What’s in a face? Facial appearance associated with emergence but not success in entrepreneurship

Abstract

Facial appearance has been associated with leader selection in domains where effective leadership is considered crucial, such as politics, business and the military. Few studies, however, have so far explored associations between facial appearance and entrepreneurship, despite the growing expectation that societies project on entrepreneurs for providing exemplary leadership in activities leading to the creation of disruptive start-ups. By using computer vision tools and a large-scale sample of entrepreneurs and non-entrepreneurs from Crunchbase, we investigate whether three geometrically based facial characteristics - facial width-to-height ratio (fWHR), cheekbone prominence, and facial symmetry - as well as advanced statistical models of whole facial appearance, are associated with a) the likelihood of an individual to emerge as an entrepreneur and b) the performance of the company founded by that individual. We find that cheekbone prominence, facial symmetry and two whole facial appearance statistical models are associated with the likelihood of an individual to emerge as an entrepreneur. In contrast to entrepreneurship emergence, none of the examined facial characteristics are associated with performance. Overall, our results suggest that facial appearance is associated with the emergence of leaders in the entrepreneurial endeavor, however, it is not informative about their subsequent performance.

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Introduction

Several studies have shown that people make inferences about the characteristics of others from their faces and that these social attributions influence leadership outcomes across a variety of contexts (Olivola & Todorov, 2010; Olivola, Funk & Todorov, 2014; Todorov, Olivola, Dotsch, Mende-Siedlecki, 2015; Senior, 2018; Antonakis & Eubanks, 2017). For example, facial judgments of political candidates as more competent-looking, intelligent or attractive are associated with a higher probability of winning elections (Martin, 1978; Todorov et al., 2005; Zebrowitz & Montepare, 2005; Ballew & Todorov, 2007; Antonakis & Dalgas, 2009; Olivola & Todorov, 2010; Lenz & Lawson, 2011; Re et al., 2013; Sussman et al., 2013; Chen et al., 2014; Laustsen & Petersen, 2016). In the military, a cadet's dominant look predicted his future rank attainment (Mazur et al., 1984; Mueller & Mazur, 1996; Muller & Mazur, 1997). Leaders with masculine and dominant looking faces are preferred during war, whereas more feminine and honest-looking faces are preferred during peace (Van Vugt & Grabo, 2015). Similarly, younger-looking leaders are preferred for new exploratory tasks and older-looking leaders are preferred for more traditional spheres (Van Vugt & Grabo, 2015).

In business settings, research has also provided evidence of an association between facial characteristics and leadership emergence (Giacomin & Rule, 2020). For example, Gomulya, Wong, Ormiston & Boeker (2017) found that when a company replaces a CEO after financial misconduct, the successor was more likely to have a face that conveyed integrity, while Jiang, Yin and Liu (2019) found that a greater expression of joy particularly at the beginning and end of a funding pitch was correlated with increased funding. Trichas et al. (2012) showed that facial expressions such as a smile or lowered and pulled together eyebrows, affected how leader-like first impressions were formed. Studies also found that smile and eyebrow expressions indicated dominance and style of a leader (Senior, Barnes, et al., 1999; Senior, Phillips, Barnes, & David, 1999). Research has also shown that people can discriminate between leaders across different domains – with business leaders associated with competent looking faces and military leaders with less attractive and less warm faces (Olivola, Eubanks & Lovelace, 2014). Overall, a recent systematic review of facial displays of leadership highlighted how facial expressions of affect, maturity, and general facial structure affected subsequent leadership attributions (Senior, 2018).

Although the studies above show that facial characteristics matter for leader emergence, it is unclear whether the performance of organizations is associated with the facial characteristics of their leaders. On the one hand, some studies show an association between facial characteristics of leaders and the performance of the organizations they lead. For example, Rule and Ambady (2008) showed that power-related characteristics from CEOs' faces were associated with firm financial performance. Rule and Ambady (2011) also found that inferences of power from current and college yearbook photographs of the managing partners of the best 100 law firms in the United Stated were associated with the profits of their firms. Also, Wong et al. (2011) showed that the facial structure of CEOs' faces (measured with the facial width-to-height ratio) was associated with higher firm financial performance. On the other hand, other studies show that there is no association between the facial appearance of leaders and their organizations' performance. For instance, although Graham et al. (2017) found that the process of CEO selection is influenced by facial characteristics, they found no significant association between facial characteristics and company performance. Similarly, while Stoker et al. (2016) found significant differences between the faces of CEOs of Fortune500 companies and those of citizens or professors, they found no differences between the faces of CEOs of the best performing companies and the faces of other CEOs.

In this study we attempt to shed light on these contradicting findings between facial characteristics and performance by examining a large sample of entrepreneurs – individuals who emerge as leaders of a business (Reid, 2018). Entrepreneurs play an influential role in economic growth and societal development (Wennekers & Thurik, 1999; Carree & Thurik, 2010). They produce a cascading effect to the economy by creating jobs, contributing to the improvement of the gross domestic product, and increasing living standards (Hood & Young, 1993; Contractor & Kundu, 2004; Van Stel et al., 2005; Acs & Szerb, 2007; Cumming et al., 2014). The relation between entrepreneurs and leaders is well documented and researchers have argued that there are many commonalities between the entrepreneurship and leadership fields and that an integration between the two fields can prove mutually beneficial (Cogliser & Brigham, 2004; Antonakis & Autio, 2014; Reid et al., 2018).

In this respect, Cogliser and Brigham (2004) identified four areas of conceptual overlap between leadership and entrepreneurship. First, leaders' vision to inspire followers is similar to entrepreneurs' vision to motivate and engage key stakeholders. Second, leaders' capability to influence others to work towards a common goal is comparable to the tactics entrepreneurs use to influence others in resource acquisition. Third, creativity and innovation are required by both leaders and entrepreneurs in idea generation, structuring and promotions (Mumford et al., 2002; Ireland et al., 2003). And fourth, carefully articulated planning is crucial for both leaders and entrepreneurs to manage successfully their complex tasks in often highly dynamic environments. These dimensions are echoed by Antonakis and Autio (2014) who argue that entrepreneurs are leaders as they need to project vision and convince others and manage the process of implementing this vision to create new products or businesses (Antonakis & Autio, 2014). Reid et al. (2018) recently extended these four areas to examine how individual differences in attitudes, dispositions and cognitions can influence both leadership effectiveness and entrepreneurial performance. The common core between entrepreneurship and leadership has also been stressed by Simsek et al. (2015) who argued that because new ventures create wealth through new products and services and innovative business models they are an important setting for strategic leadership.

We use a sample of 3032 male entrepreneurs and 3787 male non-entrepreneurs retrieved from Crunchbase (https://www.crunchbase.com) - a leading platform that collects and curates detailed business information on start-ups and companies - to investigate the following question: Do physical facial characteristics predict whether someone is an entrepreneur and do such characteristics relate to firm performance? We examine three of the most extensively studied, measurable characteristics that reflect facial geometry: facial width-to-height ratio (fWHR), cheekbone prominence and facial symmetry (Hehman et al., 2015; Mileva et al., 2014; Geniole, et al., 2015; Lefevre et al., 2013; Cunningham et al., 1990; Thornhill & Gangestad, 1993; Scheib et al., 1999; Grammer & Thornhill, 1994; Perrett et al., 1999; Penton-Voak et al., 2001). The first facial characteristic - the facial width-to-height ratio (fWHR) – has been associated with the emergence of leaders (Alrajih and Ward, 2014; Hahn et al., 2017;) and firm performance (Wong et al., 2011; Alrajih and Ward, 2014; Haselhuhn et al., 2014; Yang et al., 2018). However, the literature on fWHR is fraught with contradicting findings regarding the role of fWHR in forming social judgments from facial appearance, necessitating additional research in this area (Holzleitner & Perrett, 2016; Todorov, 2017; Deaner et al., 2012; Özener, 2012). The second and third facial characteristics, cheekbone prominence and facial symmetry have received extensive scholarly attention and have been associated with attractiveness (e.g. Tanner, 1978; Keating, Mazur, & Segall, 1981; Cunningham et al., 1990; Thornhill & Gangestad, 1993; Scheib et al., 1999; Grammer & Thornhill, 1994; Perrett et al., 1999; Penton-Voak et al., 2001), which has been linked to entrepreneurship in the management literature (Baron et al., 2006; Wood Brooks et al., 2014).

We investigate whether these three facial characteristics are associated with entrepreneurship emergence and entrepreneurial performance, the latter operationalized in terms of a) revenue of the company, b) funding received and c) the valuation of the company. Also, because studies have pointed out that one-dimensional measures (e.g., fWHR) present several shortcomings (Stoker et al., 2016; Todorov et al., 2015), we examine in robustness tests whether statistical models of whole facial appearance (Zhao et al., 2003; Stoker et al., 2016) are related to the emergence and performance of entrepreneurs. By harnessing advancements in computer vision and big data analytics our study finds that the cheekbone prominence, facial symmetry and whole facial appearance models are associated with the likelihood of an individual to emerge as an entrepreneur. However, none of the examined facial characteristics are associated with entrepreneurial performance.

Our study makes the following contributions to research. First, it contributes to the burgeoning literature on facial characteristics and leadership (Stoker et al., 2016; Todorov et al., 2015; Olivola et al., 2014; Senior, 2018; Poutvaara, 2014; Graham et al., 2017) by finding an association between facial characteristics and leadership emergence but no association between facial characteristics and leadership performance. Second, our study provides, to the best of our knowledge, the first investigation of the association between facial characteristics and entrepreneurship emergence and performance. Third, our study contributes to the literature on three well-studied facial characteristics – fWHR, cheekbone prominence and facial symmetry. Our study is in line with recent work providing evidence against the role of fWHR in forming social judgements from facial appearance (Holzleitner & Perrett, 2016; Todorov, 2017). Finally, our paper extends our understanding of why attractive individuals, often characterized by prominent cheekbones and facial symmetry, are more likely to become entrepreneurs (Langlois et al., 2000; Baron et al., 2006; Cunningham et al., 1990; Brooks et al., 2014).

Theoretical Development

Scholars have proposed that stereotyping and heuristics play a role in social judgments of faces. This is informed by social information processing theory which maintains that increasing demands and information overload can lead to an automatic attribution of facial characteristics to certain schemata based on a priori conceptions (Lord, 1985; Stoker et al., 2016). Scholars have also proposed that evolutionary mechanisms may account for these social judgments (Knowles, 2018; Van Vugt & Grabo, 2015) suggesting that leadership and followership emerged to solve coordination challenges as our species evolved (Van Vugt et al., 2008; Van Vugt & Grabo, 2015; (Bates, 2007; Clarke, 2008; Senior et al., 2012). In the following paragraphs, we propose that the fWHR, cheekbone prominence and facial symmetry may play a role in entrepreneurship emergence and performance. We first examine the fWHR.

fWHR

There have been contradicting findings on the role of fWHR in forming social judgements from facial appearance (Costa et al., 2017). On the one hand, men's fWHR has been linked with aggression (Carré & McCormick, 2008), cheating, non-reciprocation of trust (Carré, McCormick, & Mondloch 2009; Stirrat & Perrett, 2010) and this association may be attributed to these men being treated differently because of their facial characteristics. Goetz et al. (2013) indicated that wide-faced men are more prone to aggressive behavior but only in the context of relatively low social status. Stirrat and Perrett (2010) demonstrated that men's facial ratios predicted self-interested behavior and the tendency to violate trust in an economic game. Jia, Lent and Zeng (2014) argued that the fWHR of senior managers is related with the probability of financial misreporting while Haselhuhn et al. (2014) showed that men with greater fWHRs were more likely to explicitly deceive others in a negotiation. Some researchers have also argued that fWHR may be a sexually-selected signal mediated by testosterone (Carré, 2008; McCormick, 2010; Haselhuhn, 2011, 2015; Lefevre et al., 2013; Roney et al., 2006; Penton-Voak & Chen, 2004; Hodges-Simeon et al., 2016; Weston et al., 2007).

Researchers have also found an association between fWHR and leadership. Hahn et al. (2017) showed that male CEOs of US and German companies have higher than normal fWHR while the CEOs of non-governmental organizations (NGOs) and leaders of the Roman Catholic Church have higher fWHR compared to controls. Similarly, Alrajih and Ward (2014) found that male CEOs of UK companies had higher fWHR than age- and sex-matched controls. Thus, there is some suggestive evidence that individuals with higher fWHR are more likely to emerge as leaders across various leadership contexts. As entrepreneurs are individuals who emerge as leaders of a business (Reid, 2018), fWHR may also be associated with entrepreneurship emergence.

Researchers have also reported a significant association between fWHR and financial performance. Wong et al. (2011) examined whether CEOs' fWHR is associated with their firms' financial performance using a sample of 55 male CEOs of Fortune 500 firms. Their results show that firms whose CEOs had a higher fWHR, achieved better financial performance. Similarly, Halford & Hsu, 2020 found that higher fWHRs of CEOs were associated with better firm performance. As a result, a higher facial width to height ratio may also be positively associated with entrepreneurial performance.

The associations identified between fWHR and leadership emergence and performance may also hold for entrepreneurs, as they are individuals who emerge as leaders of a business (Reid, 2018). Similar to leaders, they inspire and motivate stakeholders, influence others, engage in idea generation and structuring, and are involved in carefully articulated planning (Cogliser and Brigham, 2004).

On the other hand, several scholars have been critical of the fWHR and provided evidence against its role in forming social judgments (Holzleitner & Perrett, 2016; Todorov, 2017; Deaner et al., 2012; Özener, 2012). Holzleitner and Perrett (2016) scanned the faces of people and measured their weight, height and body strength; they argue that body size influences judgments of strength and by extension the aggressiveness and dominance of others. Todorov (2017) suggested that while the fWHR predicts perceptions of strength, it does not predict actual strength. Even though some authors provide support that the fWHR is associated with levels of testosterone (Carré, 2008; McCormick et al., 2010; Haselhuhn, 2011, 2015; Lefevre, 2013; Stirrat & Perrett, 2010; Roney et al., 2006; Penton-Voak & Chen, 2004; Weston et al., 2007), Todorov (2017) found no increase in the fWHR after simulating increased testosterone levels in facial images. Todorov (2017) argued that we simply rely on body size when judging physical formidability. Men are by nature larger and stronger and as a result have faces that go with these bodies. Similarly, Todorov notes, fWHR is not a signal of aggressiveness, rather a signal of more fat mass and of stereotypes about bigger, heavier men. Along similar lines, Deaner et al. (2012) showed that weight, and not fWHR, predicted aggression in hockey players.

To summarize, some scholars have argued that people make inferences about the characteristics of others from the fWHR and these social attributions influence outcomes across various leadership contexts. However, the literature on fWHR is fraught with contradicting findings on assessing the fWHR as a mediator of facial judgements further necessitating additional research in this area. In an attempt to shed light on the conflicting evidence, we examine the following hypotheses with respect to entrepreneurship emergence and performance:

H1a: A higher facial width to height ratio is positively associated with entrepreneurship emergence.

H1b: A higher facial width to height ratio is positively associated with firm performance.

Cheekbone Prominence

The second facial characteristic we examine, cheekbone prominence, is the ratio of cheekbone width divided by jaw width. Research indicates that cheekbone prominence is associated with attractiveness (Tanner, 1978; Keating, Mazur, & Segall, 1981; Cunningham et al., 1990; Enlow, 1990; Johnston & Franklin, 1993; Thornhill & Gangestad, 1993; Scheib et al., 1999) – specifically, higher, wider cheekbones, and narrower cheeks are related to greater perceived attractiveness. For example, Cunningham et al. (1990) used two dimensional images of human faces from three male

Caucasian populations and showed a significant association between cheekbone prominence and male attractiveness. Similarly, Cunningham et al. (1995) examined Asians, Blacks, Hispanics, and Whites and found a significant association between cheekbone prominence and attractiveness.

Facial attractiveness is valued in potential leaders (Little et al., 2007; Little, 2014; Re & Perrett, 2014) and has been associated with higher perceived leadership ability (Re & Rule, 2015; Banducci et al., 2008; Berggren et al., 2010; Budesheim & DePaola, 1994; Efrain & Patterson, 1974; King & Leigh, 2009; Little et al., 2007, 2012; Spisak et al., 2011, 2012; Rule et al., 2011). Attractiveness also has important effects for entrepreneurs because in attempting to start new ventures, they often interact with individuals who do not know them and who have little information about their potential (e.g. investors, customers and employees) (Baron et al., 2006). In situations where individuals are not previously acquainted, the effects of personal characteristics, including physical attractiveness, tend to be maximized (Schlenker & Pontari, 2002). Since first impressions, which are strongly influenced by attractiveness, tend to persist and can strongly influence subsequent behavior and decisions (e.g., Fiske, Lin, & Neuberg, 1999), the impact of individuals' attractiveness on entrepreneurship emergence is likely to be considerable.

Indeed, the effects of a person's attractiveness in entrepreneurship have been shown in a variety of settings; from earning more money from investors (Wood Brooks et al., 2014), to more favorable treatment of their ideas (Baron, Markman & Bollinger, 2006), to higher annual earnings from their business (Baron et al., 2006), and to higher perceived competence (Verhulst et al., 2010). In the wider business context, highly attractive people earn 20 percent more and are promoted more frequently than people of average attractiveness (Nault, Pitesa and Thau, 2020).

The theoretical foundations of our argument rest in the framework concerning the impact of affective states on judgments and evaluations (the affect infusion model; Forgas, 1995). The affect infusion model (AIM) suggests two mechanisms through which the positive affect generated by attractiveness can influence subsequent evaluations and judgments of persons. First, affective states prime similar thoughts and memories. The theory proposes that when we experience positive affect, it evokes positive thoughts and memories. Second, affective states serve as a quick way for us to infer our reactions to any person or event. The presence of positive affect leads us to conclude that we like objects or persons at the time we experience them (e.g., Forgas, 1995, 1998). Furthermore, the model suggests that such effects may spread, through affect infusion, to judgments and evaluations of entrepreneurs' ideas for new products/services.

To summarize, the above studies suggest that individuals with prominent cheekbones are considered more attractive (Tanner, 1978; Keating, Mazur, & Segall, 1981; Scheib et al., 1999). People's perceptions of attractiveness systematically affect their choices and the attributes that they assign to other individuals. Attractive individuals are more likely to start a business and also to achieve higher firm performance (Baron et al., 2006; Wood Brooks et al., 2014). As a result, a higher cheekbone prominence may be associated with a higher likelihood of entrepreneurship emergence and performance. Therefore, we explore the following hypotheses:

H2a: A higher cheekbone prominence is positively associated with entrepreneurship emergence.

H2b: A higher cheekbone prominence is positively associated with firm performance.

Facial Symmetry

Facial symmetry, where the left and right parts of the face look alike, is the third facial characteristic that we study. Numerous studies show that facial symmetry is significantly correlated with physical attractiveness (e.g. Grammer & Thornhill, 1994; Jones & Hill, 1993; Zebrowitz, Voinescu, & Collins, 1996; Langlois et al., 1994; Rhodes et al., 1998, 1999, 2001; Scheib et al., 1999; Mealey et al., 1999; Perrett et al., 1999; Jones et al., 2001; Penton-Voak et al., 2001; Hume & Montgomerie, 2001). Grammer and Thornhill (1994) presented the first study to reveal that both sexes viewed symmetry in faces as attractive. Biologists also note that facial symmetry should be attractive as it is a signaling mechanism of mate quality (Swaddle & Cuthill, 1994a/1994b; Watson & Thornhill, 1994).

In addition, several studies found that people with symmetrical faces have greater emotional and psychological health (Grammer & Thornhill, 1994; Manning, Scutt, Whitehouse, Leinster & Walton, 1996; Shackelford & Larsen, 1997). Grammer and Thornhill (1994) suggested that healthy and immunocompetent persons are preferred during sexual selection and supported that sexual attractiveness can be indicated by certain facial features. They argued that facial symmetry is an "honest" indicator of high immunocompetence or “good genes,” to the extent that an exposure to pathogens or environmental pollutants is determined by an effectual immune system. Similarly, Shackelford and Larsen (1997) found that facial asymmetry is a cue of poor psychological and emotional health for both men and women, with stronger indications for men.

Other research suggests that symmetry is a sign of perception of evident health for both male and female faces (Rhodes et al., 2001). Jones et al. (2001) indicated that the relationship between facial symmetry and attractiveness is mediated by judgments of apparent health and this relation was stronger for judgments of female faces than for judgments of male faces. They also noted that the relationship between measured facial symmetry and ratings of apparent health remained when controlling for attractiveness. Furthermore, Penton-Voak et al. (2001) suggested that the relationship between facial symmetry and perceptions of evident health may originate from an attractiveness halo. Evidently, some researchers argue that apparent good health may simply be a 'cliché' associated with attractive individuals (Kalick, Zebrowitz, Langlois, & Johnson, 1998).

Attractive people are more likely to be trusted, receive more favorable evaluations of their business ideas and more likely to become entrepreneurs (Langlois et al., 2000; Baron et al., 2006; Brooks et al., 2014). Also, the attractiveness of entrepreneurs has been positively related to their firm's financial performance (Baron et al., 2006; Wood Brooks et al., 2014).

Another important line of work has suggested that it is asymmetry, and not symmetry, that signals strength (Senior et al., 2012: 287). Fluctuating asymmetry refers to the degree to which the left and right side of the body is asymmetrical (Bates, 2007; Senior et al., 2012) with research in this area examining finger length, wrist width and ear length (Senior et al., 2012). Scholars have found that individuals who exhibit fluctuating asymmetries 'stand out' in distinct ways (Senior et al., 2012; Zaatari & Trivers, 2007). For example, Senior et al. 2012 conducted two studies to examine the predictive value of a leader's facial asymmetry. They drew from the literature on developmental stability which refers to the extent an organism can resist genetic and environmental stressors (Clarke, 1998). In the first study, they found that fluctuating asymmetry was positively associated with transformational leadership, based on measurements of left and right fingers, wrist and ears (Senior et al., 2012). In the second study, Senior et al. (2012) showed that leaders with fluctuating asymmetry guided their groups to perform better (Senior et al., 2012). In addition, other studies have found an association between asymmetry and prosocial behaviors (Zaatari & Trivers, 2007).

To summarize, on the one hand, research suggests that individuals with higher facial symmetry are considered more attractive (e.g. Grammer & Thornhill, 1994; Jones & Hill, 1993; Zebrowitz, Voinescu, & Collins, 1996; Langlois et al., 1994; Rhodes et al., 1998). As the entrepreneurship literature has argued that attractive individuals are more likely to start a business and achieve higher firm performance (Baron et al., 2006; Wood Brooks et al., 2014), a higher facial symmetry may be associated with entrepreneurship emergence and performance. On the other hand, the literature on fluctuating asymmetry suggests that asymmetric characteristics are more likely to be positively associated with entrepreneurship. As a result, in our next two hypotheses we propose an association between symmetry and entrepreneurship emergence and performance but leave the hypotheses directionless.

H3a: Facial symmetry is associated with entrepreneurship emergence.

H3b: Facial symmetry is associated with firm performance.

Methodology

Data

We obtain our data from Crunchbase, the leading online platform that collects, curates and disseminates business information on start-ups, companies and the people behind them (namely investors, entrepreneurs, managers, etc.). The accuracy and validity of the data is ensured by 1) a plethora of work partners (e.g. venture capital firms, AngelList), 2) CrunchBase's expert team that use manual validation and curation methods, and 3) AI and Machine learning techniques that are utilized for detection of anomalies. Crunchbase has been used in recent research studies (Roberts, 2019; Ter Wal et al., 2016; Yu et al., 2017).

We collected the profiles of all people from Crunchbase in August 2017 and performed several pre-processing steps (please see Table 1). We consider as entrepreneurs all users whose job title contains any of the terms “entrepreneur”, “founder”, “co-founder”, “owner” or “co-owner”, while the rest of the users are considered as non-entrepreneurs. We excluded users who did not have a profile picture and used Face++ to exclude profiles whose pictures depicted more than one face. We also restricted the data to white males whose location is the USA to control for potential confounders (e.g. racial differences in facial features). Using Face++ (please see details below) we excluded observations with an “Age” below 18. We also used the Face-to-BMI tool (http://face2bmi.csail.mit.edu) in order to estimate the body-mass index (BMI) value from each facial photograph. We excluded observations with a “BMI” below the 1st percentile or above the 99th percentile to avoid the consequences of a potential measurement error (Zhao et al., 2011) of the Face-to-BMI tool. Including these observations makes no qualitative difference in the results.

[INSERT TABLE 1 ABOUT HERE]

Another factor that can affect our analysis is the rotation of faces in the pictures, which is represented by the pitch (rotation of face around the x-axis), the yaw (rotation of face around the y-axis) and the roll (rotation of face around the z-axis) (please see Figure 1). In particular, face rotations affect the detection of facial landmarks (Wu & Ji, 2015) that are used to calculate facial ratios. Thus, large face rotations may influence the measurement of facial ratios (Hehman et al., 2013; Kramer, 2016; Třebický et al., 2016; Zhang et al., 2020).

To solve this issue, we followed the methodological approach of Saxton et al. (2020). Specifically, Saxton et al. (2020) only used faces with maximum face rotations of [-5°, 5°] degrees in yaw, pitch and roll, as these degrees of rotations avoid measurement errors on facial ratios. Thus, in our study we used a very conservative yaw, pitch and roll rotation of [-5°, 5°] degrees. The final dataset consists of 3032 entrepreneurs and 3787 non-entrepreneurs. We also conducted the analyses using a less stringent yaw, pitch and roll range of [-10°, 10°] with similar results.

[INSERT FIGURE 1 HERE]

Image Processing

In this study we use Face++ Cognitive Service, the leading face recognition platform (Wang, 2016), which is used widely by the research community. Face++ employs advanced deep learning techniques (Fan et al., 2014; Yin et al., 2016); in particular, Convolutional Neural Networks (CNNs) (Rawat & Wang, 2017) trained with five million faces (Zhou et al., 2015). Face++ exhibits 90.6% accuracy for face detection, 92% accuracy for gender detection, 93% accuracy for race detection, and 82% accuracy for head pose/rotation detection (Jung et al., 2018; Chen et al., 2020). Face++ can be used to identify various attributes and landmarks from facial images, e.g. gender (i.e. male and female), race (limited to Asian, Black, and White) and head pose (pitch angle, yaw angle, roll angle).

fWHR, cheekbone prominence and facial symmetry

We use Face++ to measure the facial width-to-height ratio (fWHR), the cheekbone prominence, and two measures of facial symmetry: overall facial asymmetry and central facial asymmetry. To derive these facial measurements, we used 16 facial landmarks/points (see Figure 2a). Points P1 (left eye left corner) and P3 (left eye right corner) are the corners of the left eye while P2 (right eye right corner) and P4 (right eye left corner) are the corners of the right eye. Points P5 (face contour left) and P6 (face contour right) are the widest central points of a face contour. The two points are on the horizontal line below the eyes. P7 and P8 are the left and right point of the nose in the lowest nose part. P11 and P12 are the left corner and the right corner of the mouth respectively. P9 and P10 are defined as the width of the face (jaw width) at the same horizontal line as the points P11 and P12. Point P13 is the chin and P14 is the top point of the upper lip of the mouth. The final points P15 (left eyebrow right corner) and P16 (right eyebrow left corner) are the innermost eyebrow corners.

[INSERT FIGURE 2 HERE]

Calculation of fWHR

We calculated fWHR using the bizygomatic breadth (width) divided by the distance between the middle of the eyebrows to the center of the upper lip (height) (Hodges-Simeon et al., 2016; Carré & McCormick, 2008). In Figure 2b, "a" represents the width and "b" the height and the division "a/b" represents the fWHR. For the calculation of width we used the points P5 and P6 in Figure 2a. For the height, we first calculated the midpoint of the P15 and P16 and then calculate its distance to P14. In robustness tests, we also examined a different operationalization of the fWHR, called the fWHR-lower, which uses the bizygomatic breadth (width) divided by the distance between the mean eye height and the bottom of the chin (height of the lower face) (Hodges-Simeon et al., 2016; Lefevre et al., 2012). The results were qualitatively similar.

Calculation of cheekbone prominence

We calculated cheekbone prominence using the bizygomatic breadth divided by the jaw width (width at the corners of the mouth) (Hodges-Simeon et al., 2016). In Figure 2c, “a” represents the upper width and “b” the lower width and the division “a/b” represents the cheekbone prominence. For the upper width we used the points P5 and P6 and for the lower width we used the points P9 and P10 in Figure 2a.

Calculation of facial asymmetry

In our study, we focused on horizontal asymmetry using the overall facial asymmetry (OFA) and the central facial asymmetry (CFA) metrics (Grammer & Thornhill, 1994). Both of these metrics are based on the sum of the differences between pairs of midpoints, where on a perfectly symmetrical face all midpoints must be on the same vertical line. We adapted the formulas of OFA and CFA in such a way that our results will not be affected by the resolution of the photos or by the distance of the faces from the camera (please see Appendix A). Thus, instead of computing the “differences between midpoints”, we computed the “divisions between midpoints”. We used the following formula (1), to calculate the OFA, where D_1, D_2, D_3, D_4, D_5 and D_6 refer to the lines in Figure 2d. According to this formula, a perfectly symmetrical face has an OFA value equal to 0.

$$OFA = 15 - \sum_{i=1}^{5} \sum_{j=i+1}^{6} \frac{\min(midpoint(D_i), midpoint(D_j))}{\max(midpoint(D_i), midpoint(D_j))} \quad (1)$$

In order to calculate CFA, we used the following formula, where D_1, D_2, D_3, D_4, D_5 and D_6 refer to the lines in Figure 2d and where a perfectly symmetrical face has a CFA value equal to 0.

$$CFA = 5 - \sum_{i=1}^{5} \frac{\min(midpoint(D_i), midpoint(D_{i+1}))}{\max(midpoint(D_i), midpoint(D_{i+1}))} \tag{2}$$

BMI and Face-to-BMI tool

We control for a person's Body Mass Index (BMI) as this can influence the fWHR and cheekbone prominence (Coetzee et al., 2010; Lefevre et al., 2012; Lefevre et al., 2013). The BMI is defined as the *body mass* divided by the *square of the body height* (kg/m^2) and attempts to quantify the amount of tissue mass in a person. We use the Face-to-BMI tool to calculate a person's BMI from an image. In particular, Face-to-BMI applies state-of-the-art computer vision and deep learning techniques (Kocabey et al., 2017) in order to infer a person's BMI from a profile picture.

Dependent Variables

Entrepreneurship emergence: We defined as entrepreneurs those with at least one of the following terms in their job title: "entrepreneur", "founder", "co-founder", "owner", "co-owner". The remaining users were classified as non-entrepreneurs (e.g., engineers, analysts, professors, marketing, etc.). The dependent variable was coded as "1" for entrepreneurs and "0" for non-entrepreneurs. These operationalizations are well established in the entrepreneurship literature (Gartner, 1988; Mesch & Czamanski 1997; Delmar & Davidsson, 2000; Hull et al., 1980; Ahmed, 1985; Bitler et al., 2005; Shane, 2003; Nicolaou et al., 2008).

Firm Performance: We examined whether the facial characteristics of entrepreneurs are associated with firm performance using 4 performance measures. Specifically, the first dependent variable is the revenue of a company, which is provided by Owler and

Crunchbase. Owler (https://corp.owler.com) is a community-based competitive insights platform that provides up-to-date business information. Owler collaborates with Crunchbase and provides access to its dataset through the Crunchbase platform. Owler's dataset contains more than 13M company profiles, 40M competitive relationships and 500,000 monthly contributions by an active community of over 3.5M business professionals. The second dependent variable is a binary variable indicating whether an entrepreneur received funding for their venture from investors (Shane, 2003). (The data related to funding contains several types of rounds such as angel rounds, seed rounds, venture series rounds etc. Specifically, our dataset contains 944 funding rounds from which most are either venture funding (564 rounds) or seed rounds (242 rounds)). Those who received funding were coded as "1" and others "0".The third dependent variable is the total amount of funding raised. Finally, the fourth dependent variable is the most recent valuation of a company and is provided by PrivCo and Crunchbase. PrivCo (www.privco.com) is a leading financial data provider for US private companies. PrivCo also collaborates with Crunchbase as well as with other industry leaders like American Express, Microsoft and Deloitte. PrivCo builds its dataset by continuously collecting and curating data from 20,000+ unique sources like regulatory and legal filings, business journals, trade publications, press releases, social media and company sources (internal docs and presentations, intentionally or unintentionally posted).

Control Variables

We control for a number of factors that could influence our results. The first control variable is location. Different geographic areas demonstrate different rates of entrepreneurial growth and success in attracting funding (Guzman & Stern, 2016). Based on the "Global Startup Ecosystem Report 2020" (https://startupgenome.com/reports/gser2020), we extracted the top 10 US cities ranked as part of the global startup ecosystem. We used dummies for the following US cities: New York City, Boston, Los Angeles, Seattle, Washington DC, Chicago, Austin, San Diego, Atlanta and Denver. We avoided utilizing more dummy variables for US cities due to their low number of observations for some of our dependent variables. We also ran our regressions using US state dummies (instead of the city dummies) and found that the results are qualitatively the same both for entrepreneurship emergence and performance. The second control variable is the age of a person as given by the Face++ tool. The age of a person may affect his/her decision to start and run a business (Bönte et al., 2009; Lévesque & Minniti, 2011; Azoulay et al., 2020). The third control variable is the rotation angle of a face. We use the three variables, yaw, pitch and roll, to describe the degrees of rotation around the Y, X and Z axes respectively. We control for rotation angle of a face since it may affect the facial ratios. The fourth control variable is the body mass index (BMI) as given by the Face-to-BMI tool. We control for BMI since it is significantly (positively) associated with fWHR (Coetzee et al., 2010; Lefevre et al., 2012) and may also affect the other facial ratios. The fifth control variable is education. In particular, we used dummy variables to control for whether a person has a PhD, a Master, or a Bachelor degree. Education may affect an individual's decision to start a business (Wadhwa et al., 2010; Brandstätter, 2011; Schoon & Duckworth, 2012). Also, we controlled for industry since different industries are associated with different rates of performance and success in attracting funding (Shane, 2003). Crunchbase categorizes all companies in 46 industry groups (https://support.crunchbase.com/hc/en-us/articles/360043146954-What-Industries-are-included-in-Crunchbase). Based on these industry groups, we included appropriate industry dummies. Finally, we controlled for the year that a person entered the Crunchbase dataset.

Results

For the preprocessing of the facial images we used Python 3, OpenCV-Python 4.2.0.32, Face++ Cognitive Service Platform (version 2020) and Face-to-BMI v1. Finally, for our statistical analysis, we used STATA v14.2.

Entrepreneurship Emergence

First, we investigate whether fWHR, cheekbone prominence, and facial symmetry are associated with the entrepreneurial emergence. Table 2 presents the descriptive statistics and correlations and Table 3 presents the specifications for entrepreneurship emergence using the linear probability model (Greene, 2010; Gomila, 2021; Angrist & Pischke, 2008; Caudill, 1988; Huang, 2019). We also estimated all models using logistic regressions with similar results (see Appendix B). Model 1 is the base model which includes only the control variables. In Model 2, the fWHR is introduced, which is positive and insignificant (hypothesis 1a is not supported). Model 3 adds the cheekbone prominence to the base model. The coefficient of the cheekbone prominence is positive and significant ($p < .001$) providing support for hypothesis 2a. Models 4 and 5 introduce the overall facial asymmetry (OFA) and the central facial asymmetry (CFA), respectively. Both facial asymmetry measures are negative and significant ($p < .01$). This provides support to our hypothesis 3a. Please note that measures of OFA and CFA capture facial asymmetry hence the negative coefficient. Model 6 adds the overall facial asymmetry (OFA), fWHR and cheekbone prominence to Model 1. Cheekbone prominence and OFA are significant ($p < .001$; $p < .01$) while the fWHR is insignificant. Model 7 adds the central facial asymmetry (CFA), fWHR and cheekbone prominence to Model 1. The fWHR is insignificant while cheekbone prominence and CFA are significant ($p < .001$; $p < .01$). Our regression coefficients suggest that for every unit increase in "overall facial asymmetry", the predicted probability of entrepreneurial emergence decreases by 0.10, and for every unit increase in "central facial asymmetry", the predicted probability of entrepreneurial emergence decreases by 0.32, ceteris paribus. It is important to note that the proportion of the variance explained by our models is fairly small, around 10 percent. Overall, our results provide support for hypotheses H2a ($p < .001$) and H3a ($p < .01$) and no support for hypothesis H1a.

[INSERT TABLE 2 AND 3 HERE]

We also conducted the same analysis using a less stringent yaw, pitch and roll range [-10°, 10°]. This led to a much higher sample of 26,143. The results were qualitatively the same (see Appendix C).

Firm Performance

To investigate whether the fWHR, cheekbone prominence, and facial symmetry (OFA and CFA) of entrepreneurs relates to their firms' performance, we used the 4 performance indicators mentioned earlier: a) estimated revenue of the company, b) whether they received funding (0/1), c) total funding amount received and d) the most recent valuation of the company. First, we examine whether these facial characteristics of entrepreneurs are associated with the revenue of their firm. Table 4 and Table D1 in Appendix D show that none of the facial characteristics are associated with the revenue or the natural logarithm of revenue respectively.

[INSERT TABLE 4 HERE]

Second, we examine the likelihood of an entrepreneur receiving funding (Table D2 in Appendix D). All four facial characteristics are insignificant. Third, we investigate whether these facial characteristics of entrepreneurs are associated with the total amount of funding received (Table D3 in Appendix D). All facial characteristics are insignificant. Finally, we examine whether these facial characteristics of entrepreneurs are associated with the valuation of their firm. Table D4 and Table D5 in Appendix D show that none of the facial characteristics are associated with firm valuation or the natural logarithm of firm valuation respectively. Overall, the fWHR, cheekbone prominence, and facial symmetry are not associated with firm performance yielding no support for hypotheses 1b, 2b and 3b.

We also ran our regressions including firm size. Overall, the results show no qualitative differences. However, due to the relationship between firm size and our dependent variables (e.g. funding, revenue, valuation, etc.), we face possible endogeneity problems and do not include firm size in our main regressions.

Robustness tests

Facial recognition using the whole face

Scholars have argued that predetermined and one-dimensional measures (e.g. fWHR) present several shortcomings as they are superimposed upon the data (Stoker et al., 2016; Todorov et al., 2015), and there have been several failures to replicate such findings (Todorov et al., 2015). Moreover, the fWHR was initially presented as a sexually dimorphic feature (Carré & McCormick 2008; Carré et al., 2009), while afterwards it was determined that it is not a sexually dimorphic trait (Kramer et al., 2012; Lefevre et al., 2012). Additionally, there have been several failures to replicate the finding that fWHR predicts aggressive behavior (Deaner et al., 2012; Gomez-Valdes et al., 2013). The facial measures/ratios can also be affected by image variation, since expressions, head pose, and face orientation may change the facial ratios (Todorov et al., 2015).

Recently, in the biometric application of facial recognition, purely geometrically based methods like fWHR have been replaced by approaches that take the appearance of the whole face into account through statistical modelling of the whole facial appearance (see e.g. Zhao, Chellappa, Rosenfeld & Phillips, 2003). Face detection methods can be categorized into two categories (Zhao et al., 2003): 1) feature-based (facial landmarks) and 2) holistic (whole-pixels) approaches. Feature-based approaches (Tu et al., 2007; Min et al., 2017) utilize the geometrical and structural features of face (e.g., location, shape and size of eyes, nose, and mouth) and create a vector with these features. This vector is used as input to a recognition system for detecting the facial characteristics. On the other hand, holistic approaches (Stoker et al., 2016) use all the pixels of a face's image as raw data fed into a machine recognition system that performs face detection. From a technical point of view, each pixel is a single number.

Recent studies have explored the association between the appearance of the whole face and leadership emergence. For example, Stoker et al. (2016) utilized a machine learning model to examine whether the whole facial appearance predicts leader selection and firms' financial performance. To this end, they collected the facial photos of 674 white male CEOs, 229 white male citizens and 252 white male university professors and found that CEOs faces are significantly different when compared to citizens or professors. Additionally, they examined whether the whole facial appearance model predicts firms' financial performance using 481 facial photos of white male CEOs. Based on the firms' performance criteria they created two groups of CEOs (group of bottom-100 firms and group of top-100 firms). Their results show that the faces of the CEOs from the top firms do not differ when compared to the CEOs of the bottom firms.

Drawing from this line of work (Zhao et al., 2003; Stoker et al., 2016), we examine whether the whole facial appearance is related to the emergence of entrepreneurs and their company performance. By taking a whole-face model into account, we are taking advantage of a high-dimensional space that captures generic properties of faces like darkness/lightness and face shape (Blanz & Vetter, 2003; Kemelmacher-Shlizerman, 2010). To investigate the relationship between whole facial appearance and entrepreneurship emergence and firm performance, we further preprocessed the images of our dataset using Face++ and OpenCV (https://opencv.org/) (Bradski & Kaehler, 2008) (an open-source, computer vision and machine learning software library).

For the first approach, each image was cropped, resized (Table 5 & Figure 3) and transformed to a vector of 2000 elements, where each element corresponds to the cartesian coordinates of each facial landmark identified by Face++ on that image. For the second approach, each image was cropped, resized, converted to grayscale, processed to remove background noise, had its intensity normalized (histogram equalization), and transformed to a vector of 18000 elements, where each element corresponds to the intensity (between 0-255) of each pixel of the image.

[INSERT TABLE 5 AND FIGURE 3 HERE]

Next, we used k-fold cross validation (Mosteller et al., 1968; Stone, 1974; Geisser, 1993; Kohavi, 1995) in order to split our dataset to training and test sets. k-fold cross validation is a standard resampling procedure, which is widely used to a) evaluate machine learning models on a limited data sample without overfitting and b) stack/combine various machine learning models into one more potent model (Wolpert, 1992). k-fold cross validation technique avoids overfitting, reducing the likelihood that a split will result in sets that are not representative of the full data set (Lever et al., 2016). The technique randomly splits the data at hand into k groups/sets (k=10) from which 1 group is the test set while the remaining 9 groups are the training set. This procedure is repeated 10-times so that all groups have been selected once and only once as a test set. In each of the 10 iterations, first we train a two-stage dimensionality reduction algorithm (PCA and then LDA[1]) using the 9 sets of training data and then we transform/reduce the test set. Finally, all the transformed/reduced test sets are combined into an output vector, which is then used as an independent variable in our models.

In particular, the above procedure is repeated for each of the two whole facial modeling approaches, and each output vector is used as a different independent variable - "Holistic-based approach (whole-pixels)" and "Feature-based approach (facial landmarks)" respectively.

Results

First, we examine whether the whole facial appearance is associated with entrepreneurship emergence (Table 6). Models 1 and 2 compare entrepreneurs versus non-entrepreneurs. The coefficients of the "Feature-based approach (facial landmarks)" and "Holistic-based approach (whole-pixels)" are positive and significant ($p < .001$). Thus, both measures for the whole face are significantly associated with entrepreneurship emergence.

[INSERT TABLE 6 HERE]

1 The two-stage dimensionality reduction algorithm uses the Principal Component Analysis (PCA) and then Linear Discriminant Analysis (LDA) (Yu & Yang, 2001; Spreeuwers, 2011; Stoker et al., 2016). The output of the PCA algorithm is a reduced vector of size M=200, while the output of LDA is a vector of size N=1.

Next, we explore whether the whole facial appearance of entrepreneurs is associated with their firm performance. First, we examine whether the whole facial of appearance of entrepreneurs is associated with revenue or the "ln(revenue)" of their firm. Table 7 and Table D6 (Model 1 & 2) in Appendix D show that the coefficients of “Feature-based approach (facial landmarks)” and “Holistic-based approach (whole-pixels)” are insignificant and positive for the revenue and the natural logarithm of revenue.

[INSERT TABLE 7 HERE]

Second, we examine whether the whole facial appearance of entrepreneurs is associated with the likelihood of receiving funding (Model 3 & 4 from Table D6 in Appendix D). The coefficients of “Feature-based approach (facial landmarks)” and “Holistic-based approach (whole-pixels)” are insignificant and positive. Third, we examine whether the whole facial appearance of entrepreneurs is associated with the total amount of funding received (Model 5 & 6 from Table D6 in Appendix D). The coefficients of “Feature-based approach (facial landmarks)” and “Holistic-based approach (whole-pixels)” are insignificant and negative. Finally, we examine whether the whole facial appearance of entrepreneurs is associated with the valuation or the "ln(valuation)" of their firm (Model 7, 8, 9 & 10 from Table D6 in Appendix D). The coefficients of “Feature-based approach (facial landmarks)” and “Holistic-based approach (whole-pixels)” are insignificant for the valuation and the natural logarithm of valuation. Overall, the whole facial appearance of entrepreneurs is not associated with firm performance.

Additional robustness tests

We run "falsification tests" to investigate whether our independent variables only predict "entrepreneurial emergence" and have no predictive power for other occupations. We selected two subgroups of non-entrepreneurs - managers and technical people - as they can be easily grouped based on different keywords. We define managers those whose job title in Crunchbase contains the term “manager”, while we define technical people those whose job title contains any of the terms “developer”, “engineer”, “architect” or “analyst”. Table E1 and E2 in Appendix E presents the regression estimates comparing a) managers vs non-managers (DV was coded as "1" for managers and "0" for non-managers), and b) technical vs non-technical people (DV was coded as "1" for technical people and "0" for non-technical people). The results show that fWHR, cheekbone prominence and OFA are not associated with other occupations, while CFA is associated with "managers" ($p < .05$).

We also performed a series of robustness tests by comparing entrepreneurs with less heterogeneous groups than with the full sample of non-entrepreneurs: a) managers and b) technical people. Table E3 in Appendix E presents the regression estimates comparing entrepreneurs with managers (DV was coded as "1" for entrepreneurs and "0" for managers). We find that the fWHR is insignificant, while cheekbone prominence, OFA and CFA are significant ($p < .01$). Overall, our results show that there are statistically significant differences between the cheekbone prominence and facial symmetry of entrepreneurs and managers. Table E4 in Appendix E compares the facial characteristics of entrepreneurs versus technical people (DV was coded as "1" for entrepreneurs and "0" for technical people). We find that the fWHR is insignificant while cheekbone prominence and OFA and CFA are significant and marginally significant respectively ($p < .05$; $p < .1$). Overall, our results show that there are significant differences between the cheekbone prominence and facial symmetry of entrepreneurs and technical people. Table E5 in Appendix E compares the whole facial appearance of entrepreneurs versus a) managers and b) technical people. Models 1 and 2 compare entrepreneurs versus managers. The coefficients of "Feature-based approach (facial landmarks)" and "Holistic-based approach (whole-pixels)" are significant ($p < .001$) and positive. Models 3 and 4 compare entrepreneurs versus technical people. Both "Feature-based approach (facial landmarks)" and "Holistic-based approach (whole-pixels)" are significant ($p < .05$) and positive. Overall, our results show that there are significant differences between the whole facial appearance of entrepreneurs versus managers and technical people.

Discussion

In this study we investigate whether fWHR, cheekbone prominence, facial symmetry, and two advanced statistical models of whole facial appearance are associated with a) the likelihood of an individual to emerge as an entrepreneur and b) firm performance. By using a large dataset of male entrepreneurs and male non-entrepreneurs from Crunchbase and the aforementioned facial measurements, we find that cheekbone prominence, facial symmetry and the two whole facial appearance statistical models are associated with the likelihood of an individual to emerge as an entrepreneur (hypotheses H2a and H3a are supported). However, we find that fWHR is not associated with the likelihood of an individual to emerge as an entrepreneur (hypothesis H1a is not supported). Our results for fWHR are in line with studies that criticized the fWHR and provided evidence against its role in forming social judgments (Holzleitner & Perrett 2016; Todorov 2017). In addition, we find no association between facial characteristics of entrepreneurs and firm performance (hypotheses H1b, H2b and H3b are not supported). Overall, our results suggest that facial appearance is associated with the emergence of leaders in the entrepreneurial endeavor, however, it is not informative about their subsequent performance.

Our study has a number of implications for research. First, our study adds to the literature on facial characteristics and leadership (Stoker et al., 2016; Todorov et al., 2015; Olivola et al., 2014; Senior, 2018; Poutvaara, 2014). Our results support the findings in facial appearance and leadership research (Stoker et al., 2016; Todorov et al., 2015; Olivola et al., 2014), which found an association between facial characteristics and leadership emergence but no evidence for an association between facial characteristics and actual ability or performance of leaders. In contrast to entrepreneurship emergence, none of the examined facial characteristics of entrepreneurs are related with firm performance. Our results are in line with Stoker et al. (2016) and Graham et al. (2017) and suggest that facial characteristics are not associated with performance. Overall, we argue that although facial appearance can predict the emergence of entrepreneurial leaders, it is not informative about their subsequent effectiveness or performance.

Second, our study adds to the literature on attractiveness and entrepreneurship. Attractive people are more likely to be trusted, get the attention of investors and, as a result, are more likely to become entrepreneurs (Langlois et al., 2000; Baron et al., 2006). Research indicates that cheekbone prominence and facial symmetry are associated with physical attractiveness (Cunningham et al., 1990; Penton-Voak et al., 2001) and provides additional evidence on the relationship between attractiveness and entrepreneurship. These findings extent our understanding of why attractive individuals, often characterized by prominent cheekbones and facial symmetry, may more easily gain the attention and trust of investors to fund their ideas and become entrepreneurs.

Third, our study contributes to the literature on facial symmetry, cheekbone prominence and fWHR. First, it adds to the literature on cheekbone prominence and facial symmetry by showing how these two facial characteristics correlate with entrepreneurship emergence. Second, even though previous researchers have associated a higher fWHR with competence and dominance (Hehman et al., 2015; Mileva et al., 2014), characteristics that influence the likelihood of emerging as entrepreneur, we find that a higher fWHR is not associated with entrepreneurship. Our results are in line with the work of Todorov who criticized the fWHR and argued that it may just be a mediator of social impressions, relating to higher fat mass and of stereotypes about bigger, heavier men (Holzleitner & Perrett 2016; Todorov 2017).

Our study has several limitations. First, we take a snapshot of entrepreneurs' face at a given point in time and tracking this same group over time might provide different results. Certainly, longitudinal studies that examine the faces of these same entrepreneurs over time will further help to confirm if these findings can be validated over a period of time. Another limitation of our study is endogeneity due to measurement error as some of our variables are coded from entrepreneurs' pictures. Specifically, measurement error in the independent variables may cause endogeneity bias, which makes estimates biased and inconsistent (i.e., the coefficients estimated will not converge to the true population value even if sample size tends to infinity) (Wooldridge, 2002).

Our study was done with a sample of white male entrepreneurs located in the USA and, hence, has limited external validity. Future studies may focus on a more diverse group of entrepreneurs to see if the same results are obtained. Future studies may also examine female entrepreneurs, as the same metrics may be perceived differently for females. Future research could also focus on identifying the social inferences formed by the facial characteristics and how they influence entrepreneurship. In addition, additional research can examine how the interplay between facial characteristics and environmental factors might influence the likelihood of becoming an entrepreneur.

Finally, future studies may include additional control variables that are known to be predictors of entrepreneurship such as socioeconomic background (Schoon & Duckworth, 2012) and the Big Five personality traits (Brandstätter, 2011; Zhao & Seibert, 2006). Further research could also examine other facial characteristics in relation to entrepreneurship, such as mouth width. In this respect, Re and Rule (2016) found that mouth width was associated with leadership emergence and performance. Finally, people who become entrepreneurs (or become successful in attracting funding) may start to look more confident potentially giving rise to reverse causality. As we are examining objective facial characteristics, this is less of an issue in our study, because entrepreneurship is unlikely to alter structural facial properties such as fWHR, cheekbone prominence and facial symmetry. However, face-features enhancers like cosmetic surgeries or professional photographers may be able to alter the facial structure and give raise to endogeneity. We encourage future studies to examine perceptions of entrepreneurial behavior that result from fWHR, cheekbone prominence, and facial symmetry, and whether these perceptions can predict the amount of funding that entrepreneurs receive.

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Figure 1: Rotation of Face - Yaw, Pitch, and Roll

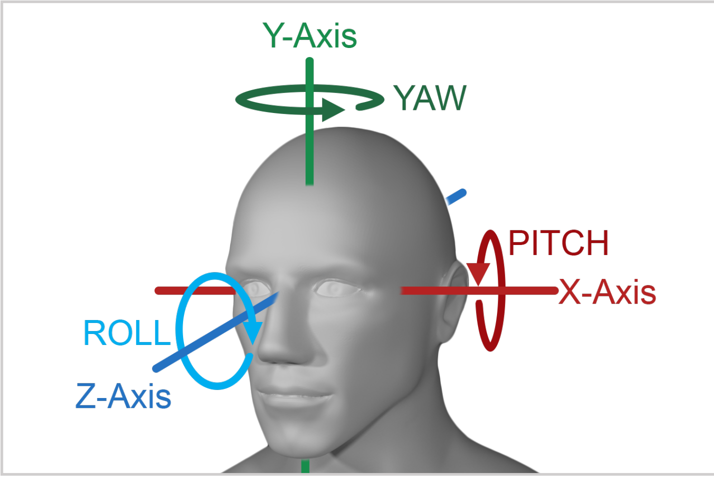
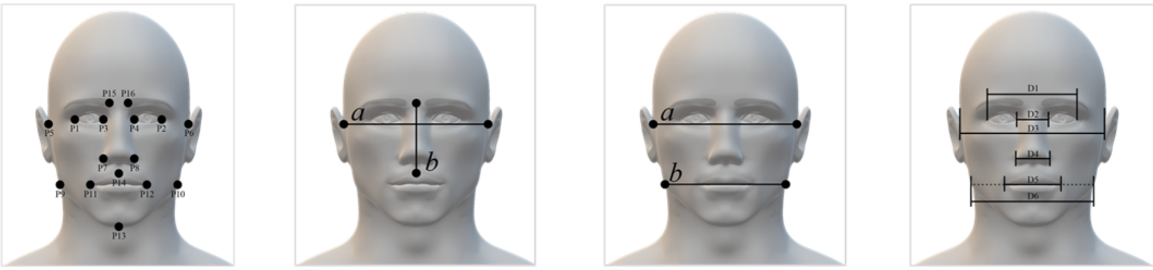


Figure 2: Facial Landmarks and Facial Ratios



a. Facial Landmarks

b. fWHR

c. Cheekbone prominence

d. Lines used for facial asymmetry

Figure 3: Whole facial appearance preprocessing for the 2 approaches

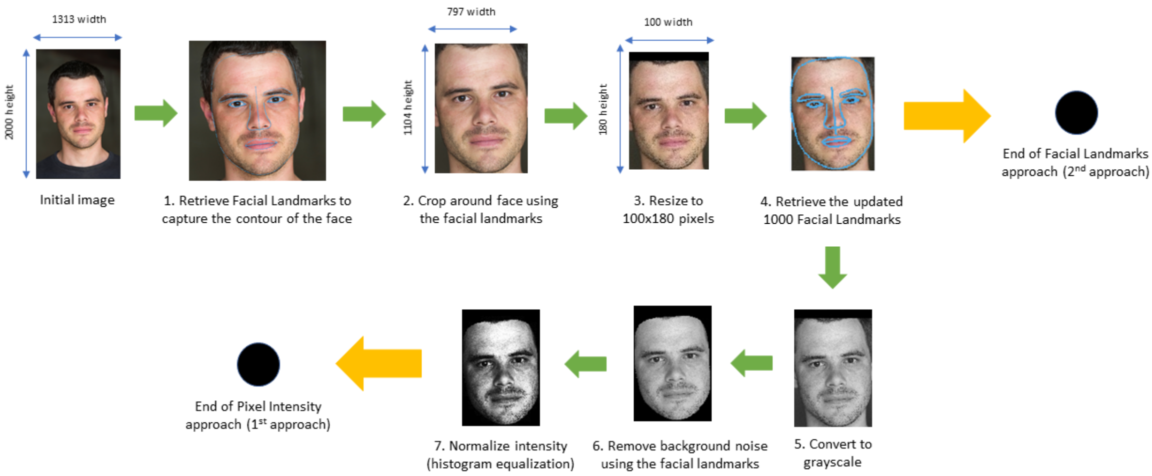


Table 1: Data Preprocessing

Steps		Entrepreneurs	Non-Entrepreneurs
1	Download the profile of people in CrunchBase in August 2017	152900	497768
2	Keep users who have a profile picture in CrunchBase	101771	336589
3	Perform random sampling of non-entrepreneurs	101771	110000
4	Keep profiles with only one face depicted in the profile image	92216	98339
5	Keep only profiles that correspond to Males	80526	78040
6	Keep only profiles that correspond to Whites	64427	66790
7	Keep only profiles whose location is in the USA	21764	24840
8	Keep only profiles that declare region information	21719	24774
9	Keep profiles that report an Age ≥ 18	21709	24765
10	Keep profiles with a calculated BMI in the range 18.4 ≤ BMI ≤ 40.5	21289	24255
11	Keep profiles with Yaw, Pitch and Roll values in the following ranges: **-10º ≤ Yaw ≤ 10º and -10º ≤ Pitch ≤ 10º and -10º ≤ Roll ≤ 10º**	11679	14464
12	Keep profiles with Yaw, Pitch and Roll values in the following ranges: **-5º ≤ Yaw ≤ 5º and -5º ≤ Pitch ≤ 5º and -5º ≤ Roll ≤ 5º** .	3032	3787

Table 2: Descriptive Statistics and Variable Correlations

Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10	11
1. Age[a]	42.241	9.433											
2. BMI[a]	29.743	3.678	.165***										
3. Created CB Year[a]	2,014.372	2.238	.027*	.011									
4. Bachelor[a]	.208	.406	-.040***	-.014	-.100***								
5. Master[a]	.159	.365	.029*	-.010	-.145***	-.222***							
6. PhD[a]	.061	.239	.034**	-.007	-.093***	-.130***	-.111***						
7. fWHR[a]	1.891	.132	-.023	.210***	.010	-.003	.025*	-.019					
8. Cheekbone[a]	1.101	.024	-.098***	-.187***	-.010	.002	-.020	-.001	-.109***				
9. OFA[a]	.238	.154	.143***	.062***	.013	-.025*	.035**	.009	.000	.005			
10. CFA[a]	.076	.058	.139***	.070***	.019	-.023	.037**	.001	.028*	-.008	.939***		
11. Entrepreneur[a]	.445	.497	-.196***	-.050***	-.222***	.052***	-.018	.051***	.002	.067***	-.065***	-.071***	
12. Revenue[b]	8.98e+07	8.70e+08	.044	-.012	-.117***	-.020	.105***	-.003	-.033	-.006	.010	.009	c*

**** $p<.001$, ** $p<.01$; * $p<.05$*

[a] Observations = 6,819, [b] Observations = 1,569

c The correlation between "Entrepreneur" and "Revenue" cannot be computed because all of the observations in the variable "Revenue" are entrepreneurs. For those observations, the value of "Entrepreneur" is always 1.*

Table 3: Entrepreneurial emergence using Facial Ratios - "Entrepreneurs vs Non-Entrepreneurs" – Linear Regression

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Age	-.010*** (.001)	-.010*** (.001)	-.010*** (.001)	-.010*** (.001)	-.010*** (.001)	-.010*** (.001)	-.009*** (.001)
Created CB Year	-.048*** (.003)	-.048*** (.003)	-.048*** (.003)	-.048*** (.003)	-.048*** (.003)	-.048*** (.003)	-.048*** (.003)
BMI	-.003 (.002)	-.003 (.002)	-.002 (.002)	-.002 (.002)	-.002 (.002)	-.002 (.002)	-.002 (.002)
Bachelor	.025 (.015)	.025 (.015)	.026 (.015)	.024 (.015)	.024 (.015)	.025 (.015)	.025 (.015)
Master	-.045** (.016)	-.045** (.016)	-.043** (.016)	-.043** (.016)	-.043** (.016)	-.042* (.016)	-.041* (.016)
PhD	.070** (.025)	.070** (.025)	.071** (.025)	.071** (.025)	.070** (.025)	.072** (.025)	.072** (.025)
fWHR		.014 (.045)				.029 (.046)	.032 (.046)
Cheekbone			1.089*** (.258)			1.125*** (.260)	1.119*** (.259)
OFA				-.102** (.039)		-.108** (.039)	
CFA					-.322** (.104)		-.332** (.104)
Constant	97.359*** (5.238)	97.352*** (5.238)	95.935*** (5.248)	97.198*** (5.230)	97.062*** (5.231)	95.703*** (5.240)	95.571*** (5.242)
Observations	6,819	6,819	6,819	6,819	6,819	6,819	6,819
R-squared	.096	.096	.099	.097	.098	.100	.100
Adj R^2	.094	.094	.096	.095	.095	.097	.097

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*

Table 4: Entrepreneurial Performance using Facial Ratios - "revenue" – Linear Regression

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Age	3,077,213 (2,987,324)	2,918,637 (2,958,394)	3,074,338 (3,001,006)	3,076,002 (3,184,822)	3,106,163 (3,140,795)	2,889,341 (3,174,375)	2,918,563 (3,129,176)
Created CB Year	-35,683,833* (16,099,625)	-35,337,881* (15,994,754)	-35,683,220* (16,110,957)	-35,682,838* (16,230,485)	-35,713,155* (16,216,723)	-35,319,269* (16,151,798)	-35,346,902* (16,137,453)
BMI	-7,192,562 (7,237,374)	-5,750,330 (7,581,317)	-7,215,324 (7,307,548)	-7,195,084 (6,863,295)	-7,116,248 (6,836,440)	-5,867,167 (7,367,017)	-5,806,853 (7,344,879)
Bachelor	-27,888,078 (31,604,689)	-26,615,979 (31,317,203)	-28,012,796 (30,701,332)	-27,880,320 (31,778,706)	-28,100,126 (31,642,451)	-27,078,562 (30,756,930)	-27,261,327 (30,652,488)
Master	2.182e+08* (1.111e+08)	2.187e+08* (1.114e+08)	2.181e+08 (1.120e+08)	2.182e+08* (1.110e+08)	2.182e+08* (1.110e+08)	2.185e+08 (1.121e+08)	2.185e+08 (1.121e+08)
PhD	-32,018,957 (59,956,097)	-33,464,121 (60,460,936)	-32,061,080 (59,807,927)	-32,011,387 (60,573,502)	-32,216,628 (60,366,056)	-33,583,756 (60,858,906)	-33,752,474 (60,660,155)
fWHR		-1.889e+08 (2.146e+08)				-1.912e+08 (2.078e+08)	-1.901e+08 (2.091e+08)
Cheekbone			-27,005,287 (8.570e+08)			-1.233e+08 (7.939e+08)	-1.198e+08 (7.893e+08)
OFA				694,805 (1.406e+08)		8,216,663 (1.413e+08)	
CFA					-51,794,808 (3.476e+08)		-24,360,723 (3.520e+08)
Constant	7.194e+10* (3.251e+10)	7.157e+10* (3.240e+10)	7.197e+10* (3.225e+10)	7.194e+10* (3.278e+10)	7.200e+10* (3.275e+10)	7.167e+10* (3.243e+10)	7.172e+10* (3.242e+10)
Observations	1,569	1,569	1,569	1,569	1,569	1,569	1,569
R-squared	.081	.082	.081	.081	.081	.082	.082
Adj R^2	.042	.042	.041	.041	.041	.041	.041

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*

Table 5: Image Preprocessing for Whole Facial Appearance

1	Use the Dense Facial Landmarks functionality of Face++ (https://www.faceplusplus.com/dense-facial-landmarks), which accurately locates facial features and contours and returns a total of 1000 facial landmarks. This functionality supports only high-resolution images that are at least 100x100 pixels. The retrieved facial landmarks from this step are used in order to capture the outline of the face and later crop the images around each face.
2	Crop all images around each face by using the outermost facial landmark in each direction (i.e. left, right, top, bottom).
3	Normalize all images using the Lanczos interpolation technique (Lanczos, 1956; Lanczos, 1988) so as to be 100x180 pixels. In particular, we resized all images based on the x-axis (width). During the resizing process, the aspect ratio was maintained for each image. Then, we padded with extra black pixels in each image so that all images have the same height.
4	Retrieve the new/updated facial landmarks from Face++ as the size of all images has changed. This is the final preprocessing step for the second approach (Facial Landmarks approach), while for the first approach (Pixel Intensity approach) the retrieved facial landmarks are used to capture the contour of the face and later remove the background noise.

5	Convert images to grayscale as luminance is more important than color for distinguishing visual features.
6	Remove the background noise (i.e. pixels that do not belong inside a face) from all images. Specifically, we created a polygon shape/mask around the face by connecting the facial landmarks. By using a polygon, we can capture more accurately the shape of a face and thus remove the background noise more precisely.
7	Normalize the intensity of the pixels using the histogram equalization technique in order to improve the contrast and suppress the variation in illumination in each image.

Table 6: Entrepreneurship emergence using the Whole Facial Appearance - "Entrepreneurs vs Non-Entrepreneurs" - Linear Regression

Variable	**(1)**	**(2)**
Age	-.009***	-.008***
	(.001)	(.001)
Created CB Year	-.048***	-.048***
	(.003)	(.003)
BMI	-.002	-.002
	(.002)	(.002)
Bachelor	.032*	.032*
	(.015)	(.015)
Master	-.041*	-.041*
	(.017)	(.017)
PhD	.072**	.071**
	(.025)	(.025)
Feature-based approach (facial landmarks)	.036***	
	(.006)	
Holistic-based approach (whole-pixels)		.038***
		(.006)
Constant	97.053***	97.138***
	(5.301)	(5.303)
Observations	6,639	6,639
R-squared	.103	.104
Adj R^2	.101	.101

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*

Table 7: Entrepreneurship performance using the Whole Facial Appearance - "revenue" – Linear Regression

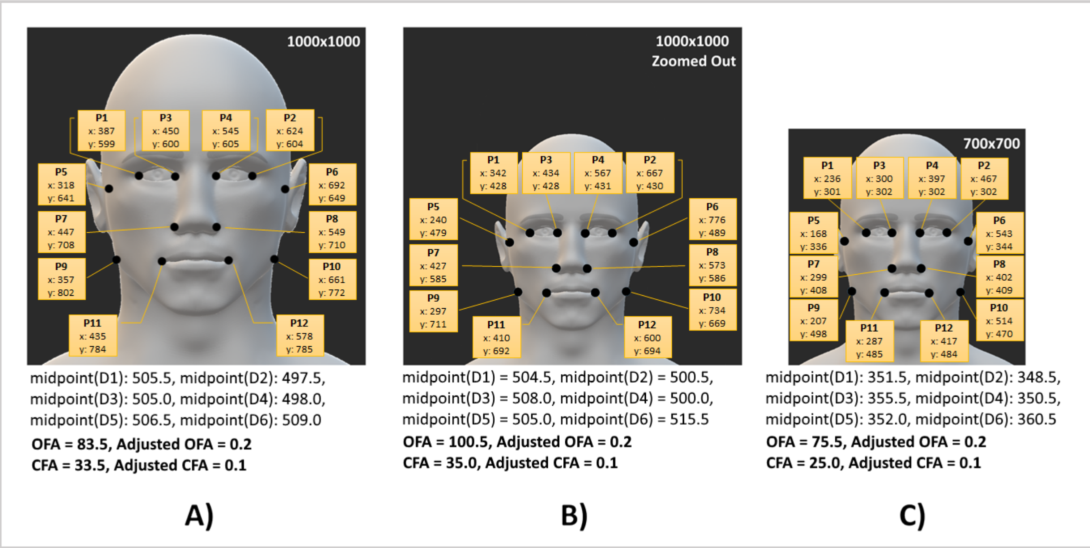
Variable	**(1)**	**(2)**
Age	2,802,475	3,222,712
	(2,871,535)	(3,227,454)
Created CB Year	-37,009,373*	-36,365,182*
	(16,436,531)	(16,372,838)
BMI	-6,867,784	-7,195,135
	(7,088,266)	(7,451,256)
Bachelor	-29,792,818	-26,242,721
	(32,354,488)	(31,637,306)
Master	2.138e+08	2.168e+08*
	(1.092e+08)	(1.103e+08)
PhD	-40,286,212	-34,003,345
	(62,975,354)	(60,205,522)
Feature-based approach (facial landmarks)	40,889,672	
	(29,899,720)	
Holistic-based approach (whole-pixels)		2,960,687
		(21,720,606)
Constant	7.462e+10*	7.331e+10*
	(3.319e+10)	(3.306e+10)
Observations	1,541	1,541
R-squared	.085	.083
Adj R^2	.044	.041

Robust standard errors are in parentheses

***** p<.001, ** p<.01, * p<.05*

Appendix A

Example with three different photos of the same face: A) original photo, B) different distance of the face from the camera (zoomed out) and C) different resolution of the original photo. The OFA and CFA metrics were calculated with the original formulas from Grammer & Thornhill while the metrics Adjusted OFA and Adjusted CFA were calculated with the new formulas (1) and (2). The results of the metrics show that the original formulas might have a significant deviation for the same face when the photo's resolution or the distance of a face from the camera is different. On the other hand, the adjusted formulas are more accurate and reliable for our use case.



Appendix B

Table B1: Entrepreneurial emergence using Facial Ratios - "Entrepreneurs vs Non-Entrepreneurs" - Logistic Regression

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Age	-.045***	-.045***	-.044***	-.044***	-.044***	-.043***	-.043***
	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)
Created CB Year	-.212***	-.212***	-.212***	-.211***	-.211***	-.212***	-.211***
	(.013)	(.013)	(.013)	(.013)	(.013)	(.013)	(.013)
BMI	-.011	-.012	-.007	-.011	-.010	-.007	-.007
	(.007)	(.007)	(.007)	(.007)	(.007)	(.007)	(.007)
Bachelor	.107	.106	.111	.105	.106	.110	.110
	(.066)	(.066)	(.066)	(.066)	(.066)	(.066)	(.066)
Master	-.204**	-.204**	-.196**	-.198**	-.196**	-.192*	-.191*
	(.075)	(.075)	(.075)	(.075)	(.075)	(.075)	(.075)
PhD	.316**	.317**	.322**	.320**	.319**	.327**	.326**
	(.113)	(.113)	(.114)	(.113)	(.113)	(.114)	(.114)
fWHR		.072				.141	.158
		(.203)				(.204)	(.204)
Cheekbone			4.812***			4.993***	4.972***
			(1.161)			(1.167)	(1.166)
OFA				-.461*		-.489**	
				(.180)		(.180)	
CFA					-1.457**		-1.516**
					(.483)		(.485)
Constant	428.260***	428.241***	423.085***	427.832***	427.249***	422.428***	421.860***
	(25.708)	(25.709)	(25.739)	(25.674)	(25.674)	(25.708)	(25.709)
Observations	6,819	6,819	6,819	6,819	6,819	6,819	6,819
pseudo-R2	.073	.073	.075	.074	.075	.076	.077
LL	-4,340.633	-4,340.568	-4,331.822	-4,337.075	-4,335.663	-4,327.603	-4,326.231
χ^2	557.378***	557.285***	568.057***	561.870***	562.445***	573.071***	573.679***

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*

Table B2: Entrepreneurial Performance using Facial Ratios - "Has the company received funding" - Logistic Regression

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Age	.029***	.029***	.029***	.029***	.029***	.030***	.030***
	(.006)	(.006)	(.006)	(.006)	(.006)	(.006)	(.006)
Created CB Year	-.036	-.037	-.036	-.036	-.036	-.037	-.037
	(.025)	(.025)	(.025)	(.025)	(.025)	(.025)	(.025)
BMI	-.002	-.007	.001	-.002	-.003	-.004	-.004
	(.016)	(.017)	(.017)	(.016)	(.016)	(.017)	(.017)
Bachelor	-.292	-.292	-.286	-.291	-.291	-.285	-.285
	(.157)	(.157)	(.158)	(.157)	(.157)	(.158)	(.158)
Master	-.282	-.287	-.278	-.281	-.281	-.283	-.283
	(.180)	(.180)	(.180)	(.180)	(.180)	(.180)	(.180)
PhD	.036	.035	.048	.038	.038	.049	.049
	(.220)	(.221)	(.220)	(.220)	(.220)	(.221)	(.221)
fWHR		.557				.607	.606
		(.444)				(.447)	(.448)
Cheekbone			2.978			3.289	3.299
			(2.649)			(2.669)	(2.667)
OFA				.121		.081	
				(.379)		(.381)	
CFA					.314		.199
					(1.013)		(1.022)
Constant	68.794	69.676	65.603	68.818	68.913	66.191	66.241
	(50.979)	(50.869)	(51.030)	(50.966)	(50.961)	(50.909)	(50.905)
Observations	2,144	2,144	2,144	2,144	2,144	2,144	2,144
pseudo-R2	.070	.071	.071	.070	.070	.072	.072
LL	-944.097	-943.339	-943.454	-944.049	-944.052	-942.530	-942.534
χ^2	137.073***	137.586***	137.412***	137.232***	137.275***	138.249***	138.298***

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*

Appendix C

Table C1: Descriptive Statistics and Variable Correlations (N = 26143) with yaw, pitch and roll within the range [-10^{o}, 10^{o}]

Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10
1. Age	42.014	9.454										
2. Roll	-1.024	4.581	.029***									
3. Yaw	.958	4.954	-.047***	-.448***								
4. Pitch	2.953	4.141	-.126***	-.012	-.017**							
5. BMI	29.601	3.671	.163***	-.014*	-.002	-.141***						
6. Education	.223	.416	.046***	-.002	-.008	.005	-.007					
7. fWHR	1.884	.131	-.039***	-.004	.063***	-.015*	.206***	.011				
8. Cheekbone	1.106	.027	-.149***	.075***	-.060***	.482***	-.202***	-.013*	-.120***			
9. OFA	.321	.205	.128***	-.015*	-.097***	-.068***	.053***	.016**	-.045***	-.027***		
10. CFA	.103	.076	.125***	.068***	-.131***	-.081***	.057***	.017**	-.028***	-.044***	.938***	
11. Entrepreneur	.447	.497	-.190***	.004	.005	.030***	-.054***	.013*	-.006	.077***	-.050***	-.059***

*** *p<.001*, ** *p<.01*; * *p<.05*

Table C2: Entrepreneurship emergence using Facial Ratios and yaw, pitch and roll between [-10º, 10º] - "Entrepreneurs vs Non-Entrepreneurs" - Logistic Regression

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Age	-.041***	-.041***	-.040***	-.040***	-.040***	-.040***	-.039***
	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
BMI	-.011**	-.010**	-.008*	-.011**	-.011**	-.007	-.007
	(.004)	(.004)	(.004)	(.004)	(.004)	(.004)	(.004)
Education	.090**	.091**	.094**	.091**	.092**	.096**	.097**
	(.031)	(.031)	(.031)	(.031)	(.031)	(.031)	(.031)
fWHR		-.129				-.066	-.063
		(.100)				(.101)	(.101)
Cheekbone			4.216***			4.236***	4.197***
			(.552)			(.555)	(.555)
OFA				-.251***		-.264***	
				(.064)		(.064)	
CFA					-.948***		-.957***
					(.172)		(.172)
Constant	1.696***	1.915***	-3.075***	1.745***	1.752***	-2.933***	-2.888***
	(.118)	(.208)	(.635)	(.119)	(.119)	(.678)	(.678)
Observations	26,143	26,143	26,143	26,143	26,143	26,143	26,143
-2LL	34,777.592	34,775.940	34,718.918	34,761.956	34,746.964	34,701.364	34,687.516
χ^2	1,167.053**	1,168.704**	1,225.727**	1,182.690**	1,197.680**	1,243.281**	1,257.128**
$\Delta\chi^2$		1.651	58.674**	15.637**	30.627**	76.228**	90.075**

Robust standard errors are in parentheses.

**** p<.001, ** p<.01; * p<.05*

Appendix D

Table D1: Entrepreneurial Performance using Facial Ratios - "ln(revenue)" – Linear Regression

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Age	.020*** (.006)	.020*** (.006)	.020*** (.006)	.019*** (.006)	.019*** (.006)	.019** (.006)	.019*** (.006)
Created CB Year	-.217*** (.023)	-.216*** (.023)	-.217*** (.023)	-.216*** (.023)	-.216*** (.023)	-.216*** (.023)	-.216*** (.023)
BMI	-.034** (.013)	-.032* (.013)	-.035** (.013)	-.036** (.013)	-.035** (.013)	-.035** (.013)	-.034** (.013)
Bachelor	.255* (.115)	.257* (.116)	.251* (.116)	.261* (.116)	.259* (.116)	.257* (.117)	.256* (.117)
Master	.418** (.149)	.419** (.149)	.416** (.149)	.419** (.149)	.419** (.149)	.417** (.149)	.418** (.149)
PhD	.490** (.187)	.489** (.187)	.488** (.187)	.496** (.187)	.494** (.187)	.492** (.187)	.490** (.187)
fWHR		-.181 (.358)				-.226 (.362)	-.224 (.362)
Cheekbone			-1.036 (1.997)			-1.276 (2.021)	-1.187 (2.019)
OFA				.530 (.312)		.545 (.312)	
CFA					.944 (.847)		.983 (.849)
Constant	451.087*** (46.464)	450.729*** (46.523)	452.210*** (46.567)	449.528*** (46.543)	450.002*** (46.538)	450.421*** (46.689)	450.801*** (46.690)
Observations	1,569	1,569	1,569	1,569	1,569	1,569	1,569
R-squared	.193	.193	.193	.195	.194	.195	.194
Adj R^2	.158	.158	.158	.159	.158	.159	.158

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*

Table D2: Entrepreneurial Performance using Facial Ratios - “Has the company received funding” – Linear Regression

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Age	.004*** (.001)	.004*** (.001)	.004*** (.001)	.004*** (.001)	.004*** (.001)	.004*** (.001)	.004*** (.001)
Created CB Year	-.005 (.004)	-.005 (.004)	-.005 (.004)	-.005 (.004)	-.005 (.004)	-.005 (.004)	-.005 (.004)
BMI	. 000 (.002)	-.001 (.002)	. 000 (.002)	-.001 (.002)	-.001 (.002)	-.001 (.002)	-.001 (.002)
Bachelor	-.039 (.020)	-.039 (.020)	-.038 (.020)	-.039 (.020)	-.039 (.020)	-.038 (.020)	-.038 (.020)
Master	-.038 (.024)	-.038 (.024)	-.037 (.024)	-.038 (.024)	-.038 (.024)	-.038 (.024)	-.038 (.024)
PhD	.006 (.036)	.006 (.036)	.007 (.036)	.006 (.036)	.006 (.036)	.007 (.036)	.007 (.036)
fWHR		.080 (.062)				.087 (.063)	.087 (.063)
Cheekbone			.412 (.374)			.458 (.376)	.460 (.376)
OFA				.016 (.056)		.011 (.056)	
CFA					.041 (.150)		.026 (.151)
Constant	10.346 (7.576)	10.487 (7.574)	9.894 (7.573)	10.327 (7.577)	10.333 (7.577)	9.985 (7.570)	9.987 (7.570)
Observations	2,144	2,144	2,144	2,144	2,144	2,144	2,144
R-squared	.069	.069	.069	.069	.069	.070	.070
Adj R^2	.040	.040	.040	.039	.039	.040	.040

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*

Table D3: Entrepreneurial Performance using Facial Ratios - "Total amount of Funding Received" - Tobit Regression

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Age	1,499,281*** (330,244)	1,506,924*** (329,946)	1,507,953*** (330,779)	1,498,037*** (326,257)	1,507,013*** (327,585)	1,517,512*** (326,734)	1,526,675*** (328,015)
Created CB Year	-3,326,985* (1,467,227)	-3,334,328* (1,469,445)	-3,320,190* (1,469,496)	-3,326,958* (1,467,088)	-3,325,805* (1,467,718)	-3,328,120* (1,471,529)	-3,326,798* (1,472,103)
BMI	-1,447,282 (871,152)	-1,504,349 (883,825)	-1,379,129 (876,249)	-1,448,779 (878,306)	-1,434,647 (878,333)	-1,440,277 (893,502)	-1,426,363 (892,386)
Bachelor	-11,470,627 (7,287,668)	-11,453,728 (7,291,622)	-11,368,529 (7,306,356)	-11,469,565 (7,287,726)	-11,485,951 (7,289,568)	-11,345,246 (7,311,887)	-11,359,983 (7,312,905)
Master	-7,024,168 (8,301,393)	-7,107,686 (8,290,418)	-6,914,282 (8,311,465)	-7,024,629 (8,301,797)	-7,033,531 (8,300,744)	-7,003,894 (8,301,966)	-7,014,783 (8,301,093)
PhD	4,484,635 (10,133,460)	4,505,046 (10,142,872)	4,692,391 (10,186,624)	4,495,203 (10,089,426)	4,406,122 (10,099,429)	4,723,856 (10,153,173)	4,638,281 (10,161,500)
fWHR		6,834,942 (19,864,710)				7,848,516 (20,104,351)	8,058,552 (20,127,550)
Cheekbone			64,881,914 (1.122e+08)			68,760,701 (1.139e+08)	70,044,016 (1.135e+08)
OFA				550,232 (16,686,657)		-144,305 (16,786,880)	
CFA					-10,612,764 (43,221,232)		-12,446,065 (43,454,020)
Constant	6.572e+09* (2.958e+09)	6.575e+09* (2.959e+09)	6.484e+09* (2.972e+09)	6.572e+09* (2.958e+09)	6.570e+09* (2.959e+09)	6.483e+09* (2.972e+09)	6.478e+09* (2.973e+09)
sigma:Constant	79,267,558*** (9,526,295)	79,282,982*** (9,527,549)	79,272,237*** (9,529,437)	79,266,580*** (9,523,537)	79,269,065*** (9,527,513)	79,290,505*** (9,528,579)	79,292,503*** (9,532,653)
Observations	2,144	2,144	2,144	2,144	2,144	2,144	2,144
pseudo-R2	.013	.013	.013	.013	.013	.013	.013
LL	-6,817.845	-6,817.793	-6,817.701	-6,817.844	-6,817.822	-6,817.633	-6,817.602

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*

Table D4: Entrepreneurial Performance using Facial Ratios - "valuation" – Linear Regression

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Age	-14,929,903 (18,890,179)	-15,284,383 (18,723,655)	-14,814,758 (19,431,112)	-13,897,448 (18,186,901)	-14,223,215 (18,527,121)	-14,233,312 (18,467,170)	-14,580,799 (18,804,726)
Created CB Year	-1.356e+08* (62,071,790)	-1.336e+08* (63,172,623)	-1.355e+08* (62,514,728)	-1.380e+08* (64,176,755)	-1.396e+08* (64,722,557)	-1.359e+08* (65,531,531)	-1.376e+08* (66,102,530)
BMI	11,663,321 (29,606,717)	16,374,577 (26,923,730)	11,966,708 (29,006,972)	14,940,342 (32,164,937)	16,046,223 (31,853,086)	19,823,117 (29,310,044)	20,827,566 (29,061,092)
Bachelor	99,521,711 (2.189e+08)	84,884,278 (2.107e+08)	1.005e+08 (2.212e+08)	1.036e+08 (2.183e+08)	90,317,122 (2.195e+08)	88,790,328 (2.117e+08)	75,441,496 (2.130e+08)
Master	2.071e+08 (2.553e+08)	2.104e+08 (2.566e+08)	2.077e+08 (2.569e+08)	2.311e+08 (2.524e+08)	2.281e+08 (2.567e+08)	2.349e+08 (2.547e+08)	2.315e+08 (2.591e+08)
PhD	7.549e+08 (5.983e+08)	7.413e+08 (6.132e+08)	7.555e+08 (5.973e+08)	7.492e+08 (5.906e+08)	7.465e+08 (5.890e+08)	7.352e+08 (6.041e+08)	7.326e+08 (6.025e+08)
fWHR		-6.393e+08 (8.657e+08)				-6.520e+08 (8.476e+08)	-6.467e+08 (8.500e+08)
Cheekbone			4.020e+08 (4.185e+09)			25,054,722 (4.055e+09)	-8,826,420 (4.088e+09)
OFA				-6.382e+08 (9.464e+08)		-6.496e+08 (9.492e+08)	
CFA					-2.322e+09 (2.543e+09)		-2.333e+09 (2.558e+09)
Constant	2.739e+11* (1.252e+11)	2.709e+11* (1.269e+11)	2.732e+11* (1.279e+11)	2.786e+11* (1.294e+11)	2.819e+11* (1.305e+11)	2.756e+11* (1.333e+11)	2.789e+11* (1.345e+11)
Observations	329	329	329	329	329	329	329
R-squared	.242	.243	.242	.244	.245	.245	.247
Adj R^2	.054	.053	.051	.053	.055	.048	.050

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*

Table D5: Entrepreneurial Performance using Facial Ratios - "ln(valuation)" - Linear Regression

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Age	.009 (.012)	.008 (.012)	.009 (.012)	.009 (.012)	.009 (.012)	.008 (.012)	.008 (.012)
Created CB Year	-.151*** (.039)	-.148*** (.039)	-.151*** (.039)	-.151*** (.039)	-.151*** (.039)	-.148*** (.039)	-.148*** (.039)
BMI	.013 (.024)	.020 (.025)	.012 (.025)	.013 (.025)	.013 (.025)	.018 (.026)	.018 (.026)
Bachelor	.439 (.228)	.418 (.227)	.436 (.229)	.439 (.229)	.440 (.228)	.412 (.229)	.413 (.228)
Master	.387 (.271)	.392 (.272)	.385 (.272)	.384 (.269)	.385 (.270)	.387 (.270)	.388 (.271)
PhD	.711* (.342)	.691* (.344)	.709* (.343)	.711* (.342)	.711* (.342)	.688* (.345)	.688* (.345)
fWHR		-.926 (.695)				-.964 (.690)	-.965 (.690)
Cheekbone			-1.240 (4.215)			-1.897 (4.199)	-1.893 (4.201)
OFA				.064 (.714)		.052 (.722)	
CFA					.154 (1.859)		.140 (1.877)
Constant	321.220*** (77.562)	316.901*** (77.743)	323.159*** (78.234)	320.744*** (78.689)	320.691*** (78.720)	319.303*** (79.351)	319.200*** (79.418)
Observations	329	329	329	329	329	329	329
R-squared	.299	.303	.299	.299	.299	.304	.304
Adj R^2	.126	.128	.123	.123	.123	.122	.122

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*

Table D6: Entrepreneurship performance using the Whole Facial Appearance

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Ln(Revenue) *(Linear Reg)*	***Ln(Revenue)*** *(Linear Reg)*	***Has Received Funding*** *(Linear Reg)*	***Has Received Funding*** *(Linear Reg)*	***Total Funding*** *(Tobit Reg)*	***Total Funding*** *(Tobit Reg)*	***Valuation*** *(Linear Reg)*	***Valuation*** *(Linear Reg)*	***Ln(Valuation)*** *(Linear Reg)*	***Ln(Valuation)*** *(Linear Reg)*
Age	.020***	.021***	.004***	.004***	15,212,578***	1,521,143***	-17,172,803	-16,070,350	.008	.009
	(.006)	(.006)	(.001)	(.001)	(338,119)	(338,132)	(19,582,898)	(20,050,774)	(.013)	(.013)
Created CB Year	-.223***	-.221***	-.004	-.004	-3,087,315*	-3,090,551*	-1.391e+08*	-1.437e+08*	-.159***	-.167***
	(.023)	(.023)	(.004)	(.004)	(1,469,928)	(1,469,948)	(63,065,943)	(61,816,684)	(.040)	(.040)
BMI	-.033**	-.034**	-.001	.000	-1,482,157	-1,484,666	10,316,468	9,886,540	.011	.009
	(.013)	(.013)	(.002)	(.002)	(881,882)	(882,194)	(30,228,747)	(31,074,289)	(.025)	(.025)
Bachelor	.230*	.239*	-.036	-.036	-10,906,575	-10,920,531	1.099e+08	1.128e+08	.396	.429
	(.117)	(.117)	(.021)	(.021)	(7,261,955)	(7,262,683)	(2.217e+08)	(2.285e+08)	(.238)	(.232)
Master	.401**	.410**	-.036	-.036	-6,762,275	-6,755,517	2.063e+08	2.048e+08	.368	.356
	(.149)	(.150)	(.025)	(.025)	(8,371,718)	(8,370,239)	(2.689e+08)	(2.658e+08)	(.283)	(.280)
PhD	.473*	.485**	.013	.013	6,099,914	6,119,587	7.258e+08	7.160e+08	.646	.629
	(.188)	(.188)	(.036)	(.036)	(10,141,415)	(10,140,386)	(6.065e+08)	(6.146e+08)	(.348)	(.352)
Feature-based approach (facial landmarks)	.090 (.047)		.011 (.008)		-372,320 (352,578)		19,848,084 (39,644,586)		-.009 (.046)	
Holistic-based approach (whole-pixels)		.033 (.043)		.009 (.008)		-379,640 (345,854)		-38,370,189 (63,117,917)		-.104 (.058)
Constant	463.518***	459.527***	8.941	8.964	6.087e+09*	6.094e+09*	2.810e+11*	2.904e+11*	336.618***	352.998***
	(47.258)	(47.354)	(7.630)	(7.632)	(2.963e+09)	(2.964e+09)	(1.273e+11)	(1.247e+11)	(80.468)	(80.736)
Observations	1,541	1,541	2,107	2,107	2,107	2,107	322	322	322	322
R-squared/ pseudo-R2	.198	.197	.068	.068	.013	.013	.244	.244	.296	.306
Adj R^2	.162	.161	.038	.037	-	-	.048	.049	.114	.126

LL	-	-	-	-	-6,731.379	-6,731.346	-	-	-	-

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*

Appendix E

Table E1: Emergence of Managers using Facial Ratios – "Managers vs Non-Managers" – Linear Regression

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Age	.008*** (.001)	.008*** (.001)	.008*** (.001)	.008*** (.001)	.008*** (.001)	.008*** (.001)	.008*** (.001)
Created CB Year	.023*** (.004)	.023*** (.004)	.023*** (.004)	.023*** (.004)	.023*** (.004)	.023*** (.004)	.023*** (.004)
BMI	.001 (.002)	.001 (.002)	.002 (.002)	.001 (.002)	.001 (.002)	.001 (.002)	.001 (.002)
Bachelor	.043* (.020)	.043* (.020)	.043* (.020)	.043* (.020)	.043* (.020)	.043* (.020)	.043* (.020)
Master	.051* (.021)	.051* (.021)	.052* (.021)	.050* (.021)	.050* (.021)	.050* (.021)	.050* (.021)
PhD	-.010 (.036)	-.009 (.036)	-.010 (.036)	-.011 (.036)	-.010 (.036)	-.011 (.036)	-.010 (.036)
fWHR		.047 (.061)				.054 (.061)	.051 (.061)
Cheekbone			.345 (.348)			.354 (.349)	.357 (.349)
OFA				.081 (.050)		.080 (.050)	
CFA					.263* (.132)		.260* (.132)
Constant	-46.577*** (8.060)	-46.646*** (8.066)	-46.852*** (8.065)	-46.749*** (8.069)	-46.593*** (8.072)	-47.110*** (8.080)	-46.953*** (8.083)
Observations	3,787	3,787	3,787	3,787	3,787	3,787	3,787
R-squared	.045	.045	.045	.046	.046	.046	.046
Adj R^2	.040	.040	.040	.041	.041	.041	.041

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*

Table E2: Emergence of Technical people – "Technical vs Non-Technical" – Linear Regression

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Age	-.003*** (.001)	-.003*** (.001)	-.003*** (.001)	-.003*** (.001)	-.003*** (.001)	-.003*** (.001)	-.003*** (.001)
Created CB Year	.004 (.002)	.004 (.002)	.004 (.002)	.004 (.002)	.004 (.002)	.004 (.002)	.004 (.002)
BMI	.002 (.001)	.002 (.001)	.002 (.001)	.002 (.001)	.002 (.001)	.002 (.001)	.002 (.001)
Bachelor	-.030* (.012)	-.030* (.012)	-.030* (.012)	-.030* (.012)	-.030* (.012)	-.030* (.012)	-.030* (.012)
Master	-.043*** (.012)	-.043*** (.012)	-.043*** (.012)	-.043*** (.012)	-.043*** (.012)	-.043*** (.012)	-.043*** (.012)
PhD	.019 (.024)	.019 (.024)	.019 (.024)	.019 (.024)	.019 (.024)	.019 (.024)	.019 (.024)
fWHR		-.009 (.038)				-.010 (.039)	-.011 (.038)
Cheekbone			-.087 (.219)			-.095 (.219)	-.093 (.219)
OFA				.018 (.032)		.019 (.032)	
CFA					.015 (.081)		.016 (.081)
Constant	-8.099 (4.545)	-8.085 (4.542)	-8.029 (4.540)	-8.138 (4.545)	-8.100 (4.546)	-8.047 (4.536)	-8.010 (4.536)
Observations	3,787	3,787	3,787	3,787	3,787	3,787	3,787
R-squared	.021	.021	.021	.021	.021	.021	.021
Adj R^2	.016	.016	.016	.016	.016	.015	.015

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*

Table E3: Entrepreneurial emergence using Facial Ratios - "Entrepreneurs vs Managers" – Linear Regression

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Age	-.013*** (.001)	-.013*** (.001)	-.013*** (.001)	-.013*** (.001)	-.012*** (.001)	-.012*** (.001)	-.012*** (.001)
Created CB Year	-.052*** (.003)	-.052*** (.003)	-.052*** (.003)	-.052*** (.003)	-.052*** (.003)	-.052*** (.003)	-.052*** (.003)
BMI	-.003 (.002)	-.003 (.002)	-.002 (.002)	-.003 (.002)	-.003 (.002)	-.002 (.002)	-.002 (.002)
Bachelor	.001 (.016)	.001 (.016)	.001 (.016)	. 000 (.016)	. 000 (.016)	. 000 (.016)	. 000 (.016)
Master	-.063*** (.018)	-.063*** (.018)	-.062*** (.018)	-.062*** (.018)	-.061*** (.018)	-.060*** (.018)	-.060*** (.018)
PhD	.064* (.027)	.064* (.027)	.065* (.027)	.065* (.026)	.065* (.026)	.067* (.027)	.067* (.027)
fWHR		-.008 (.049)				.007 (.049)	.012 (.049)
Cheekbone			.907** (.280)			.939*** (.281)	.935*** (.280)
OFA				-.120** (.043)		-.125** (.043)	
CFA					-.400*** (.116)		-.408*** (.116)
Constant	105.926*** (5.426)	105.929*** (5.426)	104.582*** (5.443)	105.544*** (5.421)	105.323*** (5.423)	104.133*** (5.439)	103.920*** (5.440)
Observations	5,516	5,516	5,516	5,516	5,516	5,516	5,516
R-squared	.133	.133	.135	.134	.135	.136	.137
Adj R^2	.130	.130	.132	.131	.132	.133	.133

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*

Table E4: Entrepreneurial emergence using Facial Ratios - "Entrepreneurs vs Technical" – Linear Regression

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Age	-.001 (.001)	-.001 (.001)	-.001 (.001)	-.001 (.001)	-.001 (.001)	-.001 (.001)	-.001 (.001)
Created CB Year	-.019*** (.002)	-.019*** (.002)	-.019*** (.002)	-.019*** (.002)	-.019*** (.002)	-.019*** (.002)	-.019*** (.002)
BMI	-.004* (.002)	-.004* (.002)	-.003* (.002)	-.004* (.002)	-.004* (.002)	-.003* (.002)	-.003* (.002)
Bachelor	.033** (.012)	.033** (.012)	.033** (.012)	.033** (.012)	.033** (.012)	.033** (.012)	.033** (.012)
Master	.037** (.014)	.037** (.014)	.038** (.014)	.038** (.014)	.038** (.014)	.038** (.014)	.038** (.014)
PhD	.008 (.020)	.008 (.020)	.010 (.020)	.009 (.020)	.009 (.020)	.011 (.020)	.010 (.020)
fWHR		.013 (.039)				.021 (.039)	.022 (.039)
Cheekbone			.434 (.224)			.459* (.225)	.455* (.225)
OFA				-.054 (.036)		-.057 (.036)	
CFA					-.146 (.096)		-.153 (.096)
Constant	38.933*** (4.121)	38.927*** (4.12)	38.282*** (4.116)	38.789*** (4.121)	38.799*** (4.120)	38.082*** (4.114)	38.101*** (4.113)
Observations	3,382	3,382	3,382	3,382	3,382	3,382	3,382
R-squared	.035	.035	.036	.036	.036	.037	.037
Adj R^2	.029	.029	.030	.030	.030	.030	.030

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*

Table E5: Entrepreneurship emergence using the Whole Facial Appearance - Linear Regression

Variable	(1)	(2)	(3)	(4)
	Entrepreneurs vs Managers	*Entrepreneurs vs Managers*	*Entrepreneurs vs Technical*	*Entrepreneurs vs Technical*
Age	-.011***	-.011***	.000	.000
	(.001)	(.001)	(.001)	(.001)
Created CB Year	-.051***	-.051***	-.019***	-.019***
	(.003)	(.003)	(.002)	(.002)
BMI	-.003	-.003	-.003*	-.003*
	(.002)	(.002)	(.002)	(.002)
Bachelor	.010	.010	.035**	.035**
	(.016)	(.016)	(.012)	(.012)
Master	-.056**	-.056**	.045**	.045**
	(.018)	(.018)	(.014)	(.014)
PhD	.064*	.063*	.009	.009
	(.027)	(.027)	(.020)	(.020)
Feature-based approach (facial landmarks)	.046***		.014**	
	(.007)		(.005)	
Holistic-based approach (whole-pixels)		.047***		.014*
		(.007)		(.005)
Constant	104.659***	104.791***	38.957***	39.023***
	(5.487)	(5.488)	(4.181)	(4.184)
Observations	5,373	5,373	3,313	3,313
R-squared	.142	.142	.038	.038
Adj R^2	.139	.139	.032	.032

Robust standard errors are in parentheses

**** p<.001, ** p<.01, * p<.05*