that the brain areas of male and females that we observed tended to react similarly to variations in gender across pitches. That is, we observed that investors’ neural activities in the left posterior fusiform cortex is significantly enhanced when presented with pitches from male versus female entrepreneurs, regardless of investor gender. Future research might continue to harness neural data to better understand when and why investor gender influences perceptions of founder gender in their assessments and investment decision making.

With regard to the contribution provided by the neuroscience approach, the fusiform area is a well-defined region of the inferior temporal cortex that is generally involved in responding to faces (e.g., Kanwisher, McDermott, & Chun, 1997). Functionally, research has shown that incoming visual information, following structural encoding, is transformed into an abstract perspective-independent model of faces occurring in the fusiform (Rotshtein, Henson, Treves, Driver, & Dolan, 2005). Our study provides new insights on its role as it pertains to male and female funding pitches.

More broadly, our study shows the value of neuroscience techniques to explore theoretical questions not well addressed by empirical designs typically employed by entrepreneurship researchers, such as asking subjects to explain their responses (e.g., Chen et al., 2015). Neuroscientists have shown that asking subjects to evaluate a task while it is ongoing interferes with the experience and response (Hsu, 2017). And when researchers wait until the end of the task to ask questions, answers can potentially suffer from recency and peak-end effects. Observing real-time neural activity offers untapped ways to avoid such problems, which is particularly important in entrepreneurship where the decision making process may not be conscious or understood by subjects (Hsu and Yoon, 2015; Venkatraman et al., 2015; Lee and Huang, 2018). This is particularly important with sensitive research topics that pertain to unconscious bias, gender, ethnicity, etc.

Moreover, while we are the first to explore the neural basis of gender in entrepreneurship, we are by no means the first researchers using functional neuroimgaing to address entrepreneurship questions. Among other examples already discussed, within entrepreneurial finance, Genevsky and Knutson (2015) examine whether neural data can predict the success of microloan requests on Kiva. Findings suggest neural affective mechanisms are correlated with microloan decisions and charitable giving. Moreover, Genevsky et al. (2017) exposed subjects to pictures and texts associated with reward-based crowdfunding campaigns for documentaries (e.g., Kickstarter), and found that neural data can forecast aggregate behavior of crowdfunding outcomes. And Shane et al., (2020) explore how displays of founder passion influence neural engagement, and investor interest.

To the best of our knowledge, this is one of the first works within the broad management literature using fMRI to appreciate neural activity associated with gender-evaluation biases. Methodologically, this is the first-known work within the emerging field of organizational neuroscience using an MVP decoding approach. We believe that this strategy grounded in machine learning is particularly valuable to move research in neuroscience and entrepreneurship forward, given that a decoding method represents a multivariate analysis of brain activity patterns distributed across brain regions. In other words, this analysis suggests that researchers can reliably investigate what information is represented in a networked array of activated brain regions, rather than just focus on isolated areas of activation relatively to the entire brain, as currently done. Moreover, the decoding accuracy we retrieved in the neural patterns is particularly encouraging when compared to neuroscience studies using similar approaches (e.g., Brosh et al., 2013: accuracy = [50.7%; 54.6%] ($p < 0.003$; 0.006).

The results herein should be seen in light of their limitations. First, we note that as characteristic of most fMRI analyses the activations patterns, even if multivariate, are correlational. Second, it is possible that other contextual factors played a role in brain activations. To minimize this possibility, we used a randomized approach and controlled for known confounders, both in the design of the experiment and in the fMRI analyses, e.g., by regressing for investors’ own gender to rule out possible homophilic effects. Third, while investors watched elevator pitches based on real entrepreneurial concepts that were fundraising, they nonetheless viewed them on a screen while having their brains scanned. As with all fMRI research, neural responses may differ when viewing live pitches in the field. Fourth, subjects were not investing their own money, which could alter responses when one's own savings are at stake. Finally, increasing the number of investors and entrepreneurs used in this study might improve the already good accuracy of the decoding models and allow us to establish a more direct brain-behavioral association. Future research might consider addressing these limitations as opportunities to advance research.

Collectively, this paper is, to the authors' knowledge, the first-known experimental investigation to explore a) the role of founder gender in the pitch setting and b) the differential patterns of neural activations when investors assess founder by gender. Doing so, we advance the neuroscience research agenda in entrepreneurship (Day et al., 2017; de Holan, 2014; de Holan and Couffe, 2017; Krueger et al., 2010; McMullen et al., 2014; Smidts et al., 2014; Ward et al., 2017), and advance multivariate pattern analysis as methodology, thereby shedding light on the neural-based underpinnings of differential gender evaluations in entrepreneurship. We hope these efforts lead to more neuro-entrepreneurship research more broadly. It has not escaped our notice that more nuanced neuroscience-based investigations of gender in entrepreneurship can help shape the conversation on biases in business organizations and lead to more diverse, fair and equitable workplaces.

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